Proceedings of the First Young Water Professionals Symposium

22nd and 23rd November 2012
Galadari Hotel, Colombo

Organized by

Sri Lanka Water Partnership (Lanka Jalani)
In association with
International Water Management Institute (IWMI) and Unilever-Pureit

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Abbreviations

CBO - Community Based Organization

CKD-U - Chronic Kidney Diseases, Unknown

COD - Chemical Oxygen Demand

IPCC - Intergovernmental Panel on Climate Change

IWMI -International Water Management Institute

IWRM -Integrated Water Resources Management

NGOs - Non Governmental Organizations

NSF - National Science Foundation

O&M - Operations and Maintenance

PAC - Powdered Activated Carbon

R & D - Research and Development

SLWP - Sri Lanka Water Partnership

SPI - Standard Precipitation Index

SWARM - Sustainable Water Resources Management

UDDT - Urine Diversion Dry Toilet

YWPS - Young Water Professionals Symposium

Foreword

The Young Water Professionals Symposium (YWPS) was an outcome of the efforts of the Sri Lanka Water Partnership (SLWP) Programme Committee which in early 2012 had identified the limited opportunities available to young water professionals to contribute to water sector issues as a constraint to the development of the sector. The YWPS was planned as a platform where these mid- career water professionals could make their voices heard and present innovative solutions that could be adopted to better plan and manage water resources in Sri Lanka.

SLWP is thankful to its sponsors the International Water Management Institute (IWMI) and Unilever-Pureit for meeting a large proportion of the costs of YWPS and for enabling SLWP to hold this event on a scale that provided a high degree of impact and visibility.

Six themes were included in a comprehensive portfolio of subjects and issues to be addressed and dealt with through the YWPS. Thirty papers were selected from over 55 abstracts and an opportunity was provided for 24 papers to be presented at the symposium. SLWP is indebted to the Technical Committee for selection of papers and to the Awards Committee for ranking the presentations.

The overall management of the YWPS was by a hard working Organizing Committee representing SLWP, IWMI and Unilever- Pureit who deserve all credit for YWPS and its impact.

The organizers are especially appreciative of the support for this event extended by Hon. Dinesh Gunawardena, Minister of Water Supply and Drainage who was the Chief Guest at the Inauguration and to Prof. Mohan Munasinghe, Joint Nobel Peace Prize Winner 2007, for making the keynote address. The initial support given by Dr. Colin Chartres, former Director General IWMI, the continuing support of Mr. Jeremy Bird, Director General of IWMI and Mr. Amal Cabraal, Chairman Unilever Sri Lanka, the contribution of the Session Chairs and Rapporteurs at the Technical Sessions and that of the authors/presenters whose efforts made the YWPS such a successful event are also greatly acknowledged. Special thanks go out to Mr. Lalith Dassenaike for preparing the original concept note and catalyzing Unilever to support this activity and to Ms. Joanna Kane -Potaka for promoting support for the YWPS by IWMI and to Ms. Renuka Jeya Raj for continuing this support after the former left IWMI. Ms Mala Ranawake and Ms Leelangi Wanasundara are gratefully acknowledged for their services in editing the proceedings and Mr. Thakshila Premaratne for the logistical and administrative support during and after the event.

Kusum Athukorala
Chair SLWP & Organizing Committee YWPS

March 2013

Symposium Organization

Organizing Committee

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Mr. Udith Perera
Ms. Renuka Jeya Raj
Dr. Deepthi Wickramasinghe
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Report on Proceedings
Young Water Professionals Symposium (YWPS)

Introduction
"Towards a Water Secure Future" was the theme of the Symposium for Young Water Professionals held on 22nd and 23rd November 2012 in Colombo. Organized by the Sri Lanka Water Partnership (SLWP) and sponsored by the International Water Management Institute (IWMI) and Unilever-Pureit Sri Lanka, the symposium afforded the opportunity for young water professionals to present their research findings on a wide range of topical issues currently facing the water sector

This event, which was held for the first time in Sri Lanka, provided a platform for young water professionals and academics to express their views, highlight research findings and experiences and also provided them with the opportunity for intra and inter sector networking and collegial interaction among professionals.

The symposium was open to water professionals below 35 years employed in public, private, academic and civil society institutions and was expected to add to the knowledge base that needs to be utilized to meet current water challenges in Sri Lanka.

The rationale for bringing together young water professionals was to recognize them as emerging sector leaders and to develop their research skills and initiatives in order to drive change within a sector that is faced with complex challenges and crises. This first Young Water Professionals Symposium (YWPS) was meant to be a starting point of a longer process of development of the talents of these professionals. The opportunity for young professionals to interact with their peers and senior water professionals, network and collaborate was also an objective of the symposium. As a follow-up activity, a synthesis paper on the recommendations/outcome of the symposium will be prepared to be further examined through an expert consultation with the intent to draft and submit a policy brief to the relevant authorities for consideration

At the technical sessions of the symposium, presentations were made on a range of topics under six broad themes which included optimizing water utilization, improving water delivery, good governance, economic/financial feasibility and environmental sustainability, drought, floods, pollution and cross cutting themes such as Integrated Water Resources Management (IWRM), capacity building, climate change adaptation and risk management. Aspects such as health/ sanitation, water delivery services, water quality issues in surface/groundwater, infrastructure management, floods and drought management, legal aspects, stakeholder participation, O&M, environmental issues, wetlands and biodiversity were among the many subjects covered.

This report summarizes some of the main points of the presentations made in the inaugural and three technical sessions that included the key note address, plenary discussions and a panel discussion.

Papers (both presented and not presented) accepted by the YWPS Technical Committee have been included in the compilation while notes of discussion during the technical sessions are given in Annex 3.

The Inauguration was attended by over 150 invitees that included water professionals from the state and non-state sector, academia and the private sector. The Technical Sessions had over 60 participants representing water interests.

Inaugural Session
The opening of the Symposium was on 22nd November at the Bougainvillea Ballroom, Hotel Galadari, which commenced with the traditional lighting of the oil lamp at 9.00 a.m., followed by a welcome address by the SLWP Chair Ms. Kusum Athukorala, a water song by children, an address by the Chief Guest Hon. Dinesh Gunawardena, Minister of Water Supply and Drainage and a keynote address by Prof. Mohan Munasinghe, the 2007 Nobel Prize co-winner on Sustainable Water Resources Management (SWARM) - Poverty, Security and Climate Change Nexus. The Director General of IWMI, Mr. Jeremy Bird and Chairman of Unilever Sri Lanka Mr. Amal Cabraal also addressed the gathering.

SLWSP Chair welcomed the invitees to this path breaking activity aimed at harnessing the talents of young professionals to address the ever increasing issues, some at crisis levels, that confront the water sector. Not only was there a need to bridge internal divides within the country, overcome the institutional chasms between agencies, institutions and communities by dedicated professionals and activists but there was also an urgency in opening up access to the decision making processes within the sector and agencies to the young professionals as well. Loss of many talented young minds to out migration has been not only on the issue of remuneration but also due to lack of career and professional fulfillment.

In his address, IWMI's Director General stated that the symposium was a pioneering initiative to look at current water problems through the lenses of future managers. It offered practical and effective ways for mid-career professionals to follow their interests and build their skills. Sri Lanka is one of the fastest developing countries in the region with development activities resulting in tremendous pressure on water resources exacerbated by climate change. There is a critical need to develop a new generation with a daring and unconventional mindset with fresh perspectives and out of the box thinking. IWMI was delighted to support this initiative and would partner SLWP in similar endeavors for mutual benefit.

Chairman Unilever Sri Lanka welcomed the opportunity afforded by this symposium to partner in this important initiative. The partnership highlights its corporate belief of "doing well by doing good" and reinforces the Unilever Sustainable Living Plan that identifies ways in which it can enhance positive social impact in a manner that is environmentally and economically sustainable. The intent is to decouple growth from environmental impact and the Unilever goal is to halve the environmental footprint of its product base while doubling its business. The Unilever-Pureit vision is to improve the lives of 500 million people by providing access to safe drinking water. This event should not be just the first but the beginning of many initiatives to making the world a more sustainable one.

Referring to the main findings of the IPCC in his keynote presentation, Prof. Munasinghe stated that the increasing ecological footprint of human consumption and poverty linked to unfair world income distribution is now further compounded by climate change. The issue of triple crisis bubbles is driven by greed with the motto 'enjoy now pay later' resulting in a few getting rich quickly and many innocents, mainly the poor, paying a heavy price afterwards. The importance of sustainable water resources management (SWARM) was emphasized along with the challenges and opportunities afforded. The global water scarcity and our own falling per capita variability compounded by high pollution, wrong values driving unsustainable development and the need for application of sustainable water pricing principles were highlighted by him, as were a range of climate change predictions for Sri Lanka with implications for attainment of development goals.

The Hon Minister, in his speech, said that he was very happy to participate at an event such as this. Sri Lanka had recently experienced water related crises and extreme events attributed to climate change.

He stated that Sri Lanka has to be prepared for such an eventuality and one way to do this is by building resilience through capacity development of the poor who suffer the most due to poor water security. Young water professionals can play a key role at this juncture. We need to become a water sensitive society trained to understand the importance of conservation from our early years. Young professionals can become conduits of information especially to other young persons and school children. To ensure that communities are strengthened to take up these challenges thewater sector needs to make sure that women, who constitute more than half the population and are usually ignored in the water sector, are fully integrated into the decision making process. Here, too, women water professionals have a vital role.

Over one sixth of the population in Sri Lanka obtain their water supply from 3500 community based organization (CBO) schemes run by volunteers. The role of CBOs in the management of these systems must be recognized and strengthened. As the state agencies alone cannot bear the full responsibility for developing the capacity of these CBOs young professionals need to participate in this endeavor. It is important that senior water professionals support such initiatives and encourage young professionals to contribute to mainstream water supply decision making and policy. The Minister wished the symposium all success.

The Technical Sessions followed immediately after the inauguration.

Technical Session 1

Session Chair: Ms. Badra Kamaladasa
Rapporteur: Mr. M. M. Aheeyar

Ms. Kamaladasa in her opening remarks said that as the Director of Irrigation, she was happy to be present at the first ever symposium of young water professionals and to be chairing its first technical session. She said that this symposium provides a forum not only for presenting research findings but also an opportunity for networking. She said that it is very encouraging to see professionals from many areas of the water sector coming together. Their presence would encourage the young professionals to collaboration and cooperation among them and would go a long way in the development of water resources in Sri Lanka. She was confident that this initiative would be continued in the future.

Six papers were presented at this session. The first presentation addressed the theme Improving Water Delivery focusing on management information systems using synthetic aperture radar in the Kelani and Kalu Ganga. The next four presentations addressed the theme Optimizing Water Utilization, with the first of these focusing on water quality and delivery covering safety and acceptability of drinking water supplied from irrigation tanks; the second on health and

sanitation dealt with the findings of a study in the Mahaiyawa slums in Kandy on knowledge, attitudes and practices of urban poor women on water and sanitation; the third on irrigated agriculture focused on sustainable use of run off harvesting tanks in small holder farming systems in the Vellaveli area of Baticaloa; and the fourth on the impact of extensive agriculture on groundwater chemistry in the eastern part of Sri Lanka. The final presentation of the first technical session was on Improving Water Delivery and dealt with the importance of water as a construction commodity in infrastructure construction and management.

Day 2

Session 2

Session Chair :**Dr. Herath Manthrithilake**
Rapporteur :Dr. Deepthi Wickramasinghe

The seven presentations in this session addressed several themes that included optimizing water utilization with a focus on water quality, health and sanitation, groundwater, water delivery and technology options and new technology, environmental sustainability focusing on environmental degradation and mitigation, and good governance.

The first presentation which was on chronic kidney disease of unknown origin(CKDU) in Sri Lanka in the region of irrigation reservoirs which was first noticed in the 1990s pointed out that thecontamination of groundwater due to aggregation of irrigation water around main tanks and canal couldbe the possible cause of this disease.

The second presentation covering the aspect of technology options under the theme of water delivery discussed the effect of water absorbent material, super polymer, to provide water for agriculture, specifically the growth of tomato under plant house conditions and that it should be used optimally to maintain the water retention capacity of the soil.

The third presentation addressed the issue of climate change adaptation and risk/drought management under cross cutting themes. The first presenter who looked at climate change discussed the severe drought conditions in the period after 2009 in Hambantota when no irrigation scheme was able to cope with the problem and the resultant socio economic impacts of drought on farming community. The presenter stressed the importance of managing water to mitigate the effects of drought.

The next presentation on the impact of agricultural activities on groundwater quality and its sustainability for drinking in Valikamam area in Jaffna peninsula addressed the theme of optimizing water utilization covering groundwater and water quality issues.

This was followed by a presentation on the importance of addressing water related issues through a rights based approach in the Sri Lankan context: right to water, under the theme of good governance focusing on legal aspects. The fundamental right to water which is a human right was the focus of this presentation. The presenter discussed how water could be preserved to safeguard life, eco systems and the environment through such an approach.

The sixth presentation under the theme of environmental sustainability discussed the degradation of the Maha Oya system which has river and coastal related problems and the consequent impact on communities.

The final presentation of this session was on the use of local technology to remove hardness in water in the Jaffna Peninsula under the theme Optimizing water utilization, water quality and improving water delivery.

Session 3

Session Chair :Prof. Nimal Gunawardena
Raporteur :Dr. M.M.M. Najeem

Day two's programme consisted of the 3rd session, the panel discussion and closing remarks.

The ten papers that were presented covered the themes of optimizing water utilization, and focused on water quality issues, health, sanitation and urban planning, improving water delivery, groundwater, and technology options. Three presentations covered cross cutting themes of environmental sustainability and climate change adaptation and risk management.

The first presentation under optimizing water utilization and water quality discussed the findings of a study carried out to detect and identify the presence of *P. aeruginosa* in bottled water and identify and evaluate the efficacy of ultraviolet (UV) radiation in eliminating it in source water used in the bottling industry.

The next presentation under the above theme but addressing health/sanitation was a case study of a small town in the periphery of Kandy where the water and sanitation infrastructure and practices of people impact the pollution of a perennial stream.

The study that was presented next covered a cross cutting thme, being an assessment of the social and environmental impacts of intensive agricultural activities in the Nuwara Eliya area and the usefulness of applying Integrated Water Resources Management (IWRM) concepts to overcome the resultant existing environmental and socioeconomic problems.. Sanitation was the focus of the next presentation that discussed the underlying causes of poor sanitation and related fecal contamination and policy issues related to sanitation and water pollution management under the title Analysis of Priorities in Achieving Environmentally Safe Sanitation: A Note for Policy Reformation in Sanitation and Water Nexus. The findings of a study to assess whether the water treatment plants at the University of Peradeniya, Polgolla and Matale were adhering to the required water quality standards was also presented.

A a presentation on impact of over extraction and improper agricultural practices on groundwater quality in the Puttalam area was followed by a pilot study on heavy metal pollution and burden of aquatic animal heatlhin an urban wetland through the onsequences of heavy metals in *Euphlyctus hexadactylus* (Indian Green Frog)
The next presentation of the morning session was titled Quantification of Potential Impacts of Urban and Peri-urban Agriculture and Forestry under the cross cutting theme of climate change adaptation and risk management suggested that urban and peri-urban agriculture and forestry are viable options to mitigate climate change.

The effect of climatic factors on the mortality rate of CKD-U was presented by comparing monthly temperature, rainfall, water capacity of reservoirs, water issue patterns and farming seasonality with monthly mortality of CKD-U over a period of 10 years. The presentation titled The Role of Environmental Factors on the Pathogenesis of Renal Failure, again under the theme of environmental sustainability and heath/sanitation also addressed aspects of capacity building in water resources.

This was followed by a presentation on sanitation titled An Iconoclastic View of Sanitation in Modern Sri Lanka highlighting the need for looking at sanitation infrastructure, toilets and fittings from a non-traditional and location specific perspective. A critique of the now established and standardized pour/flush system used without reference to suitability at all locations was a key focus of the presentation.

The last presentation was from the private sector and covered optimum water utilization and technology options and sustainable use through study of water use at the Unilever Plant in Horana. Reuse and augmenting supplies through use of rainwater harvesting was highlighted in this presentation.

Summing Up of Technical Sessions

The chairpersons of the technical sessions commended the presenters for their excellent, delivery and research outputs. These were basically long term research studies that had been carried out mainly in academic institutions. The methodologies that have been followed are comparable to methodologies used in other parts of the world. Therefore it is difficult to dispute these findings. What is i important however is to make use of these findings to promote action to ensure an impact.

That is where, perhaps, Net Wwater, IWMI, Sri Lanka Water Partnership and other organizations can sythesise the information and continue to feed the public and the policy makers to inform them that the situation is bleak and that action has to be taken. The politicians have to be adequately sensitized to impress upon them that the situation with regard to the natural resources of the country cannot be ignored any longer.

Panel Discussion

Current Challenges in the Role of YWPs for Transformational Impact Outcomes in the Sri Lanka water sector was the theme for the panel discussion at the Symposium. The panelists were Dr. Meredith Giordano of IWMI, Prof. Ajith de Alwis, Mr. Nalaka Gunawardena and Mr. Missaka Hettiarachchi, the latter representing the young water professionals.

The first panelist, Dr. Merdith Giordano / IWMI focused on the global perspective of some of the challenges and issues that had been discussed during the presentations. She shared the lessons learnt through a project that she was involved in in Africa and South Asia on smallholder agriculture and identified some key lessons that will build on the challenges that many had posed during the presentations.

The project referred to had looked at the opportunities and constraints that small holders in sub Saharan Africa and South Asia are facing in private irrigation, the use of water pumps, manual water lifting devices and the role of small private irrigation. She said that on the positive side there are opportunities for smallholder farmers to use water to

improve livelihood through small private irrigation. Data had been collected to support the livelihood benefits that they get as a result of having water for cultivation. Several models had also been developed to project the potential for the smallholder agricultural sector in sub Saharan Africa and South Asia and in a number of other countries.

The project had also assessed the constraints that farmers are facing. Although there are opportunities for small farmers to improve their livelihood through small private irrigation, many rely on manual methods to access water and that limits the extent of land that can be cultivated and the amount of incomes that can be generated. Moving into more mechanized systems is hampered by gaps in information as well as the lack of financial resources.

Prompted by a query by the Gates Foundation when seeking financial support for the project as to what could be done if there is potential but farmers face practical difficulties, Dr. Giordano said that farmer driven solutions were used to address this problem. In this case, some farmers were buying one or more pumps and providing mobile irrigation services on bicycles to those who could not afford to buy pumps. This was providing an income to the entrepreneur, the irrigation services provider as well as an additional income to the farmers themselves. Next, the donor had asked them to visualize a solution that could be applied on a broader scale, that is basically taking a solution that they found through the research in particular locations in Gujarat, India and Burkina Faso and to upscale it. Through that visualization and a lot of trial and error they had come up with an investment model where investors themselves can push forward the idea of that irrigation model to other parts of the world. Where is it feasible to do, how feasible is it to do, and specifically what could an investor, a government agency or a donor do to make this solution a reality?

She said that it was this challenge that she would like to leave with the young water professionals and others. She said that the research, data collection and analysis should be continued, but at the same time, she urged them to visualize, as they had done when challenged, how the research findings can be turned into solutions to improve livelihoods of people all around the world.

The next panelist Prof. Ajith de Alwis said that the data shows the seriousness of issues confronting us. Global organizations have forecasted that by 2030 water, food, and energy requirements will increase by 50%, 50% and 30% respectively over current levels. These requirements will have to be met while trying to curtail a one degree rise in climate and these are all interconnected. One million people will be added every 11 years. These are enormous challenges. Locally too, the issues and challenges are the same. It appears that Sri Lanka has not done the basics. Taking the example of the chemical industry, he said that more and more chemicals are being pushed into the domain. There are more than one million known chemicals; more than one lakh of chemicals used in industrial processing come into commercial use. And each one of these chemicals finds their way into the environment.

Citing another example, he said that medical studies undertaken by 3M found some unusual compounds in the blood samples of their workforce. These were associated with Teflon cookware. Similar compounds detected in faraway places as well showed the extent of environmental accumulation through the spread of these chemicals. Effects of these chemicals are not fully known. Though there is no conclusive evidence it is suspected that these compounds can contribute to chronic kidney diseases. These are the complexities that occur with what we bring into use, when they are disposed of and re-consumed.

He said that there is the argument that environmentally sound practices cannot be achieved because of cost. Referring to sanitation, he said that UDTV had existed long before Abhayagiriya and Thapovanaya had UDTV. Sanitation practices in the early centuries were better than now but the country seems to have lost its way in the middle. Pour flush toilets are now fashionable but sanitation is unsatisfactory and Sri Lanka is nowhere near the 21st century. Sri Lanka had better sanitation practices in the early centuries, but the country seems to have lost its way in the middle. And that, he said, is not right.

The young water professionals, therefore, should take up this challenge – look at the past, the present and the future that the country is heading to, not only through organizational aspects but also more importantly by strengthening the efficiency of the actions that are being undertaken and engaging effectively.

He said that science should match societal needs. Even when promoting UDTV it is necessary to study the way a person thinks and develop the technology in a way to make it the best that has been socially fashioned.

It is necessary to close the loop in thinking, and not think in compartments. Economists try to make a profit in one segment while paying a huge price in another. Sanitation, needs of water, energy and food are sacred to society, any society. Self-reliance and stability depend on those things. It appears that some of the fundamentals are forgotten.

For example Sri Lankan activated carbon is exported but it is inconceivable that Sri Lanka prefers to sell it for a dollar rather than for a rupee and consequently pay a big price to solve internal health issues.

Several challenges have to be addressed. It may not be possible to do this in a day, but it is necessary to constantly raise the issues and identify what has to be addressed. Research alone is not enough for this purpose. Advocacy is essential. Research has to be converted into action. Data has to be collated, packaged and presented in an easy to understand format to get the attention of the policy makers. He said that success may not come in a day or even in a year but if young professionals persist they will succeed.

Mr. Missaka Hettiarachchi who represented the young water professionals in the panel discussion said that he would highlight some issues from a different perspective, from the view point of young water professional. Young water professionals in Sri Lanka as well as around the world face extreme challenges. However, he said that Sri Lanka is not up to facing these challenges. Young professionals fear that they may not be able to take up these challenges. There are several reasons for this.

First, there is a serious lack of mentoring of young professionals both in terms of achieving professional goals and getting adequate technical skills. Mr. Hettiarachchi said that as an engineer he was fortunate to have mentors such as Prof. Alwis, but most of the other young professionals are not as fortunate. They are unable to achieve their fullest potential. For example, most of the graduates do not even get the proper guidance to obtain the charter.

Further, they do not acquire the skills to work in the field. He compared the current situation with those who were trained in the 1970s or early 1980s and said that today's professionals may not achieve those standards. This is also because there is no mentoring.

Secondly, young professionals are confronted with disincentives. What Sri Lanka has done most successfully with regard to young professionals is to export them to developed countries – Sri Lanka is one of the biggest exporters of professional talent in the world.

There are disparities in remuneration for the same skills. He said that not all professionals are focused on money, even those who come from not so strong economic backgrounds. However, those who receive lower salaries do not even receive other benefits that can compensate for lower remuneration.

The third issue is one of opportunity. Most of what was discussed during the symposium are actions that can be taken without a large monetary outlay. They are localized initiatives that can be implemented with community participation. As Unilever pointedout much can achieved at the shop floor, that is at the lowest level. A substantial amount of work has been done in the academic sector including by students and young researchers. A spectrum of innovations that can be applied directly has been developed by the undergraduates and post graduates of the University of Moratuwa. However, there is a gap and some friction in getting these innovations and inventions into commercial use including industry and communities. Young professionals can contribute if they are given the opportunity.

The last panelist, Mr. Nalaka Gunawardena said that he adopts a different perspective on the theme and issues because his background is in journalism and media. He said that at one level the media covers the bigger picture while at another level it is showing things as they are and connecting the dots when the connections are not very clear.

All work in the water sector, private and research and academic sectors, and many are technocrats and managers of different aspects of this large water sector. He said that one of the things that he as a science writer and as an occasional television host has to do is to talk to people such as water professionals and to connect their expertise and experience to some of the policy debates and discussions that are going on. That is often a challenge to those in the media and to others such as water professions to relate their knowledge and expertise and experience to the unresolved questions and debate. He said that that is the nexus, interface where media personnel come in.

Nalaka Gunawardene said that one of the phrases that he had been using in these discussions is "Everybody lives downstream", which sums up what this sector is about.
Each and every one in turn has a downstream impact on the other. The interconnectedness and the multiple dimensions of this sector makes it not only a very interesting area to study and work in but also very challenging to find the niche and to relate the particular knowledge to the wider discussion. One of the challenges that young water professionals face is that of balancing self interest in such discussions with the larger public interest. How, he asked, is it possible to get a more rational and informed discussion on water related issues in Sri Lanka. This is very challenging. Water is one of the topics where passions and emotions are aroused very easily and discussions become very heated. An informed and

dispassionate discussion is often not possible or does not happen. He said that one of the points he wants to raise at this discussion is how professionals along with the media can enrich the debate.

One possible way to do this is to understand public perceptions, which are very different to public knowledge. There are different ways of measuring and evaluating knowledge. Perceptions are what people think, feel or they think they know. Whether it is technically or scientifically right or wrong, it is necessary to pay more attention to this area of public perceptions because that influences how people react to situations, the formulation of new policies and regulations while they also set the political agenda. In a democracy politicians first look at their electorate, at the mass voting base and, then, perhaps if they are sympathetic enough they will talk to experts or researchers such as those gathered here today.

People react to their perceptions and politicians react to people's sentiments and emotions and people in the media shape public perceptions by capturing it, amplifying it and sometime confusing them even further. Media is part of the problem but it also can be a part of the solution.

Therefore studying public perceptions is necessary but it is not happening partly because it is not a well-developed field in this country. Very few surveys and studies have been done exclusively on public perceptions although there are a few. However, there are no studies that look at the broader picture and gather information on without making judgments. This is not happening because such studies fall between different research silos and tools.

One example, or rather an exception, was the study done in 2010 on public perceptions on climate change in Sri Lanka (full report is available online). The study was commissioned under the Sri Lanka climate adaptation strategy preparation process of the Ministry of Environment with the help of a professional market research company. One thousand persons from all districts of Sri Lanka, from all demographics over 18 years were surveyed for what they felt about land, water, weather, and the changes they have perceived if they lived in the same area for 10 years or more. One of the questions asked was, what in their own understanding, would be the impact of climate change and changing weather in the long term. Very interestingly the top three answers were water shortage cited by 87% of respondents, drop in food production cited by 68% while the third most cited answer was health problems triggered by abnormal weather. Therefore, there is a widely felt concern that water short shortage would be a likely impact of climate change. These are ordinary people – farmers, shop keepers, school teachers, housewives – not technical persons although there were a few as respondents were selected through random sampling.

Perceptions like these cannot be analyzed too deeply because that would be misleading but at the same time taking note of such perceptions would be very useful.

It is necessary to have more social scientists, anthropologists working with the natural science experts in trying to capture and understand what these perceptions mean and also how they inform and influence politicians and finally policies.

There is the conflict between factual accuracy and perceptions. It is interesting to see what is thrown up when these two collide. One example that Mr. Gunawardena cited was the sanitation debate in India after the 2011 census which reported that there were more mobile phones than toilets in the country. This had triggered many headlines and discussion including in the mainstream and international media. It had become a one liner. But there was no deeper probing. Interpretation of the data depends on those interpreting it – whether activists or journalists come into the debate. Activists and certain development professionals say it is a bias in public policy; others say that it is cultural – people would much rather spend their last dollar or rupee on a mobile phone than on a toilet. However, in the end people are not so simplistic and society cannot be so simplistically analyzed. It is necessary to look behind the headlines. Mr. Gunawardena said that his next column is titled 'Toilets or Cell Phones? That's the Wrong Question'. This is a very misleading and unfair comparison. It distorts and distracts the whole debate from the real issue. Unmet sanitation is a very real issue. It has no direct bearing on the communication needs of people, including poor people. Trying to artificially connect the two and do a comparison is in fact blocking real issues.

He gave another example, that of recent heated activist reactions in Sri Lanka on a perceived tax on groundwater usage. He said that he is not sure where the debate was left off. Most often groundwater is usually out of sight and therefore it does not enter the discussion unless an issue comes up and then even a rational policy does not have the chance of being debated properly because of the very activist positions that are taken on this widespread concern. Groundwater misuse is common and there is data to show that and when trying to rationalize use, there are vocal groups who get in to the spotlight and distort the discussion. He asked what water professionals can do in such a situation.

He presented two concluding thoughts. One, the water professionals have data and insights that would enrich these debates and discussion and make it more meaningful. The stakeholders who are not technically well versed may not ask the right questions to elicit answers. Therefore it is necessary to go out and find the people and relate the expertise and answers to the needs that are out there. He said that it means going out of the comfort zones and areas of expertise of the young water professionals and entering the wider debate. It may not be very pleasant, it is possible to get vilified and labeled especially when talking about costs of water supply. But, Mr. Nalaka Gunawardena said the activist should not be feared - they have a particular point of view- but rather they as well as other stakeholders should be engaged in the water debate. It is necessary to have more water voices, new voices, passionate informed voices to enrich these debates. The challenge to the young water professionals is to become a water voice.

The second challenge is to collaborate more with social scientists, market researchers to better understand the nebulous area of public perceptions. Why do people fear something? Why do they have distorted ideas or understanding of certain aspects of water, land and the environment? Rather than dismissing them as ignorant and scoffing at them he said that it is necessary to understand them. That will perhaps enable young water professionals to be a better water voice. He hoped that at least some of the young water professionals will take up these challenges.

Discussion

On behalf of SLWP Mr. Lalith Dassanayake thanked all four panelists for the valuable insights presented at the conclusion of the symposium, but more importantly for setting the stage for the beginning of a new era for young professionals.

It was mentioned more than once at the inaugural session that it was a historical day. Why? Because it is the first young water professionals symposium.

IWMI and Lanka Jalani have a responsibility from today onwards to see that this process moves forward. Mr. Dassanayake said that the young water professionals are an extremely valuable asset of the country. Before we or Sri Lanka loses them it is necessary to think strategically of the next step. All the professionals here, as well as those who are not here, are in their peak with25 to 30 years left in their career. He said that we are investing in a pot of gold and consequently we have to recognize them and their work. Most of the actors – the academics, media, the private sector, government agencies, researchers, the scientists, the development practitioners are represented here but more importantly there are more professionals who are not present here. It is for IWMI and Lanka Jalani to take the lead to priorities and strategiesand to take the process forward.

He gave two suggestions. There were 24 presenters in this first symposium. But, he reiterated that there are many more professionals and they have to be recognized. Perhaps it would be possible to have more symposia, in different formats such as thematically and geographically, and to develop the data base.

Second, the research output is available but it is the impact of the research that is more important. Although the impact may come after our life time the next step would be to use the research output for a development outcome. The Challenge Programme at IWMI does not refer to research and development but refers to it, as the private sector would do, as R for D, research for development. An important area is gap analysis. A few themes were covered in the symposium but many more issues in the water sector have to be addressed. Research has been done but the gap analysis will show what more needs to be done. Therefore, the format and a process have to be identified and Mr. Dissanayake hoped that IWMI and Lanka Jalani will take it upon themselves, as a priority, to take this symposium into the future.

A media representative said that she appreciated the presence of Mr. Nalaka Gunawardena, who represented the media. She said that the way the media, especially the way the electronic media presents issues relating to water lead to public protests. Therefore a greater involvement of the media is needed to report issues properly and to change the perceptions of people and institutions and policies.

Chair SLWP said that the panel was very insightful and the discussion generated many ideas. She questioned as to who decides on water in Sri Lanka – is it the professionals, the politicians or the politicians pushed by the media. What has to be done to get the required change, she asked, as we need a paradigm shift in the sector?

Mr. Nalaka Gunawardena said that as in many other debates there is no quick fix. But he said that it is important to start engaging in the public space, not within the private space and among peer groups. It is hazardous no doubt but a few people are taking up these issues. For example, the book titled *Apita Galapena Arthika Kramaveda* by Prof. Rohan Samarajeewa is an attempt to demystify the big infrastructure related public policy dilemmas and debates, one of which is water. It looks at a range of issues from dams to groundwater to urban water supply and addresses in concise form contentious areas and gives an opening for others to intervene in the inconvenient truths that the water professionals have, which do not fit into preconceived, romanticized, notions of activists.

The problem with activists is that they have already decided and made up their minds. They would not let evidence get in the way of their theories and notions. How does one, as those who get evidence, analyze data and engage, particularly the activists?

They are disproportionately represented in debates on television channels, talking to the mass circulation newspapers, media. There is no counterbalancing voice, a more rational voice.
It is a slow, difficult process, especially on television, where the art of the sound byte holds sway and everything has to be said fast and precisely in a couple of seconds. Government proposes, activists oppose and the public is confused. The nuances have to be brought out as everything is not black and white. He said to work with the media for long term gain.

Mr. Lalith Dassanayake once again thanked the four panelists, who had given ideas to take this initiative forward, and hoped that the four panelists could be engaged in future deliberations.

Closing Remarks

Kusum Athukorala, Chair SLWP and Chair of the YWPS Organizing Committee made the closing remarks. She started by thanking the sponsors without whose support this symposium could not have been held. She said that when the Sri Lanka Water Partnership mooted the idea of a young water professionals' symposium and needed sponsors who understood the logic, the ideology, and the need to have a symposium of this nature to carry it forward, it was fortunate that the International Water Management Institute and Unilever Sri Lanka came on board.

She then invited Mr. Lalith Dassanayake of IWMI and Mr. Udith Perera representing Unilever to address the gathering.

Mr. Lalith Dassanayake from IWMI and Member of the YWPS Organizing Committee said that the inspiration for this symposium came from an idea/event that was held last year in Johannesburg for the Challenge Programme on Water and Food. He said that it is very gratifying not only to see the work of the young professionals but also the effort and the time they had spent in preparing for the symposium. He reiterated that those who are not present here also have to be recognized. He said all have a responsibility to position themselves and move the process forward.

In conclusion he thanked Unilever and Mr.Udith Perera, IWMI, Sri Lanka Water Partnership and all the professionals who made the event a success. He hoped that it would be possible to take this historical event forward for the betterment of the young water professionals and the people of Sri Lanka.

Mr. Udith Perera said that Unilever strongly believes that in doing business it is possible to do well by doing good. He said this is a part of the sustainability living plan of Unilever. They are concerned not just about the supply chain and manufacturing, but also about the consumers who use products that cause a lot of environmental damage.

Unilever, as a business has given a global commitment of halving its environmental foot print while doubling its business. Sustainability is at the centre of Unilever business. It is in this context and to save lives by providing access to safe drinking water that Unilever- Pure was launched. He said that it was a pleasure to be at the symposium as a representative of Unilever and to see it through with many young water professionals presenting solutions to the problems that Sri Lanka faces.

Sri Lanka has an abundance of water: it is one of the best resources that Sri Lanka has but there are limitations. Mr. Udith Perera who said that it has been inspiring partnering this event gave an assurance that it will not be the last and their support will continue into the future. Unilever will be committed in supporting initiatives that will do good that will also help Unilever, as a corporate entity, to achieve the sustainability mission it has set itself.

In conclusion, Ms. Kusum Athukorala said that the presentations and the papers will be evaluated and the awards given at the Partner Forum to be held on the 18th of December 2013.

She thanked Ranjith Ratnayake, Renuka Jeya Raj, Deepthi Wickramasinghe, Pramith Ruwanpathirana, Thakshila Premaratne and Mala Ranawake, the team responsible for organizing the symposium. She said that it was a small team that was very good at multitasking.

The final comments of Kusum Athukorala included the following:

1. There is very little understanding about the relationship between juniors and seniors and how professions and knowledge are handed down from one generation to another. There is no formalized structure of mentoring and coaching. Although water professionals are from a particular culture, as pointed out by Mr. Gunawardena, it is necessary to work with anthropologists, media and others who are outside the water

sector (though actually no one is outside as the water sector is all encompassing and they are inside). However, the connection between science and social science is not so clearly understood. Therefore, multidisciplinary papers should be included in future symposia.

2. The research that was presented is good for evidence based advocacy, especially for the advocacy that the Sri Lanka Water Partnership engages in. Giving an example, she said that before the Sri Lanka Water Partnership engaged in advocacy for sanitation it had done a survey of the entire Central Province. Similarly in Deduru Oya. SLWP engages in evidence based advocacy, and in this context the work that has been done by the young professionals is invaluable.

3. It is necessary to go to the field and engage with communities.

4. In 2000, the World Water Forum took the decision to access political decision makers. The work that is done is usually doomed to sit in a bureaucrat's cupboard and never gets translated into action. Therefore, it is necessary to convert the research that has been done into good communication messages in easily digestible capsule form for both politicians and the general public. IWMI has the expertise to get the message out to those that matter.

5. Social change is possible. Sulab in India is a good example, where Dr. Pathak, took it upon himself to address open defecation and the sanitation problems facing low caste and low income groups in India. Also, there are people in India who now say that no one should marry into a family that does not have a toilet! Social change is possible but all have to work together to bring about social change

All those present at the First Young Water Professionals Symposium agreed that it was a much needed innovative initiative to provide recognition and encouragement to a valuable resource that is available to Sri Lanka in meeting the challenges of the water sector. The presentations were diverse, informative and contained valuable data; the viewpoints expressed were frank and open and the discussions were constructive. It is hoped that the symposium will be the starting point for continued dialogue and collaboration, resource sharing and networking and greater involvement of young professionals in the water sector.

Awards for Three Best Presentations

Three awards were announced, two by SLWP for the two best papers/presenters at the symposium and the third by Unilever for best paper/presentation on water quality. A three member Awards Committee evaluated the presentations made while the rankings of this committee and that of the Technical Committee with respect to papers submitted were collated for final selection.

The SLWP awards were to sponsor the two selectees to participate at a regional water event, while the Unilever award of sponsorship to the value of Rs 100,000/- would cover participation of the awardee at an appropriate water event subject to the concurrence of Unilever and SLWP.

Ms. Sutharshini Arasaratnam was ranked first based on her paper and presentation on *Impact of agricultural activities on groundwater quality and its suitability for drinking in Valikamam area, Jaffna Peninsula.*

Ms. Indika Gunawardena was ranked second for her paper and presentation on *Analysis of priorities in achieving environmentally safe sanitation: a note for policy reformation and water nexus.*

Mr. K.D.A. Samaraweera received the award on water quality by Unilever for the paper and presentation on *Impact of extensive agriculture on groundwater chemistry in the Eastern part of Sri Lanka*

All three were presented with Letters of Award at the SLWP Partners Forum on 18th December 2012 held at Hotel Galadari.

Papers Accepted for YWPS

Papers selected for presentations

Flood mapping using synthetic aperture radar in the Kelani Ganga and the Bolgoda Basins, Sri Lanka

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ABSTRACT
Kelani ganga and Bolgoda basins are adjacent basins within the wet zone of Sri Lanka and are subject to frequent floods specifically, during the southwest and second inter monsoon episodes. The main goal of this research is to develop a flood extent map from a series of Synthetic Aperture Radar (SAR) images for the downstream area of the two above-mentioned basins. For this study we have employed a series VV polarized Advanced SAR (ASAR) Image Mode (IM) images collected in the period from 2005 to 2007 for mapping of the flood extents.

From the series of ASAR IM products, image of the time series statistics (mean, standard deviation, minimum and maximum) were derived. Then, colour composites were created to better visualize the various landscape features within the study area. The major land cover categories in the study area were identified with the help of high resolution optical images. Four land cover categories could be identified, which are open water, periodically flooded area, non-flooded area and urban area. Supervised maximum likelihood classification technique was usedto extract this information from the time series statistical parameter images and the overall classification accuracy and kappa coefficient were observed to be 88.35% and 0.84, respectively. In addition to the reliable accuracy, periodically flooded area (PFA) was found to be in good agreement with the DEM and land use data.

To study the flood effect of the study area with respect to the rainfall inputs, temporal variation of mean σ° of the PFA was analyzed for individual ASAR images and for sequences of five consecutive ASAR images over the period 2005 to 2007. Combinations of three factors, which are rainfall, mean σ° fluctuations of the PFA and classified images suggest that three flood vulnerability zones can be distinguished: Zone A, Zone B and Zone C. Zone A consists of southeast part of the Bolgoda basin and has high vulnerability to flood. Zone B consists of south of the Bolgoda basin and downstream area of the Kelani ganga basin and has moderate vulnerability to flood. Zone C has low vulnerability to floods and consists of northeast part of the Bolgoda basin.

INTRODUCTION
Kelani ganga and Bolgoda basins (Figure 1) are adjacent basins located within the wet zone of Sri Lanka and subject to frequent floods,especially during the southwest (SW) monsoon (May – September) and second inter monsoon periods (October – November).Downstream area of the Kelaniganga basin covers almost all the potential flood areas in the Kelani ganga basin, which is situated within the denselypopulated Colombo and Gampaha districts. The Bolgoda basin is located 25 km south from the capital Colombo and entirely within the Colombo and Kalutara districts. In addition, this area is used for rice production. Thereforepre-prepared flood extent mapping of this area is important and could be effectively used for mitigating the impact of flood events.

Maps are valuable tools for representing the spatial distribution of flood hazard and vulnerabilityas well as assessing the flood risk. They provide a more direct and stronger impression than any other forms of presentation such as verbal description, diagram. Flood extent mapping is a necessary step for developing flood risk management strategies (Merz, et al., 2007)and can serve several purposes among which are raising awareness among people at risk and decision makers, providing information for land-use planning and urban development, investment planning and priority setting, helping to assess the feasibility of structural and non-structural flood control measures, serving as base for deriving flood insurance premiums, allowing disaster managers to prepare for emergency situations(Merz, et al., 2007).

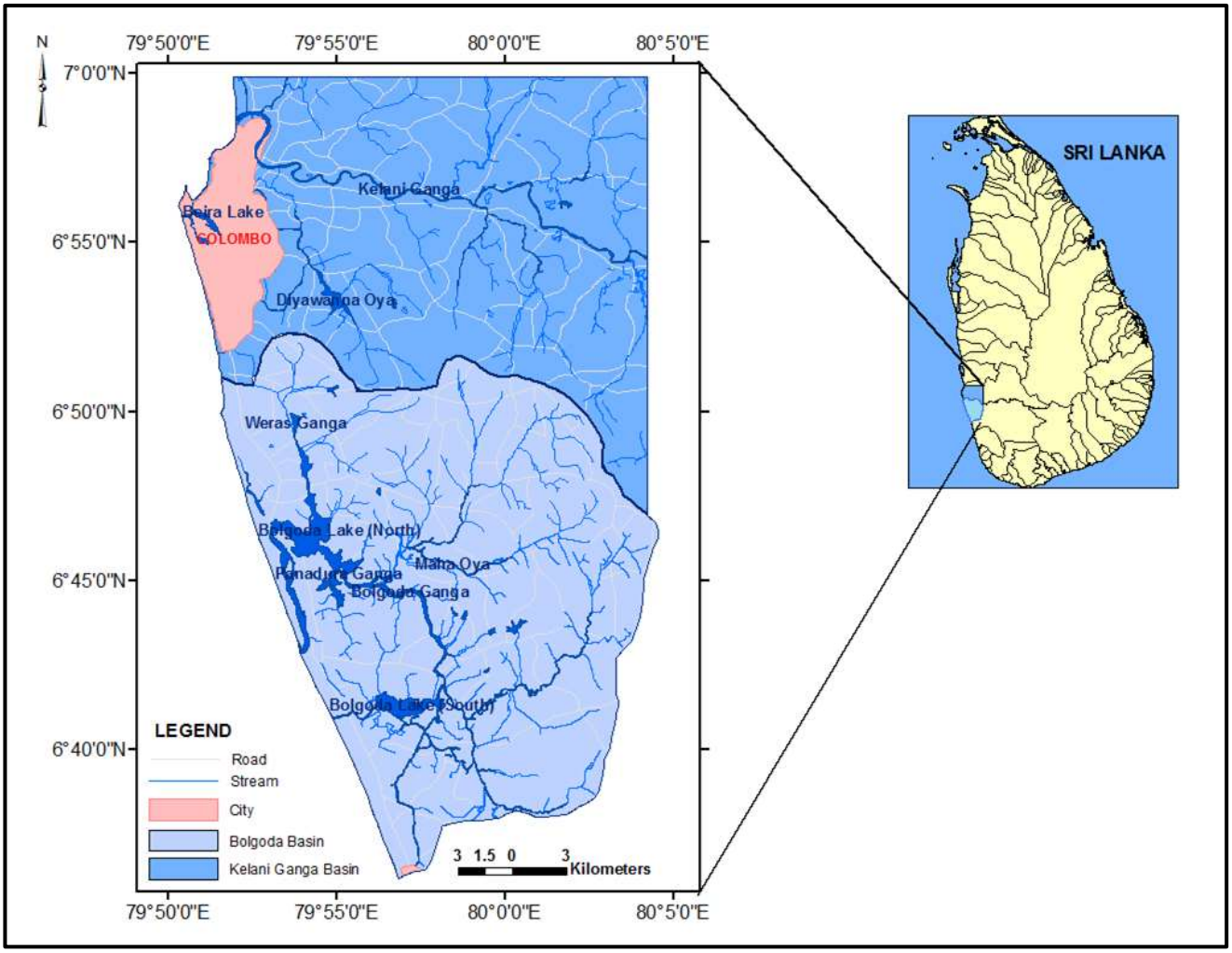

Figure 1 - Location map of the study area

Various researches have carried out flood extent mapping using satellite observations acquired especially in the visible and infrared part of the spectrum. However, the visible and infrared part of the spectrum are affected by atmosphere, whereas the land surface can be hidden in the presence of clouds or shadow induced by clouds,especially in the monsoon countries where flooding occurs due to heavy rainfall. It does often restrict the useful land observations and the results of the flood extent mapping will be lead to underestimation of the flooded area. Alternatively, active microwave observations collected via Synthetic Aperture Radar (SAR) technique are much less affected by weather, and provide day and night coverage(Horritta, et al., 2003). Additionally, the great sensitivity to standing water permits SAR to distinguish between land and water surface. Based on these properties, it is widely recognized that satellites carrying SAR sensors can support flood mapping, modelling and management (Di Baldassarre, et al., 2011).

So far, only few investigations on the operational use of SAR data for flood extent mapping isavailable in literature primarily because of the fairly long revisit time of high resolution SAR observations(Pulvirenti, et al., 2011). Thus monitoring floods from space in near real time is currently only possible through low resolution SAR imagery (Di Baldassarre, et al., 2011). Up to now, however, SAR systems have only been operated on a best effort basis and a regular revisit time was not guaranteed. Unavailability of frequent revisit time in SAR sensors is one of the critical issues in operational flood mapping. However, considerable data base of SAR imagery is available from the previous satellite missions such as European Remote Sensing-1/-2 (ERS-1/-2), Environment Satellite (ENVISAT), Radar Satellite (Radarsat-2), that can be used for flood mapping. For the Kelaniganga and the Bolgoda basins, SAR data sets are available from archives of ERS-1/-2 and ENVISAT supported by the European Space Agency (ESA). We will utilize this data base of SAR imagery for flood extent mapping in downstream area of the Kelaniganga basin and the Bolgoda basin.

Previous flood extent maps for the Kelaniganga and the Bolgoda basin areas were based on only few satellite images and have been produced for specific flood events to provide information for civil protection officers and decision makers. In most of the cases, only two images, acquired before and after the flood, were used to prepare the flood extent maps. For these cases, the satellite overpass often did not coincide with the flood peak. Moreover, the satellite images from the different sensors were selected for the flood mapping. This image may be more than one day after the flood peak and so that the ground condition may be entirely different from flood situation. Additionally, images from different sensors may

provide uncertainty to data integration, because different sensors have different sensor properties such as spatial resolution, wavelength.

The main objective of this research is to develop a flood extent map from a series of SAR images for the downstream area of the Kelaniganga basin and the Bolgoda basin in Sri Lanka. For achieving this objective, we will use statistical parameters (mean standard deviation, minimum and maximum) derived from a time series of SARimages to extract the flood extent, which are derived on a pixel basis.Use of a series of satellite images to prepare flood extent map is better suited than the use of few images since it can reduce the uncertainty associated with different sensors' images or by same sensor's images with different time. Moreover, time series analysis through image fusion can extract the features from source images that impossible to derive from individual images and provide more information since the improved interpretation capability (Wen & Chen, 2004).

STUDY AREA

The study area consists of the downstream areas of the Kelaniganga basin and the Bolgoda basin (Figure 1) between longitudes 79^0 50' – 80^0 5' E and latitudes 6^0 40'- 7^0 0' N. It belongs to the western province of the country and has an area of approximately 870 km^2. This area receives an annual amount of rainfall of 2000 -3000 mm; it is in the wet zone of the country. Mean annual temperature of the area is varying between 26.5 °C to 28.5 °C.Kelaniganga is the fourth longest river in Sri Lanka, which originates in the central hills and flows mainly to the west until it reaches the sea at Colombo. Bolgoda basin mainly consists of two interconnected north and south Bolgoda lakes, which are mainly fed by monsoon rains. This lake is the largest brackish water body as well as an important natural wetland area in Sri Lanka. The lake has an area of approximately 347 km^2 and the depth ranges from 6-16 m.

DATA

Advanced Synthetic Aperture Radar Data

In this research, Advanced Synthetic Aperture Radar (ASAR)Image Mode (IM) geo-coded images were requested from the ESA for extracting the flood inundation areas. The ENVISAT ASAR IM images are characterized by a pixel size of 12.5 m and a ground resolution of approximately 25 m. We have obtained a total of39 ASAR IM geo-coded images and 8 ASAR IM precision images from ESA archives which covered the study area. A quota of 47 ASAR IM images were provided free of charge by ESA.

Ancillary data

Precipitation data, Shuttle Radar Topographic Mission (SRTM) data and digital landuse data are used as the ancillary data of this research.In-situ monthly precipitation data for three rainfall stations; Colombo, Ratmalana, Hanwellagroup in and close to the study area have collected from Department of Meteorology in Sri Lanka. Moreover, daily precipitation data have been obtained from Global Land Data Assimilation System (GLDAS) and Climate Prediction Center Morphing Method (CMORPH).SRTM data with 90 m resolution at the equatorhave been used as the digital elevation model (DEM). Digital land use data collected from Department of Survey in Sri Lanka has been used to identify the land use of the flooded areas.

METHODOLOGY

Mapping of water surface using SAR is possible because the SAR backscatter is very low due to the specular reflection when the water surface is smooth (Di Baldassarre, et al., 2011). As a result of that, flooded areas appear as dark tones due to the low backscattering response whereas land surface appear as bright tones because the rough soil surface and vegetation produce diffused reflection resulting in a strong backscatter. This tonal variation according to the backscatter response in SAR images can be used to distinguish waterfrom land.Methodology of this research is mainly consisting of the following four main parts:ASAR image processing, Statistical parameter images, Classification and Verification. Details of the methodology arediscussed under "Result and Discussion".

RESULTS AND DISCUSSION

ASAR Image Processing

ASAR IM images were calibratedto obtain the radar backscatter of the reflecting surface directly from the pixel value of the images.Then, these images were filtered to suppressthe inherent granular noise called speckle. AnASAR IM image was tested by the median and Gamma map filtering techniques with the different sizes of the moving filter window.In the resulting images, we see that the ASAR IM image filtered by median 7x7 moving window gives the less noise imagethan other images As such, the entire ASAR IM data set was subjected to the median 7x7 filter and used for the further analysis of this research. To obtain a high quality ASAR data, filtered images were re-projected (co-registered)with sub-pixel accuracy. Then, these images were used to create the image stack for further analysis such as production of statistical parameter images.

Statistical Parameter Images

Statistical parameter images: mean, standard deviation, minimum and maximumwere derived from the series of images on a pixel basis.For instance, the mean statistical parameter image of the time series of backscatter observations represents an idea about the average backscatter condition of the each land cover category and based upon that the land cover can be grouped in to the different categories. Standard deviation image can be utilized to get the idea about the backscatter coefficient (σ°) fluctuations within the respective land cover category such as water, land. Minimum and maximum statistical images can be used to identify the dynamic range of the σ° variations in the study area on pixel basis.

Figure 2 shows the statistical parameter images: (A) mean, (B) standard deviation, (C) minimum and (D) maximum of the ascendingimage (22 images) stack with temporal coverage from 2005 to 2007. According to the mean σ° image (Figure 2A), it can be clearly seen that water surfaces have darker tones since low σ° due to the specular reflection over the smooth water surface (Mason, et al., 2010). Land surfaces havea range of brighter tones since the diffuse reflection from rough land surfaces (ex: soil and vegetation) cause high backscatter returns.Inthe standard deviation map (Figure2B), we can see high bright tone in the water surfaces since the large variation in the backscatter, which is created by the wind induces waves on the water surfaces versus the low reflection from the smooth, windless situations. In land surfaces we can see the darker tones since the low standard deviation occurs due to the stable land features. Moreover, land features are not changed much by the wind or rain actions. As lower σ° corresponds to the water body, water area shows the very smooth dark tone in the minimum statistical parameter image (Figure 2C) whereas land area shows bright tones since high σ°.Moreover, the periodicaly flooded area (PFA) becomes apparent in the minimum statistical parameter image. Figure 2D shows the maximum σ° value of the respective pixel among 22 images and here the water surfaces are not maintained the lower σ° (darker tone).

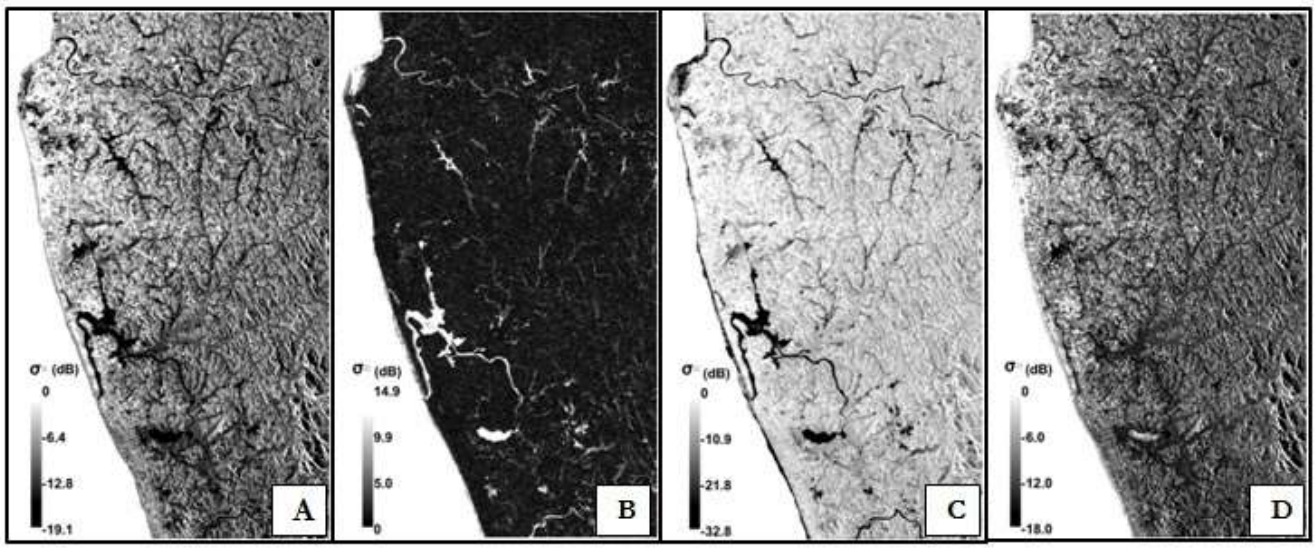

Figure 2 - Statistical parameter images for the ascending stack with 22 images in the time series of 2005 to 2007 (A) mean (B) standard deviation (C) minimum (D) maximum

Feature Extraction

Output of the statistical parameter images are in black and white tones and only possible to identify land and water and difficult to get the information about any other land cover categories. Therefore the combination of statistical parameter images to a colour composite can be utilized to better identify the land classes that can be detected. For that, we tested the different Statistical Parameter Multiband Composite (SPMC) by combining different statistical parameter bands. The SPMC created assigning mean, minimum and maximum statistical parameter bands to red, green and blue (RGB) respectively, gave the best scene with four distinguishable colours: blue, purple, white and green. According to the ground truth identification using high resolution optical images, we recognized the four different land cover categories for these four distinguish colours in the SPMC. Blue colour represents the open water (OPW) or water bodies (Figure 3A) and bright white patches represent the urban or built-up areas (Figure 3B). Further, green colour represents the non-flooded areas (NFA) (Figure 3C) and the purple colour represent the periodically flooded areas (PFA) (Figure 3D). Based on this, the time series of ASAR images at hand has the potential of identifying four main land cover categories in the study area.

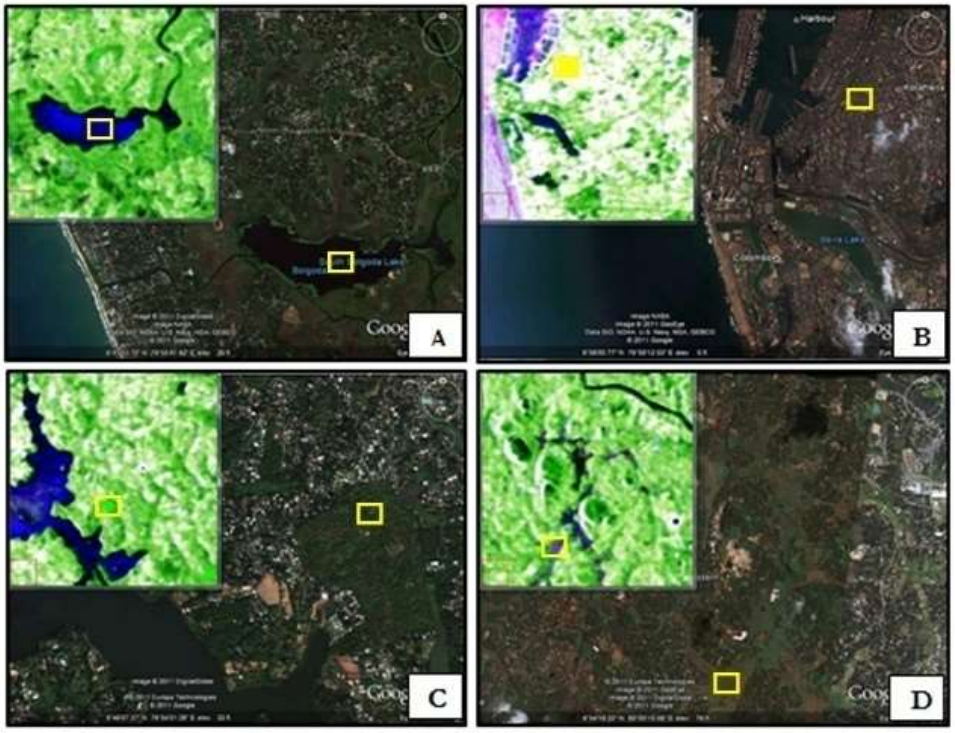

Figure 3 - Identification of land cover categories in SPMCs using high resolution optical images
(A) blue - open water (B) white - urban (c) green – non-flooded area (D) purple - periodically flooded are

Backscatter Analysis

To examine the backscatter response from the respective land cover categories, σ° data was extracted from the each land cover class. We selected the 5 training data sets (region of interest-ROI)for each land cover category, such as5 ROI sets forOPW. We use the backscatter data to analyse the temporal statistics such as mean, standard deviation, minimum, and maximum on basis of each training data set regions. Then, the 5 ROI regions were merged as single ROI region to obtain improved and more reliable statistics for the respective land cover category and then again analysed the temporal statistics. Finally, mean σ° of the respective land cover categories from the result of statistical analysis was selected for the further analysis in this research.

Using this statistical analysis, we can identify the dynamic σ° range for the all land covers in the study area (Table 1). It lay in between -20 and -2 dB.OPW has the lowest σ° than the other 3 land categories since the specular reflection from the smooth water surface (Table 1). Urban area has the highest σ° of all the four identified land cover classes since the diffuse reflection due to the rough surface. We can see very little variation of σ°(Table 1) with the time in the urban areas since urban areas mostly consist of stable objects such as buildings, bridges. The σ° statistics of PFA and NFA are lying in between OPW and the urban. NFA has higher σ° than PFA since some specular reflection over PFA due to the flood inundation and therefore radar signals scattered away from the radar antenna. Moreover, PFA shows a different σ° response than the OPW since the double bounce backscattering between flood water surfaces and the vegetation. It leads to more backscatter response from the PFA to the radar antenna than from OPW.

Table 1 - Statistical result (merged 5 ROI) of the imagestack (2005 -2007)

Land cover category	Mean (dB)	Standard deviation (dB)	Minimum (dB)	Maximum (dB)
Open water (OPW)	-12.21	4.40	-19.94	-5.07
Periodically flooded area (PFA)	-7.88	2.10	-12.94	-3.44
Non-flooded area (NFA)	-6.93	0.91	-8.67	-5.18
Urban	-4.42	0.94	-6.26	-2.72

Classification

The SPMC were subjected to maximum likelihood supervised classification technique since it gives more reliable classified image. For this purpose,merged ROI'sfor each land cover categorise were used to classify the SPMC.The classified image consists of four land cover categories: OPW, PFA, NFA and Urban, represented by blue, magenta, green and yellow colours, respectively (Figure 8).Urban and NFA cover more percentage of the study area than other two: OPW and PFA. When consider the spatial distribution of the land cover categories, urban areas are more concentrated into the western part of the study area where as NFA is more distributed across the middle and eastern parts of the study area.

OPW area demarcated the permanent water bodies. As such, this method can be used to obtain the area of the permanent water bodies in the studied area.

Western part of the study area mainly consists of highly urbanized areas such as Colombo, Ratmalana. From past experiences, we know that most of these urban areas are frequently subjected to the flood events as other PFA in the scene. Using this classified image, it is impossible to observe the urban flood since ASAR IM images have some limitations such as a coarse spatial resolution (25 m). High spatial resolution (1-2 m) radar images (ex: TerraSAR-X), topographic data (ex: DSMs from LiDAR) with high resolution(0.5 m/ 1 m) and supervised method with large amount of user interaction are required to perform a reliable flood extent mapping in the urban areas (Mason, et al., 2010). All above requirements are essential for the better understanding and detection of urban floods but those are very expensive and not part of this research.

Spatial distribution of the PFA is mainly laid on north-eastern and south-eastern parts of Bolgoda basin and in the downstream area of the Kelaniganga basin. Further, it is important to know the temporal variation of the PFA and areas vulnerability to the floods. For this purpose, image stacks of 5consecutive months were utilized for image classification and it is further discussedin section 5.5.

Verification (Accuracy assessment)

Flood extent maps provide information of events which are extreme compared to the everyday life experience and they show situations, which are not observed daily. Therefore, validation of flood extent maps is usually difficult and such maps are expected to be uncertain. Moreover, flood maps should be prepared using consistent, scientific based and reproducible methods (Merz, et al., 2007). Therefore, validation is not available for many flood events and the level of uncertainty associated with the flood information should be presented with the flood map. In this research, we produced the confusion matrix to assess the accuracy of the classify images and verify the result with ancillary data sets such as precipitation, DEM, land use.

According to the confusion matrix, overall accuracy of the classified result is 88.35 and Kappa coefficient is 0.84. Here, for the reference data sets, 5 another ROI regions were selected for each land cover category using high resolution optical images from the Google earth. Moreover, the area classified as PFA, which is extracted from the classified image was overlying onto the DEM and land use of the area and bothare in good agreement with the overlaid PFA.

Five Consecutive Image Analysis for Temporal Variation

To study the temporal variation of the each land cover categories of the study area, 15 image stacks were created adding 5 consecutive images. Then they were used to create another 15 SPMCs by producing statistical parameter images. Temporal coverage starts from 3-3-2005 and ends at 1-2-2007 and has 19 sequential images with approximately 35 days temporal resolutions. Aim of using 5 sequential months to create the SPMCto study land cover changes along the seasons. SPMC no. 4 and 13 cover the combination of southwest (SW) and 2nd inter monsoon seasons and SPMC no. 9 covers the combination of northeast (NE) and 1st inter monsoon seasons.

OPW shows the lowest σ° whereas Urban shows the highest σ° (Table 2). The σ° of PFA and NFA lay in between OPW and Urban. NFA shows higher σ° than PFA. It may possibly due to the more diffuse reflection over NFA than flooded areas. The temporal variation of the mean σ° value of the OPW shows very high fluctuation whereas PFA shows relatively moderate fluctuation. NFA and Urban area show minor fluctuation (almost constant) with respect to the other land covers. Although OPW has shown high fluctuation (Figure 4), it is independent from other land cover categories. High σ° fluctuation range (5.54 dB) of OPW may possibly due to waves on the water surface caused by wind and rains. However, we cannot see higher range variation of σ° in NFA and Urban. Range difference of σ° of NFA and Urban are 0.47 dB and 0.56 dB (Table 2), respectively. Further, σ° range difference of PFA is significant (1.96 dB) since flooded water move within different features such as vegetation, soil, and homestead. Variation of double bounce backscattering between vegetation and water surfaces could be the possible reason for this significant σ° difference in PFA. Furthermore, two remarkable decreasing trends of σ° can be seen in between stack no. 3-4 and stack no. 12-13 (Figure 4). According to these important facts, a detailed investigation of the PFA backscatter in relation to time and precipitation is needed. For that purpose, mean σ° of the PFA was plotted against the month (and the SPMC no.) with 5 months' average in-situ and GLDAS precipitations (Figure 5). Here, month of the SPMC was considered as the middle month of the 5 image as in Figure 5. Also, the precipitation was averaged on 5 consecutive months corresponding to the temporal coverage of the SPMC. Moreover, classified images correspond to each SPMCshave shown in Figure 6 and 7 which covers classified images corresponding to SPMC no. 1 to 9 and SPMC no. 10 to 15, respectively.

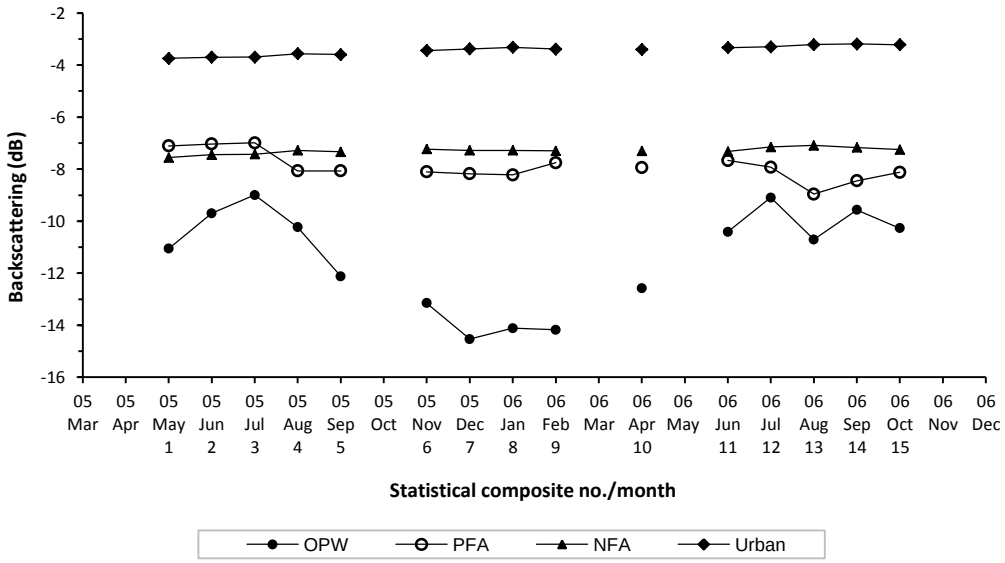

Figure 4 - Temporal variation of the mean σ° value (band 1) of the four land cover category

Table 2 - Dynamic range of mean σ° in four land cover categories within 15 SPMCs

Land cover category	Minimum σ° value (dB)	Maximum σ° value (dB)	Difference (dB)
Open water (OPW)	-14.54	-9.00	5.54
Periodically flooded area (PFA)	-8.96	-6.99	1.96
Non flooded area (NFA)	-7.56	-7.08	0.47
Urban	-3.74	-3.19	0.56

According to the σ° fluctuation of the PFA, we can identify 4 distinguished parts (I, II, III and IV) based on the σ° stages. SPMC no. 1, 2 and 3 (Part I) shows the highest σ° among other stacks (Figure 5) and we can expect less inundated areas than others. Also, time duration for these three stacks is from 3-3-2005 to 29-9-2005 and the relatively high σ° shows the dry condition than others sincemore double bounce backscattering due to the low flood inundation. This situation can be positively proved by the classified images no. 1, 2 and 3 (May –July, 2005) in Figure 6 since these images show relatively low PFA than other classified images (visual interpretation). In addition, the 5 months average precipitation corresponds to part I is showing somewhat decreasing trend. In fact, Part I represent the start of the SW monsoon period. Also, we can see PFA mainly concentrated in to the southeast part (green boundary) of the Bolgoda basin (Figure 6).

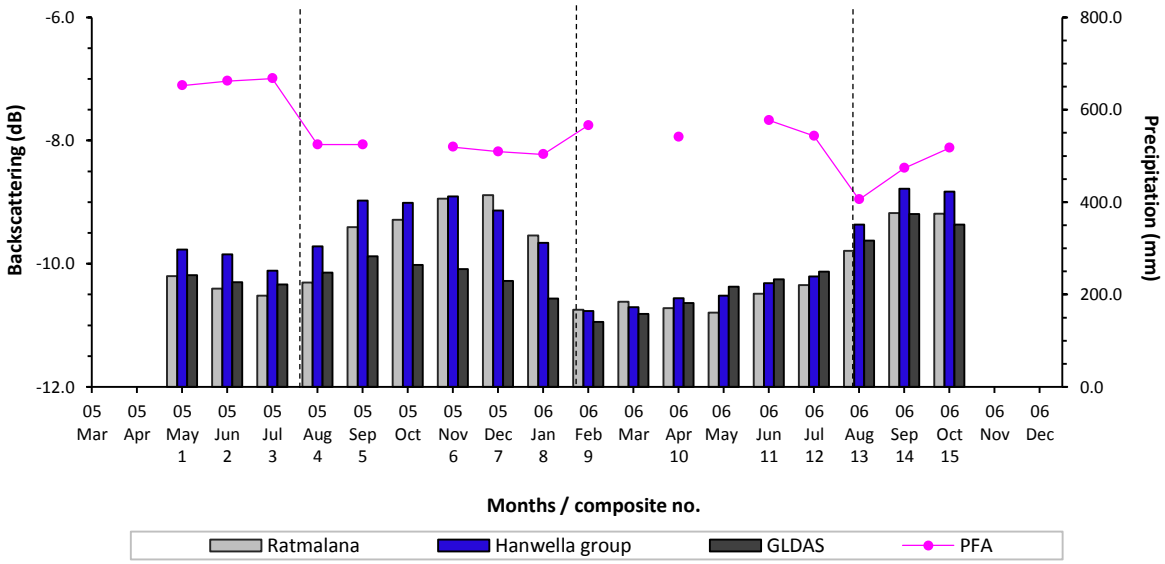

Figure 5 - Temporal variation of PFA with 5 months average in-situ (Ratmalana and Hanwella group stations) and GLDAS precipitation (2005-2006)
* SW- southwest monsoon, 2nd inter - 2nd inter monsoon

The SPMC no's from 3 to 4 (05-July to 05-Aug) and from 12 to 13 (06-July to 06-Aug) have shown almost similar strong decreasing trend (Figure 5) with respect to others. Depression for the SPMC no. 3 to 4 and 12 to 13 are 1.07 dB and 1.03 dB,respectively. In addition,these two incidents has similar temporal coverage for the corresponding years and SPMC no. 4 and 13 represent the combination of entire typical SW and 2ndinter monsoons periods. In addition to that, all the in-situ and GLDAS precipitations show the increasing trend corresponding to these stacks (Figure 5).

After SPMC no. 3 to 4, we can see continuity of the low mean σ° until SPMC no. 8 (Part II) with almost horizontal trend within the period of 16-6-2005 to 27-4-2006. In fact this time period mainly represents both the SW and the 2nd inter monsoon periods. Low σ° is due to the more specular reflection over the more inundation with high precipitation than situations in Part I over the PFA. Therefore more PFA can be expected during these periods. So, it can be seen by the classified images from 05-August to 06-January (image no. 4,5,6,7 and 8) in Figure 6. In these classified images we can see more PFA in addition to the southeast part of the Bolgoda basins. Those additional areas are south and northeast part (magenta circle) of the Bolgoda basin and most of the areas in the downstream of the Kelaniganga basin (Figure 6).

Again after 06-January (SPMC no. 8), we can see some increasing trend of mean σ° from 06-January to 06-February (SPMC no. 8 to 9) since the more diffuse reflection than previous due to lowering of the flood water level with decreasing of precipitation (Figure 5). This situation continues until 06-July (SPMC no. 12) with minor fluctuations (Part III)with the precipitation. Temporal coverage for these SPMC is from 8-12-2005 to 14-9-2006.In this PART III, mainly SW monsoon is responsible for the flood inundation. The classified images corresponds to these periods (06-February to 06-July) are showing the results as we expected. In Figure 6 and Figure 7, classified images for the period from 06-February to 06-July (image no. 9, 10, 11 and 12) we cannot see considerable PFA in the northeast part of the Bolgoda basin.

After 06-July (SPMCno. 12), we can see remarkable depression of mean σ° from 06-July to 06-August (SPMC no. 12 to 13) as discussed early and from 06-August to 06-October (SPMC no. 13, 14, 15: Part IV) has low mean σ° than fromPart III. Again, it is due to the more inundation than occurred previously since the high precipitation because PART III consists of end part of the SW monsoon and 2nd inter monsoons periods. This area experiences highest precipitation during 2ndinter monsoon periods. It can be proved from the classified image from 06-August to 06-October (image no. 13, 14 and 15) in Figure 7. In those three images we can clearly see the PFA in northeast part (magenta circle) of the Bolgoda basin in addition to the southeast of the Bolgoda basin and downstream area of the Kelaniganga basins (Figure 7).

According to the above facts, we can identify the 3 flood vulnerability zones in the study area by the temporal variation of the PFA and the visual interpretation of the classified images. Those are high, moderate and lowvulnerability zones (Table 3). Southeast of the Bolgoda basin has high vulnerability to flood and name as ZoneA (Figure 8). This area is more vulnerable to flood throughout the year with considerable rainfall effect. South of the Bolgoda basin and downstream area of the Kelani ganga basin have moderate vulnerability to the floods and name as Zone B (Figure 8) and more vulnerable to flood during both southwest and 2ndinter monsoons periods (May to November). Northeast part of the Bolgoda basin has low vulnerability to the floods and name as Zone C (Figure 8) and vulnerable to flood during second inter monsoon period (October to November).

Table 3 - Flood vulnerability zones in the study area

Zone	Flood vulnerability	Location	Periods of vulnerability
A	High	Southeast of theBolgoda basin	throughout the year with considerable rainfall
B	Moderate	South of the Bolgoda basin and downstream area of the Kelani ganga basin	during southwest and 2nd inter monsoons periods
C	Low	Northeast of the Bolgoda basin	during 2nd inter monsoon period

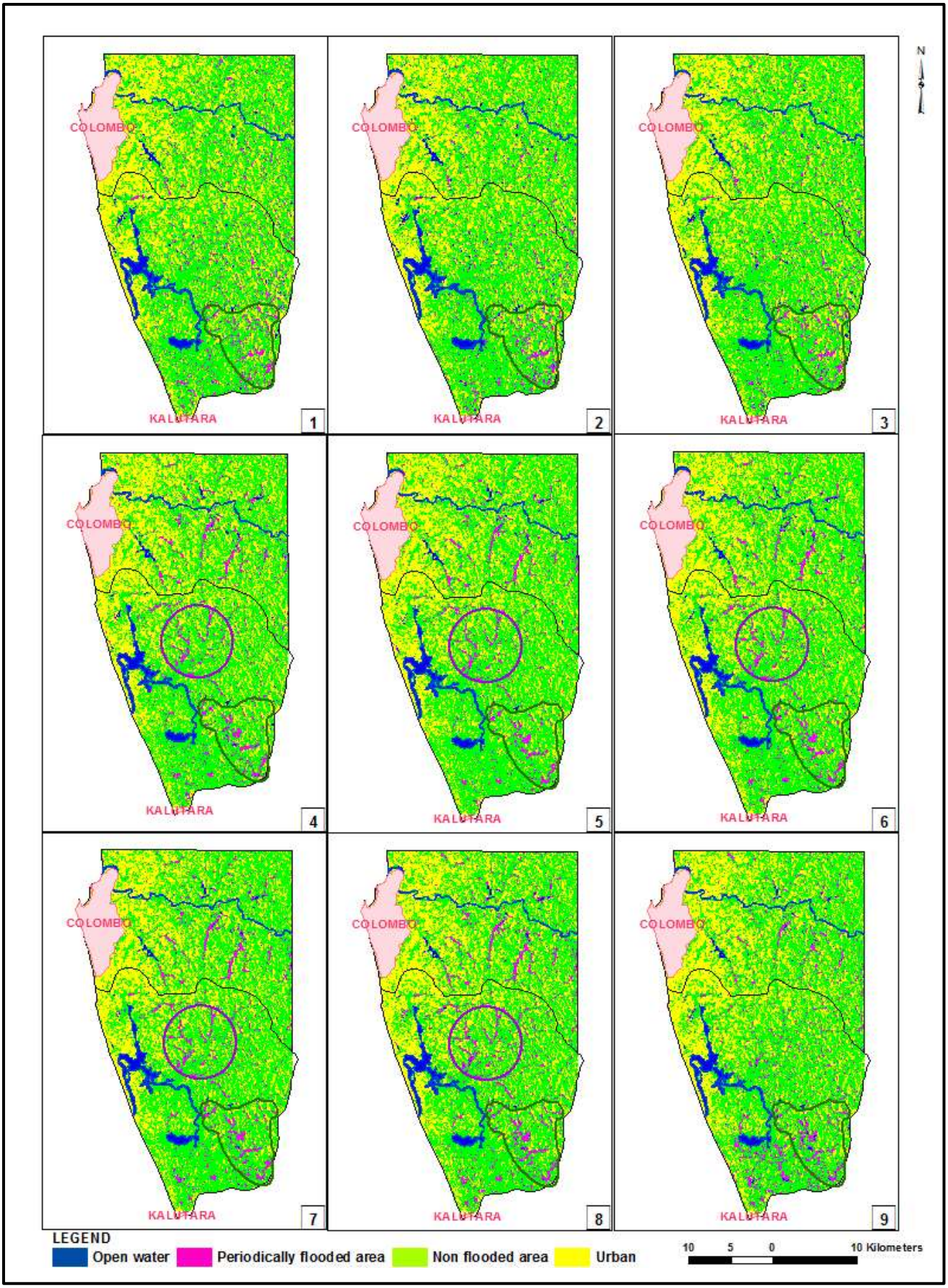

Figure 6 - Classified images correspond to SPMCs (SPMC no. 1 to 9)

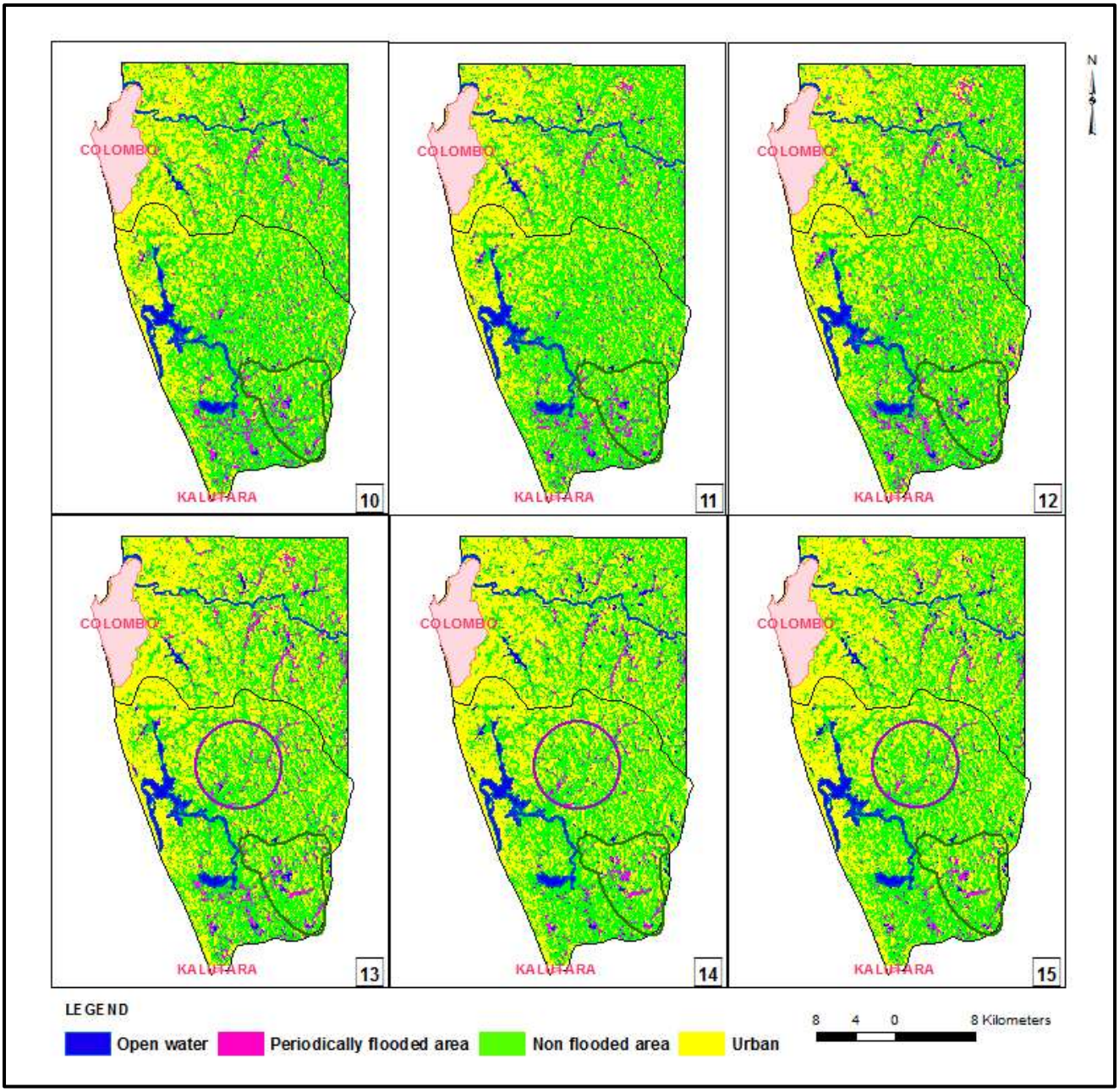

Figure 7 - Classified images correspond to SPMCs (SPMC no. 10 to 15)

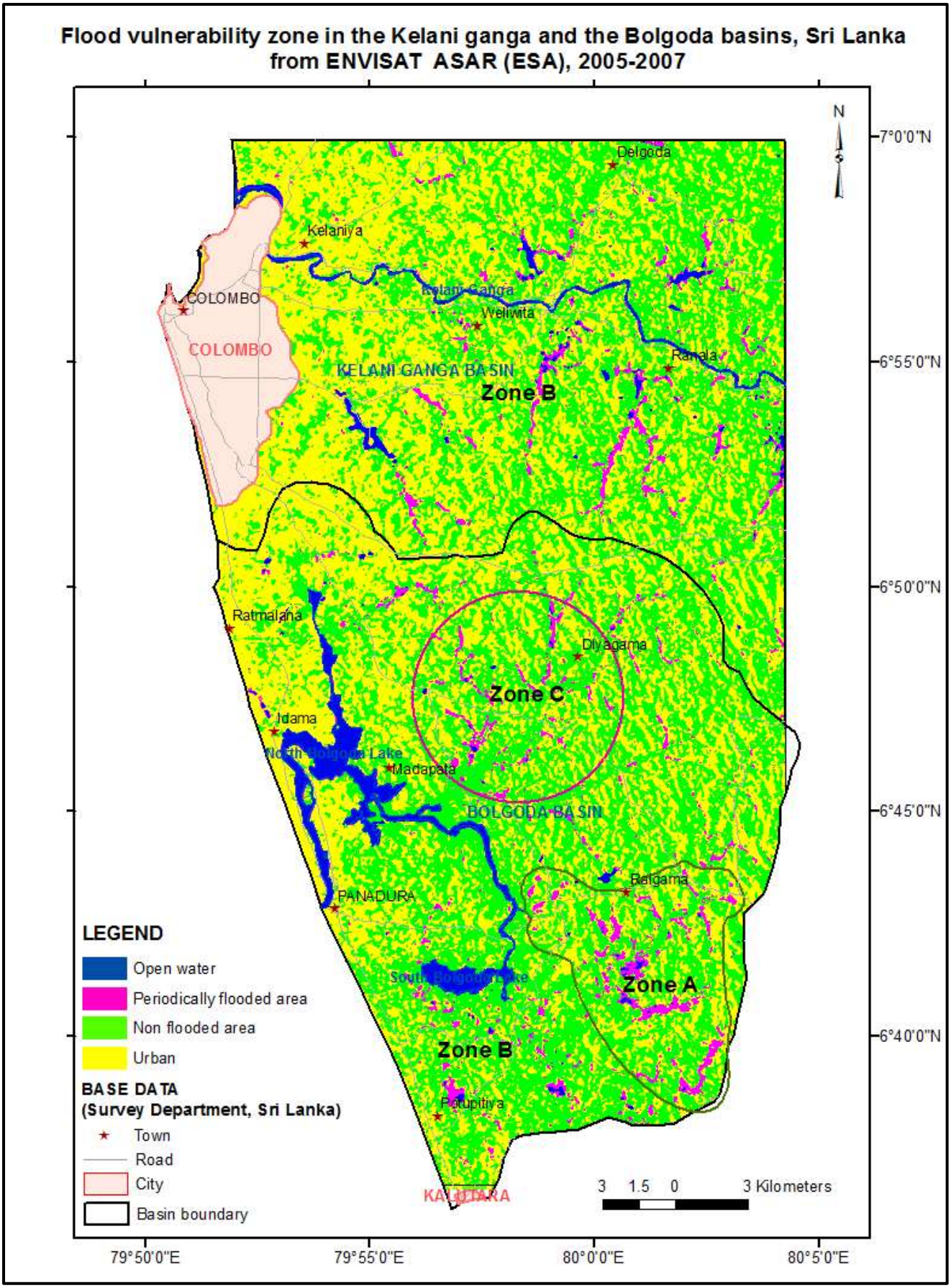

Figure 8 - Flood vulnerability zone map for the Bolgoda basin and the downstream area of the Kelani ganga basin, Sri Lanka

CONCLUSIONS

The main objective of this researchwas todevelop a flood extent map from a series of SAR images for the downstream area of the Kelaniganga basin and the Bolgoda basin in Sri Lanka.The novelty of the adopted approach was the use of time series analysis to extract the flood extent dynamics from the ASAR IM images. The following conclusions can be drawn from the results and the discussion.

- The SPMC was classified in to four land cover categories, which are OPW, PFA, NFA and urban based on the mean backscattering properties of the land features. OPW has the lowest mean σ◦ whereas Urban has the highest mean σ◦. PFA and NFA lay in between OPW and Urban. PFA has the lower σ◦ than that of NFA. The land cover categorieswithin the study area falls in to the dynamic range of meanσ° in between -20to -2 dB.
- Spatial distribution of the PFA area laid mainly south, southeast and northeast part of the Bolgoda basin and the downstream area of the Kelaniganga basin.
- The classified image output showed that the potential of the ASAR IM data for discriminate major land cover categories in addition to the PFA.
- The overall accuracy and the kappa coefficient for the main classified image were 88.35% and 0.84, respectively. Additionally,both DEM and land use were in good agreement with the overlaid PFA.
- Based on the factors such as precipitation, mean σ° fluctuations of the PFA, classified images,the study area can be categorized in to three flood vulnerability zones. They are Zone A, Zone B and Zone C. Zone A consists of southeast of the Bolgoda basin and has high vulnerability to floods throughout the yearand sensitive to antecedent rainfall. South of the Bolgoda basin and downstream area of the Kelaniganga basin belongs to Zone B and has moderate vulnerability to the floods. Zone B is more vulnerable to floods during both SW and 2nd inter monsoon periods. Zone C has the lowestvulnerability to floods and consists of southeast of the Bolgoda basin. This area is more vulnerable to flood during 2nd intermonsoon period.

Limitations

- Classified images were consisted of some misclassifications since some urban features such as roads, ground, and runaways haveshown similar backscatter response as smooth water surface. However, by producing mean statistical images by the time series analysis, we minimized this effect to get more reliable result.
- Limited number of land cover categories can be identified using microwave imagescompared to multibandoptical images.
- Validation of flood extent map is usually difficult since flood events are not related with the everyday life experiences. Therefore, those flood maps may be related with uncertainty and so accuracy of the product, data and techniques used to prepare the flood extent maps should be specified.
- Some inherent uncertainty may be related with the accuracy of confusion matrix computation since both training data sets and reference data sets were selected from the same ground truth source (high resolution optical images from Google earth).
- Although the urban areas are subjected to the frequent floods during southwest and second monsoon periods, we cannot determine the PFA in the urban areas due to the insufficient data, such as topographical data, high resolution images. Fulfilment of those requirements are expensive and not part of this research.

Recommendations

- Attention should be paid to the identified flood zones (Zone A, B and C) in the study area according to the monsoon periods and priority should be given according to the vulnerability (high, moderate low).
- Problems encountered due to the lack of regularly available high resolution SAR observations in the moment of the flood peak can be overcome to some extent by analysing series (time series) of SAR images since this method provided more efficient storage, faster interpretation capability, improved accuracy and reliability than single or few images.
- Classified image output has showed that ASAR IM data aided with ground information has the capability of discriminating major land cover types such as open water, urban, vegetation in addition to the flood extent in an efficient and economical way.
- The study of temporal variation of mean σ◦ of PFA hasshowed that this research method can be used to identify the flood vulnerability zones in response to the precipitations.
- In addition to the above recommendations, the research methodology, which was used to extract PFA, can be used to extract the water bodies in a specific area.

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Improvement of the safety and acceptability of drinking water supplied from irrigation tanks by proper selection of unit operations

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INTRODUCTION

Scarcity of unpolluted ground water and natural surface water sources such as rivers and lakes, has forced many parts of the dry zone in Sri Lanka to choose irrigation water tanks as the source for drinking water supply schemes. Surface runoff draining to these shallow water bodies through cultivated catchment areas is generally rich in nutrients, leading to eutrophication and rapid growth of algae, which tend to develop into large populations, called algal blooms. Where cascading systems of tanks are present, the drainage waters from paddy fields add large nutrient loads to the tanks in the lower elevations.

These algal blooms can cause several problems, depending on the algal species and their concentrations. On the operational side, algae cause problems such as increasing coagulant demand, settling dysfunction, filter clogging, membrane fouling, increase of disinfectant demand etc., while regarding the water quality, algae have a strong influence on pH, dissolved oxygen content, level of chlorophyll a, biodegradable dissolved organic carbon, turbidity, presence of cyanotoxins and taste, colour and odour causing compounds. (Baudin et al., 2006). These problems can impact the plant's operation as well as the treated water quality.

Conventional water treatment unit operations may not always produce satisfactory quality of water in suchsituations. Unit operations of conventional water treatment plants are not aimed at removal of dissolved organic substances or cyanotoxins. It has been identified that different cyanobacterial speciesproduce different types of cyanotoxins, whichnormally remaining in the algalcells but get dissolved in water when the cells are stressed or ruptured (cell lysis). They are thermo stable and therefore cannot be destroyed by boiling. They are cumulative and hence can accumulate in small amounts over a period of time before any ill effects are manifested (WHO, 2010).

Eastern Coastal Towns of Ampara District (ECTAD) Water Supply Project, where the raw water source is Konduwatuwana Tank, an irrigation tank with high inflows of nutrients, is the focus of the present study. It has been identified that Konduwatuwana Tankwater has high cyanobacteria content.ECTAD water supply project was initially designed to provide piped water services for a narrow strip of coastal towns in the Ampara District. Today there are about 50,000 connections for the ECTAD water supply scheme (WSS), which means that more than 250,000 people are dependent on this scheme.

This water treatment plant consists of pre-chlorination, coagulation, flocculation, dissolved air floatation (DAF), rapid gravity filtration, disinfection and post lime addition for stabilization. Powdered Activated Carbon (PAC) dosing was introduced to treatment system in order to overcome taste and odor incanted in treated water from time to time. The present case study was carried out to evaluate the efficacy of pre-chlorination, activated carbon adsorption, dissolved air flotation, filtration and disinfection in removal of cyanotoxins, taste and odor causing dissolved organic substancesfrom the source water, in order to provide satisfactory potable water.

BACKGROUND STUDIES

Scientists and water supply engineers have been concerned by the presence of blue green algal species in the cascading tank systems in the past few years, and a few studies have been conducted to identify the species occurring in several irrigation tanks in Sri Lanka, including KonduwatuwanaTank.

Paststudieson Kondiwatuwana Tank (Padmasiri, 2004;Pathmaseelan, 2006;Outokumpu, 2006; Silva, 2006 andAapola,2007) show that presence of cyanobacteria species of *Microcystis* and *Cylindrospermopsis* have been consistent, even though the species dominance seems to have been shifting between *Microcystis* and *Cylindrospermopsis*. Both of above species are well known producers of cumulative algal toxins Microcystin LR and Cylindrospermopsin.

Review of literature on the technology options available for dealing with the algal problems, it appears that pre-chlorination has shown in many instances to improve algal removal as a result of 'algal inactivation' (Henderson et al., 2008). However, there are a number of drawbacks to pre-chlorination, such as formation ofdisinfection by-products (DBPs), specifically trihalomethanes (THMs) when using chlorine or chlorine dioxide on water containing organic substances. Irrespective of oxidant utilized, overdosing cannot only induce cell lysis, releasing undesirable toxins or taste and odor compounds are formed. Therefore, the optimum dose is that which achieves cell modification without cell lysis and this has been shown to be species dependent (Jurczak et al., 2005, Henderson et al., 2008). Therefore, pre chlorination, if toxin removal is a priority issue, cannot be recommended.

Past studies have shown that the rate of inactivation of *Microcystis* is affected by pH and contact time; as pH increased the inactivation rate decreased and less degradation of Microcystin occurred, while in acidic conditions *Microcystis* chlorination has been more effective (Tsuji et al., 1997 and Xagoraraki et al., 2006). Hitzfeld et al. (2000) also reported that a chlorine residual of at least 0.5mg/l should be present after 30 min contact time in order to destroy toxins completely.

In addition, Hitzfeld et al. (2000) has shown that Cylindrospermopsincan beeffectively oxidized by 4 mg/L chlorine at pH 7.2-7.4 from water containing toxin concentrations of 20-24 µg/L. Acero et al. (2005) has reiterated this. They have found that the chlorination of Cylindrospermopsin (CYN) leads to the formation of 5- Cl- CYN, a non toxic compound that reacts with chlorine 10 -20 times slower than CYN.

Hitzfeld et al. (2000) showed that coagulation can be an efficient method for eliminating cyanobacterial cells from water, whereas soluble cyanotoxins are not very efficiently removed by this method. He reported that only PAC adsorbtionat a ratio of 1:10 to 1:100 (toxin: activated carbon)effectively and quickly (contact times of 30 min are sufficient) eliminate cyanotoxins from water.

Teixeira & Rosa (2006) andHenderson et al. (2007) have reportedthat DAF has become more popular in terms of algae removal, as it can take advantage of the low density of algae.When employing DAF, it is important to consider that different cyanobacterial species behave differently, depending on their physical properties: in a Belgian DAF plant *Microcystis*was removed by 40-80%, *Anabaena* by 90-100%, but *Planktothrix*only by 30% (Hitzfeld et al., 2000).

OBJECTIVE OF THE STUDY

The broad objective of the studyis improvement of the safety and acceptability of drinking water supplied from irrigation tanks by proper selection of unit operations using ECTAD Water Supply Project, taking into account the diurnal and seasonal variations of water quality of Koduwatuwana Tank and to study the applicability of the results to other irrigation tanks in Sri Lanka.

The specific objectives are as follows:

1. To study the presence of cyanobacterial species and level of cyanotoxins in raw water & treated water
2. To study the efficacy of treatment unit operations on cyanotoxinsandtaste and odor causingdissolved organic substances
3. To determine optimum operational condition for the treatment units in order to provide satisfactory treated water throughout the year
4. To study the applicability of the results to other surface water sources in Sri Lanka.

METHODOLOGY

The case study was designed to evaluate the efficacy of pre-chlorination, PAC adsorption, DAF, filtration and disinfection in removal of cyanotoxins and taste and odor causing dissolved organic substances from the source water.The normal operation of the plant was interrupted and operation sequence was modified as shown in Figure 1 during four dayswiththe assistance of the Chief Engineer at the ECTAD Water Supply Project.The samples were collected at the source, the inlet and outlets of each unit operation,in the morning and afternoon to capture the diurnal variations in quality. It was decided to carry outfour trials during two dry seasonsand two wet seasons since the raw water quality reports showed that the quality was significantly varied seasonally.

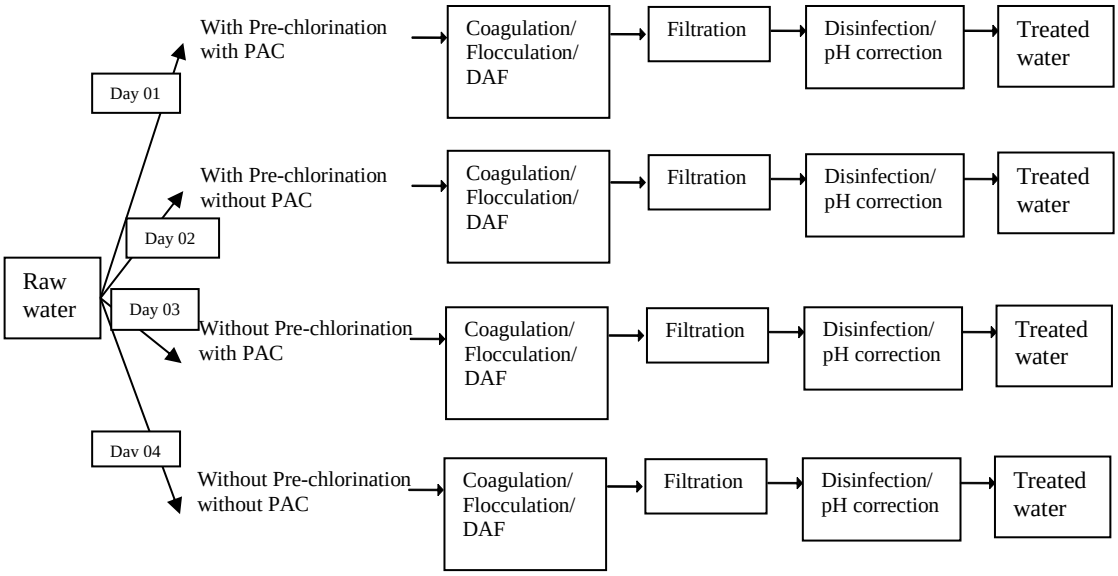

Figure 1 - Operation sequence of the trials

Even though the standard method for determination of cyanotoxins is using the HPLC, due to unavailability of standards, it was not possible, and the approximate method using Enzyme Linked Immuno Sorbent Assay (ELISA) strips was used instead.For measuring of algae concentration a microscope and a Sedgwick- Rafter Chamber were used.

The type of PAC used at the Plant is a wood based carbon that is imported from Australia. Since several types of PAC are produced in Sri Lanka, the possibility of substituting the locally produced PAC was also studied, by running laboratory tests on the raw water using the wood based Australian PAC, a coal based local PAC and a coconut shell based local PAC having nearly same surface area. These laboratory tests were conducted by introducing different PAC doses to a 500 ml flask containing the raw water and allowing it to absorb the organic matter using the shaker, over a period of 60 minutes. The Chemical Oxygen Demand (COD) was measured before and after absorption, and the percentage removal of COD calculated. Threshold number was also found by diluting the sample with distil water before and after adsorption. The optimum and maximum dosages of PAC required were calculated using the isotherms obtained.

Records of raw water quality of the irrigation tanks in Sri Lanka were collected for generalizing the results. Among those tanks some are in the Gal oya cascade system, some are in the North Central Province, currently used for water treatment projects.

RESULTS AND DISCUSSION

Algal concentration

Algae counting results confirmed that raw water of Konduwatuwana Tank has high cyanobacteria concentrations, particularly in the dry season.*Microcystis aeruginosa* is the predominant species, with concentrations of the order of 10,000 cells/ml. Another *Microcystis* variant named *Microcystiswesenbergii*and *Cylindrospermopsis*werealso identified, in lesser amounts compared to the concentration of *Microcystis aeruginosa*(See Figure 2).

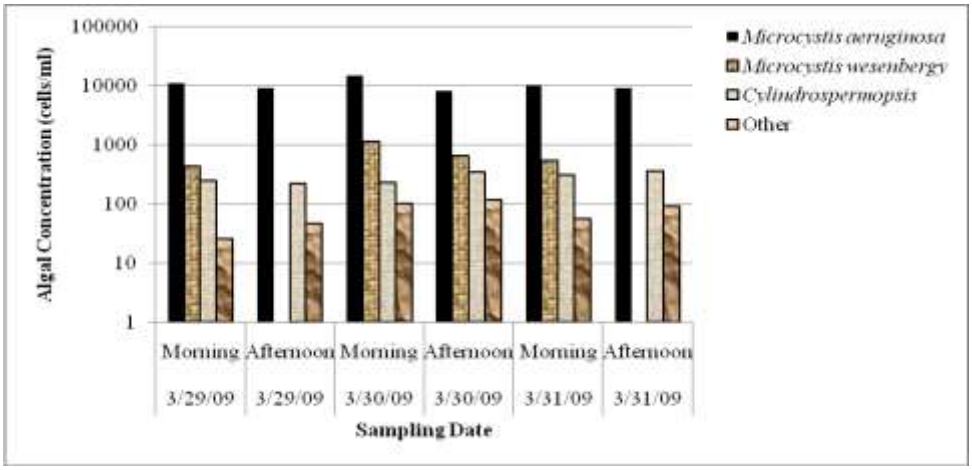

Figure 2-Algal analysis results in raw water samples during the study period

Observations on the diurnal variation of dominant and subdominant species of cyanobacteria found in Koduwatuwana tank showed a clear pattern of regular movement. Surface water *Microcystis aeruginosa* concentration seems to be higher than middle depth water in the morning samples, while in the afternoon time *Microcystis aeruginosa* concentration of middle depth water is higher than the surface water. The reason for this is in the morning, cyanobacteria discharge O_2 molecules as a result of photosynthesis, which attach to the cyanobacterial cells, giving them a buoyancy force, and they tend to float. In the afternoon, once the bacteria are at the surface, the O_2 molecules are detached from the cyanobacteria cells, and they tend to sink.

There is a significant difference between algae counting results of this study and the results of the past latest study (Aapola, 2007). According to Aapola's study the predominant algal species was *Cylindrospermopsis*. Later it was identified that Microcystis colony have been counted as a cell in their study. In the counting procedure using Sedgwick-Rafter cell, the *Microcycstis* look like a bunch (See Figure 3) and such a colony is counted as a cell. Therefore, it is clear that Microcystis is the dominant specie in both the studies.

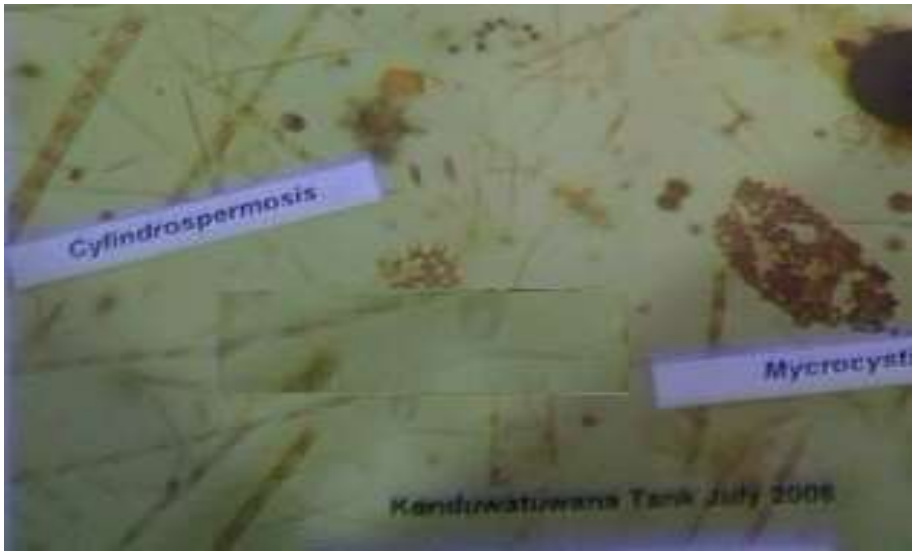

Figure 3-Mycrocystis and Cylindrospermopsis in a sample.

As a guide, three alert levels based on algal cell counts have been determined for drinking water supplies (Padmasiri, 2004).

Alert level I is when algae counts are 500-2000 cells/ml or where offensive odours or tastes are noticed. Increasing monitoring frequency is recommended for level I stage.

Level II is when algae counts are 2000-15000 cells/ml and the algae species is one that is potentially toxic. Further intensive monitoring and consultation with health agencies is recommended for this level. In addition to that operational changes should be made to decrease the likelihood of supply contamination.

Level III is when algae counts are exceeded the 15000 cells/ml and the bloom is widespread within the water body. According to Padmasiri's (2004)recommendation, if the toxicity levels are rising water authorities should switch to alternative supplies or treat the water with activated carbon (AC). From our results it can be manifested that Konduwatuwana tank is gradually approaching from level IIto level III, which indicates the need for considering an alternative source or considering that treating water with AC is essential.

Mycrocystin LR removal

According the results, the raw water always contained Microcystin LR levels exceeding the WHO guideline of 1 µg/l, while in the first trial (Table 1) results showed that the Microcystin LR is not detectable in the treated water samples treated using PAC. Pre-chlorination without PAC does not appear to help, whereas post-chlorination after using PAC does seem to remove the remaining toxins. In the second trial (Table 2), Microcystin LR was not detected in any of the treated water samples. This may be due to the lower concentration of Microcystin LR in the raw water samples compared to the first trial.

Table 1 - Microcystin LR identification test results for dry season 1st trial

Operations	Date	Morning/ Evening	Raw water	Rapid mixer	Before DAF	AfterDAF	Filt. water	Treated water
With Pre-Cl, With PAC	28.03.2009	Morning	>20µg/l	NM	NM	NM	10-15µg/l	ND
		Evening	15-20µg/l	NM	NM	10-15µg/l	NM	ND
With Pre-Cl, Without PAC	29.03.2009	Morning	NM	NM	>20µg/l	NM	10-15µg/l	10-15µg/l
		Evening	>20µg/l	NM	>20µg/l	NM	>20µg/l	10-15µg/l
Without Pre-Cl, Without PAC	30.03.2009	Morning	NM	NM	NM	>20µg/l	NM	10-15µg/l
		Evening	>20µg/l	NM	>20µg/l	NM	10-15µg/l	10-15µg/l
Without Pre-Cl, With PAC	31.03.2009	Morning	10-15µg/l	NM	NM	10-15µg/l	NM	ND
		Evening	NM	NM	NM	10-15µg/l	NM	10-15µg/l

Table 2 - Microcystin LR identification test results for dry season 2nd trial

Operations	Date	Morning/ Evening	Raw water	Rapid mixer	Before DAF	AfterDAF	Filt. water	Treated water
With Pre-Cl, With PAC	21.09.2009	Morning	15-20 µg/l	10-15µg/l	ND	ND	ND	ND
		Evening	15-20 µg/l	10-15µg/l	ND	ND	ND	ND
With Pre-Cl, Without PAC	20.09.2009	Morning	15-20 µg/l	10-15µg/l	15-20 µg/l	10-15µg/l	ND	ND
		Evening	15-20 µg/l	10-15µg/l	15-20 µg/l	10-15µg/l	ND	ND
Without Pre-Cl, Without PAC	22.09.2009	Morning	15-20 µg/l	ND	ND	ND	ND	ND
		Evening	15-20 µg/l	ND	ND	ND	ND	ND
Without Pre-Cl, With PAC	19.09.2009	Morning	15-20 µg/l	ND	ND	ND	ND	ND
		Evening	15-20 µg/l	ND	ND	ND	ND	ND

Note: ND – Not Detected; NM – Not Measured

According to the results, the worst treatment option was the treatment with pre-chlorination and without using PAC. On the other handas mentioned in the background studies, the rate of inactivation of Microcystin LR is affected by pH and contact time, and the effectiveness of chlorine reduces at pH values higher than 7, as well as at lower contact time. In Konduwatuwana tank, the raw water pH is greater than 7 during most times, the maximum contact time available in this treatment plant is only 22 minutes. A further complication is the arrangement of dosing chlorine, coagulant and PAC all at the rapid mixer, simultaneously. Therefore it is clear that pre-chlorination operation of this plant has not fulfilled the requirements needed for Microcystin LR inactivation. Another factor is the effect of chlorine on the adsorption capacity of carbon. Because oxygenating the carbon surface decreases its affinity for aromatic compounds. Therefore, it may be a better option to remove the pre-chlorination step, and optimize the conditions for removal of the Microcystin LR as well as other dissolved organics using PAC, assisted by post chlorination, where a sufficient contact time can be provided.

Most of the time lysing of cyanobacterial cells due to physical stresses, leading to release of toxins. Therefore removing cyanobacterial cells using micro-strainers at the intake may be more effective than removing cyanotoxins from the water.

Taste and Odor Removal

As mentioned earlier,taste and odor problem is persistent in the treated water. The presence of offensive taste and odor compounds including 2-methylisoborneol (2-MIB) and geosmin in the drinking water supply has also been attributed to high algae populations(Tsuji et al., 1997). In 2006, Outokumpu Technology Pty Ltd has measured the 2-MIB and geosmin concentrations of Konduwatuwana tank water. (See Table 3)

Table 3 - MIB and geosmin concentrations of Konduwatuwana tank water

Date	Sample collected point	2- (MIB)/(ng/l)	Geosmin /(ng/l)
01/03/2006	Plant Raw Water	18	5
	Flocculated	9	2
	Floated	18	5
	Filtered	8	7
	Filtered with Cl	4	2

The algae counting results showed that the current algal concentration is about 10- 10^2 times greater than the algal concentrations in 2006, and therefore it can be expected that the 2-MIB and geosmin concentrations also may be increased in proportion to the algae concentration. The use of activated carbons is known to be effective in removing MIB and geosmin from water (Tsujiet al., 1997).

Due to the unavailability of equipment for measuring the individual organic substances, COD is used as the parameter for representing all the taste and odor causing compounds including MIB and geosmin in this study. It was clearly observed that COD removal is proportional to the odour removal. Four different water samples were tested for COD and threshold number for odour before and after PAC treatment simultaneously. Since the adsorption kinetics and equilibrium capacity is dependent on the type of PAC used, adsorption isotherms were obtained for COD removal using three different types of PAC. The adsorption isotherms of COD on the three PAC's are shown in Figure 04. Clearly, wood based Australian PAC has a higher adsorption capacity than coal based local PAC and coconut based local PAC.

It should be noted that using 100mg/l of wood based Australian PAC, 84% of COD could be removed, while the maximum percentage COD removal using the same PAC was 85% at a corresponding dosage of 200 mg/l. In other words, optimum PAC dosage of wood based PAC for COD removal of this particular type water was 100mg/l. Resultsof this study have showed that the optimum dosages of coal based PAC and coconut shell based PAC were 80mg/l and 60mg/l, respectively, and corresponding COD removals were79% and 72%, respectively.

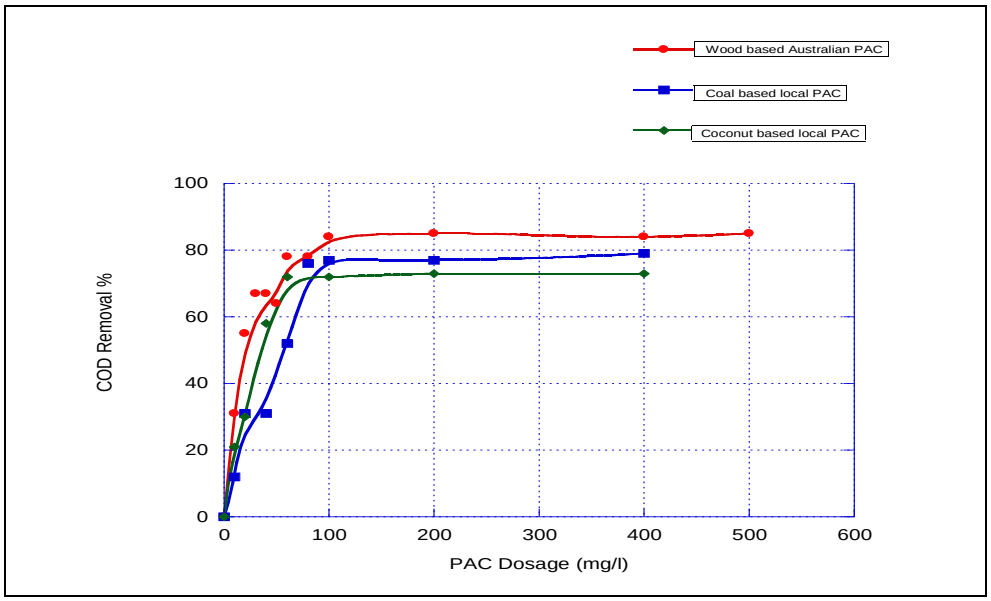

Figure 4 - Percentage COD removal of three different PACs for 60 minutes contact time

The efficacy of adsorption operation also depends on the contact time and pH of water.It was also interesting to study the removal efficiencies when the PAC is allowed only the maximum contact time (22 minutes) available in this Plant. The results show that the efficiency of all three types of PAC is very much less than optimum and the required PAC doses are much higher. Therefore, it is imperative that the arrangements at the Plant should beredesigned to increase the contact time of PAC. Adsorption at high pH is often poor than at low pH, because many organic contaminants are weak acids that ionize at high pH, rendering them more hydrophilic, and difficult to be attracted to the solid carbon phase.

Generalizing the Results

Algal species of Inginiyagala Tank, Himidurawa Tank and Weeragoda Tank (tanks in the Gal Oya cascade system) have been analysed by regional laboratory, Ampara. According to these results the predominant species is *Microsystis* in eachtank.Although algal concentration of these tanks is much lower than the Konduwatuwana Tank algal concentration, there is a possibility that microcystin is present in those waters also. Since *Cylindrospermopsis* also present as sub-dominant species in each tank, there is a probability that cylindrospermopsin is present in those tanks. Therefore, it is essential to check cyanotoxin concentration, if these tanks will use as raw water sources for drinking WSSs.

Institute of Fundamental Studies (IFS) has carried out a study for identifying algal species and counting algal cells in nine irrigation tanks in North Central Province. Most of those selected tanks are used as raw water sources of drinking WSS. From this analysis they have observed that *Cylindrospermopsis* isthe predominant specie in every tank. Among these tanks Thuruwila Tank (source for Anuradhapura WSS), Nallachchiya Tank (source for Thambuttegama WSS), Parakrama Samudra (source for Polonnaruwa WSS), Tisa Wewa (source for Anuradhapura Scared City WSS), Nuwara Wewa and Minneriya Tank have high concentration of cyanobacteria, especially high concentration of *Cylindrospermopsis.* Generallyin these tanks *Cylindrospermopsis* concentration varies 9000- 60000 cells/ml. In addition to that several types of Cyanobacterial species have been found from those tanks. However water quality of Galnewa Tank (source for Galnewa WSS), Eppawala Tank and Kala Wewa are better compared to other irrigation tanks stated above. *Cylindrospermopsis* is the only one cyanobacterial specie found in those irrigation tanks. The concentration of *Cylindrospermopsis* is very low compared to others. Therefore, it is clear that except Galnewa WSS other four WSSs stated above need additional treatment operations for cyanotoxin removal. It is essential to monitor cyanotoxin concentrations of raw water and treated water regularly. Since the pre dominant specie of all of these tanks is *Cylindrospermopsis,* definitely water may contain high amount of cylindrospermopsin. In addition to that water may contain various types of cyanotoxins, because many types of cyanobacteria present in those tanks. Adsorption by PAC can be recommended for those WSSs. Since according to past studies (Hitzfeld et al., 2000), pre-chlorination has effectively removed cylindrospermopsin,it is suggested to study the effectiveness of pre-chlorination for removing cylindrospermopsin also.

CONCLUSIONS AND RECOMMENDATIONS

The following conclusions can be drawn from this study.

1. Raw water in Konduwatuwana Tank has high cyanobacteria content. *Microcystis aeruginosa* is the predominant specie.The results also show that the algae population is the highest in the dry months.According to the alert levels have been determined by based on algal cell counts, Konduwatuwana Tank is gradually approaching fro*m* Level IIto Level III.According to the recommendations for Level III condition, considering alternative source or treating water with AC is essential.
2. *Microcyst*in concentration in the raw water during the dry season consistently exceeded 15 µg/l, and occasionally exceeded even 20 µg/l.
3. PAC was effective in reducing the microcystins concentration, while pre-chlorination without PAC does not help, whereas post chlorination after using PAC helps to achieve desired removal.
4. Taste and odor problem is persistent in the treated water. Water contains 2-MIB and geosmin which have been attributed to high algae content.
5. Odor removal seems to be proportional to the COD removal. Laboratory studies showed that the effectiveness of PAC in removing COD was depended on the type of PAC and the contact time.Wood based Australian PAC has a higher adsorption capacity than coal based local PAC and coconut based local PAC.Sufficient contact time is necessary for the efficient adsorption process. It is clear from laboratory experiment that available contact time is not sufficient.

It is recommended that when selecting treatment operations for water treatment plants where irrigation tanks are used as the source, paying special attention to cyanobacterial and cyanotoxin concentration is essential. It is suggested to remove the pre-chlorination step and optimize the conditions for removal of microcystins as well as other dissolved organics (including taste and odor causing compounds) using PAC, assisted by post- chlorination with sufficient contact time. When selecting the type of PAC for taste, odor and dissolved organics removal, local PACs are also recommended with appropriate dosages and sufficient contact times.

However in the long-term, it is recommended to look for a better source of water for ECTAD Water supply project considering the fact that the raw water contains high amount of microcystins, and other undesirable constituents such as 2-MIB and geosmin.

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Knowledge, attitudes and practices of urban poor women on water and sanitation-a case study in Mahaiyawa slums, Kandy

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ABSTRACT

Women play a central role in Water resources management as recognized by the concept and principles of IWRM that were expressed at the International Conference on Water and Environment held in Dublin in 1992. Women could play a major role in practicing correct sanitary practices at domestic levels- in terms of drinking water, sewerage/ drainage, sanitary toilets, and solid waste disposal. Women and girls also pay the heaviest price for poor sanitation. In Sri Lanka the women amount to 51%. This research was conducted to determine the level of knowledge, attitudes and practices on water and sanitation of the women in urban slums in Sri Lanka and the frequency of occurrences of water related diseases. The research was conducted using PRA tools and a questionnaire survey, in an urban area in the Kandy District, Central Province, Sri Lanka. The urban setting that was selected is a high population density area within the Kandy municipality council (KMC)limits. The GN division is Poornawaththa West 240, which is popularly known as the Mahaiyawa slums. There is a total number of 1390 households and a population of 5982 out of which the number of women is 2978 which equals to 49.78% of the total population. The selected women for the questionnaire survey were between the ages of 30 to 40. Motherhood was an essential requirement. The data gathered were analyzed using the SPSS software. According to the findings of this research, 66.7% of the women in Sri Lanka possess primary education and had a basic knowledge on sanitation and hygiene. This is due to the free education system that prevails in Sri Lanka. But the practices and attitudes differed and were of a very low level. The women in the urban slums face a lot of difficulties in practicing proper sanitation, because the population density is very high. 46.6% of the households in the urban slums did not comprise a latrine. They were compelled to use the public latrines that are provided and maintained by the Kandy Municipality council. Women and children were the most affected by it. It was observed that open defecation was a common practice among children and women at nights as in and around the public latrines a lot of illegal activities are carried out during this time. Slum dwellers are considered to be essential for the survival of a town as they carry out the most janitorial activities. Their lifestyles are backed by politicians. The solutions of lower levels of knowledge, attitudes and sanitation practices of women can be categorized as follows: Creating supportive and healthy environments, Strengthening community action, Develop personal skills and creating awareness, reorient health services.

BACKGROUND OF THE STUDY

"We shall not finally defeat AIDS, tuberculosis, malaria, or any of the other infectious diseases that plague the developing world until we have also won the battle for safe drinking water, sanitation and basic health care."

Kofi Annan, United Nations Secretary-General (2001)

The World Health Organization reports that 2.4 billion people in the world live in highly unsanitary conditions and have such poor hygienic behaviour that their exposure to risks of incidence and spread of infectious diseases are enormous. (WSH report 2011)

More than 80% of diseases that affect humankind are water related. Water related diseases (since they spread through contaminated food and water) are common in Sri Lanka and diseases such as Hepatitis A, Typhoid fever, viral gastroenteritis, Giardiarsis could be prevented through better hygienic practices. Sanitation acts as a barrier for disease transmission and created an environment which is free from contamination and disease promotes health and hygiene.

Providing access to improved sanitation and good hygiene practices would help break the fecal-oral pathogen contamination of water bodies, yielding benefits to health, poverty reduction, well-being and economic development. (WHO, 2006).

Cleanliness should begin with a person's immediate environment-"Home". Women hold the main role of domestic responsibilities and could play a major role in practicing correct sanitary practices - in terms of drinking water, sewerage/

drainage, sanitary toilets, and solid waste disposal at domestic levels. 51% of the population in Sri Lanka is women as such their contribution to the overall health of the country is substantial. However, it is women and girls who suffer most from poor sanitation.

Proper sanitary practices include using and cleaning a latrine, wearing slippers when using a latrine, washing hands, bathing, using soap and other detergents, environmental cleaning, etc. In addition to these, water storage and purification practices also contribute to the health of the water consumers. Removing household wastewater is an important environmental health intervention for reducing disease. Poorly drained household waste water forms stagnant pools provide breeding sites for disease vectors. Household wastewater may also contain pathogens that can pollute groundwater sources, increasing the risk of diseases.

These sanitary practices and facilities might differ from urban to rural settings and also may differ according to the knowledge and attitude and practices of women. Though 80% of Sri Lanka is defined as rural (Census and Statistics Department, 2001), the urban community is growing at a rapid pace. And there perhaps exist a noticeable difference in the sanitation practices and living conditions of women of the rural and urban areas. Environmental pollution and waste generation are seemingly higher in the urban areas which may be due to the higher population density. Rapid, unplanned and unsustainable patterns of urban development are making developing cities focal points for many emerging environment and health hazards. As urban populations grow, the quality of the urban environment will play an increasingly important role in public health with respect to issues ranging from solid waste disposal, provision of safe water and sanitation.

This research strives to determine the level of urban poor women in terms of their knowledge, attitudes and practices on water and sanitation and the frequency of occurrences of water related diseases.
It is common knowledge that there is an inseparable relationship between health issues related to water and the environment and it is vital to find out the intricacies associated with this relationship. Water related diseases remain a cause for concern as more than 80% of diseases that have afflict people are water related. (WHO,2003) Furthermore there is a significant disparity between the urban and the rural way of life. Knowledge, Attitudes and Practices of women are a key component when it comes to the overall health of the society due to their responsibilities in taking care of children and also in maintaining clean households; thus it is imperative to study the factors affecting the differences of Knowledge ,Attitudes and Practices (KAP) of poor urban women.

METHODOLOGY

The research was conducted in a highly populated urban area in the Kandy District, Central Province, Sri Lanka. The GN division is Poornawaththa West 240, which is popularly known as the Mahaiyawa slums. There is a total number of 1390 households and a population of 5982. Out of the total populations 2978 were women which is equal to 49.78%.Transect walks through these two areas were carried out to comprehend the situations and observe the facilities and sanitation practices of women. To understand the factors that impact, the knowledge, attitudes and practices of women an interview administered questionnaire survey was conducted. The questionnaire focused on acquiring data on their sources of water, sanitation facilities, sanitary practices, attitudes and knowledge regarding water borne diseases. A sample of 30 women from this area was selected to be questioned for primary data collection. The selected women were between the ages of 30 to 40. Motherhood was an essential requirement. This was due to the fact that mothers carry the responsibility of bringing up the children and all other domestic duties.Then the questionnaires were analyzed using the SPSS (Statistical Package for the Social Sciences) software.

Other participatory appraisal tools such as focus group discussions (FGD) with the specified women were conducted. Focus groups consisted of 8-10 women fulfilling the same criteriaas the participants of the questionnaire survey.Key Informant Interviews (KII) were conducted with health officials and other relevant government authorities in the study area to triangulate the information regarding the incidences of health issues related to water and population densities. The Community Health Officer of the health department, Kandy Municipality Council, who is in charge of Poornawatta west GN division, was interviewed and secondary data were collected from their records. Chief water Engineer of the Kandy Municipality council, the deputy project director and the project engineer of the sewerage and waste water treatment project of the National Water Supply and Drainage Board (NWSDB), Kandy were also interviewed under the Key Informant Interviews. The chief sociologist of the NWSDB was also interviewed with special emphasis regarding the attitudes of women on water and sanitation.

RESULTS AND DISCUSSION

Mahaiyawa spreads over a land area of 10 acres which is legally owned by the Kandy Municipality Council (KMC). There is a total population of 5982 in the area out of which approximately 50% are women. Most of the dwellers arelabourers or minor workers of the KMC and some of them were given pieces of land in this region in the past. There are other houses that are illegal constructions, known as “unauthorized settlers”. The urban slums of Mahaiyawa are multi ethnic and

multi religious. Majority were Hindus while there is an equal number of Christians and Catholics. There are also a considerable number of Muslims, and a rather small number of Buddhists. Mahaiyawa consists of a lot of people who do important odd jobs that others in the society refuse to undertake. Janitorial services, garbage collectors are few such jobs. The service rendered by them to the city of Kandy is usually undervalued and neglected.

One of the essential services for any community is water. Mahaiyawa has a municipality water supply scheme. Some households, who are more economically stable, had water supply to their own house while others used the public water taps. A public water tap is averagely shared by 8-10 families and the water is free from these public taps and has a water supply of 24 hours a day. 46.7% of the women in the area depend on it for their water requirements for bathing and washing clothes. Bathing places covered to safeguard the privacy of women are kept in good condition, modified and renovated with foreign funds. There are no regulations to control water usage of the inhabitants. They do not have to pay any fee for the water that they are using from these public taps.

It was noticed that there were taps with running water even when not in use. Due to years of free water supply there is an attitude generated among the dwellers that water comes at no cost. Whenever something is provided for free, it is given less value and less consideration. Hence, people are not motivated to take any action to save water.

The participants of the survey were asked whether they boil water for drinking and were given three options to select. The percentages of women who boil water regularly, occasionally and never are given in the table below.

Table 1 -percentages of women who boil water regularly, occasionally and never

Area	Regularly	Occasionally	Never
Urban	30%	43.4%	26.7%

They were also asked the reason behind the answer given.Due to the primary education that they have received, the majority of women in Sri Lanka are aware that water can cause sicknesses. Over 90% of the women agreed that polluted water can cause ill health in humans. Although it is an accepted fact that boiling is a method of infection, only 30% women boil water for drinking regularly. Women who boil water are an extreme minority, they particularly said that their children disliked the taste of boiled water and hence they preferred not to boil the water.

Another reason given as to why they only boil water occasionally was as they have limitations in time. They have to spend a lot of time standing in queues to collect water, and to use public latrines especially in the mornings when children have to be sent to school. 40% of the urban women used kerosene oil for boiling water. The rest used firewood and gas. In the urban slums means of boiling water is costly, as even the firewood costs them money. Hence boiling water is an additional cost for them. Some mentioned that they boil water only for children and adults drink water straight from the taps. These facts show that women are aware of the advantageous of boiling water. They have been taught that at school or by their elders. But due to lack of finances and time limitations they do not use this simple method of disinfection of germs and pathogens of water.

The KMC has provided public latrine facilities to this community as most of the households do not have the required space to build a private latrine. A line of latrine consists 4-5 units of latrines. These are placed at 9 different places in the area, and have a total of 92 units of pour flush latrines. There had been renovations of these latrines by various NGOs.The municipality council is responsible for maintaining and cleaning these latrines, 3 municipality council janitorial workers are assigned to clean them each morning. Every Monday and Friday they clean the pits using gullies of the Municipality Council. During festivals the pits are cleaned daily. Also the families contribute Rs.30.00 every 3 months to buy necessary detergents and antiseptics which are used for the cleaning. And the users conduct shramadhana campaigns to clean the latrines they use. The graph below shows the facilities of public latrines available.

Photo -Public Latrines in Mahaiyawa

Public latrine line	Total number of households around the area	Number of houses with private latrines	Units in the line of latrines	Number of houses per latrine
1 & 2	156	19	26	6
3	34	8	7	5
4	17	13	4	5
5	55	19	11	5
6	23	15	8	3
7	44	7	4	11
8	72	11	12	6
9	21	17	12	2
Total	422	109	84	5

The table indicates that each unit of latrine is shared by at least 5 or more families. The average family size is close to 4 as per the data gathered from the research. Therefore, as an average, 20 people are assigned one latrine. This shows the unhygienic situation in the urban society due to lack of facilities and higher population density. The families are unable to build their own latrine as the houses are congested and they lack space to build sewerage tanks.

It was observed and confirmed by the officials of the waste water project of the National water supply and drainage board that open defecation was a common practice among the children below 5 years in the slums of Mahaiyawa. Common toilets are hardly used at nights especially by the women and the children as it's not safe in the nights to walk far from homes. So the option they are left with is to use the drain that runs right in front of their houses. There are complains that the latrines are used for various illegal activities such and consumption of alcohol. Such law breakers destroy electric bulbs of the latrines for their illicit work, making it impossible for others to use it.

Most children used the drains that run in front of their houses rather than using the public latrines even during the day. The excreta can get stagnated in the drains and cause an obstruction for the flow of water. During heavy rain falls, this can cause flooding which includes human excreta which can also contaminate other water sources in the Kandy city. The root cause of this issue is again the lack of private sanitation facilities. But it is not practical for urban women to walk to a public latrine either to accompany the child to the latrine or to dispose their child's stool. Since it is a hassle and consumes a lot of their time they prefer the most convenient way; that is to let their children use the drains to defecate.
An unclean latrine can be grounds for spreading diseases. Cleaning the latrine is included in the list of domestic responsibilities of women if they own a latrine. The women in the urban community who use the public latrine mentioned that it's the responsibility of the municipality council. 96.7% of the women in the rural setting said that they were responsible of cleaning their own latrine. They were aware of the danger of unclean latrines. On the other hand 33.3% of the women of the urban slums found their efforts to clean the latrines are in vain because the users do not maintain the cleanliness of the latrines.

Methods of disposal of liquid wastes generated from domestic activities were taken in to consideration in this research as it is of vital importance that proper measures are taken to prevent spread of diseases, stagnation of water and breeding of mosquitoes. The urban community has the facility of disposing their waste water to the drain system constructed by the KMC. Every house hold in the area disposes their waste water to this network of drains. It was observed that there were illegal construction of houses obstructing this drain system and no action is taken by the authorities against such activities. Some houses had the drain running through their front hall. The municipality workers collect solid waste from every house in the morning and the solid waste is then taken to the open dump site in Gohagoda, Kandy. Yet 3.3% of the women dump the garbage into the drains. It was observed that there are always domes of solid waste in the drains in the area. Though it's a small percentage it's crucial as it indicates that women are ignorant about the bad effects of improper disposal of solid waste. Though the Kandy Municipality has set up a proper system to collect garbage there is still solid waste found dumped by the roadsides and drains.

Respondents were given a list of diseases and were asked to differentiate the diseases that are water related and those which are not. The diseases that were given were A1H1 virus, typhoid, common cold, Hepatitis A, diarrhea, skin infections, cancer, high blood pressure, cholera, HIV. The percentages of answers are given below:

Disease	Yes	No	Don't know
Typhoid	13.3%	70%	16.7%
Diarrhea	60%	23.3%	16.7%
Hepatitis A	20%	73.3%	6.7%
Cholera	40%	56.7%	3.3%

The answers showed that diarrheal diseases were popular among these women as water related diseases. And cholera was placed the second according to the ranking.

Frequency of washing hands is extremely low, especially for those who do not have a water supply at home and have to use the public water connection. They have to walk out of their homes a few meters to reach these taps and it is time consuming. The water that is stored in their homes is carefully used for cooking. Washing hands frequently, becomes an added burden to them as their supply of water is outside their homes. It was shown that though they are aware of its necessity, due to the lack of facilities they cannot practice good hygienic behaviors. The women were also asked if unclean hands spread diseases. Majority of them agreed and were aware that unclean hands spread diseases. The various types of soap advertisements on media made contributed to this perception.

There is a low trend for women to gain knowledge on sanitation through media. There is a lot of awareness created about the epidemic of dengue, and almost all the women were aware of this disease. However, the knowledge on other water borne diseases was much lower. With the number of deaths rising due to dengue there is a lot of campaigning about dengue through the media. Women were very knowledgeable regarding what causes dengue and measures that can be taken to avoid it. They actively involve themselves in dengue prevention activities. But the table below depicts that there is a low tendency for them to gain knowledge on water, sanitation and water related diseases through mass media.

Area	Knowledge gained through media	Regularly	Occasionally	Never
Urban		3.3%	60%	36.7%

There is an NGO working on sanitation projects in the Mahaiyawa area but the women complained that they lacked time to participate. It is required that government and NGOs implement projects to create awareness among the rural areas of the island since consideration is given to them is minimal.

CONCLUSION AND RECOMMENDATIONS

Slum dwellers are usually a neglected community in the society yet their contribution towards the city cannot be ignored. They carry the sole responsibilities of keeping the cities clean in most part of the world by doing jobs such as janitorial work, drainage and public area maintenance etc. Ironically they live in the most unclean and unhygienic conditions exposing themselves to a lot of sicknesses. When considering the slums like Mahaiyawa, we see a lower tendency towards proper sanitation practices. This research strived to find gaps of knowledge, attitudes and practices of women of this area regarding water and sanitation and to recognize possible reasons behind such gaps.

There is a rapid growth of urban poor community attributed to both natural population growth, and rural to urban migration. This population growth in the area, increases the intensity of the issue causing more land fragmentation, high housing densities and lack of sanitation facilities. Through the research it was reconfirmed that women and children are the most vulnerable. With the prevailing free education system in Sri Lanka, majority of the women have obtained primary education and have the basic knowledge on sanitation. A lot of women in the urban have given up education due to poverty and early marriage.

Water borne diseases are undoubtedly a critical problem in the society and the main responsibility of preventing it falls on to the women who are in charge of day to day domestic work. It is evident that poor urban women possess only a basic knowledge on sanitation and should be given a proper training and a proper education on sanitation which is a responsibility of schools, mass media, and religious institutes.Women could be motivated and empowered to raise a voice against consumption of alcohol and other related illegal activities that take place in and around the latrines which prevents them from using the latrines in the urban slums. Proper actions should be taken against vandalism. They are silent against the injustice that happens against them where they have to wait till morning or use the nearby drains instead of using the latrine. It can be considered as a violation of one of their basic human rights.

Regulations should be imposed by the KMC to control water usage or to recover cost by the people in the Mahaiyawa area. Education of women on saving water was identified as a necessity. Health education encourages behavior that promotes health, prevent illness, cure diseases and facilitate rehabilitation. The role of health education officers in planning, implementing, monitoring and evaluating health promotion programmes are critical if we are to see a behavior change in the community. The public health officer, community health officers and midwives are the main health officers at the grass root level. They can directly influence the women in the society and make a change.

The solutions of lower levels of knowledge, attitudes and sanitation practices of women can be categorized as follows.

a) Creating supportive and healthy environments
b) Strengthening community action
c) Develop personal skills and creating awareness
d) Reorient health services.

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Sustainable use of runoff harvesting tanks in small holder farming system: A case study at Vellavelli area of Batticaloa District

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ABSTRACT

The Coastal areas especially in dry zone of Sri Lanka face difficulties in accessing quantity as well as quality of water for irrigation and livestock rearing activities because of seasonal water scarcity during Yala season. Similarly, the Vellaveli area of Batticaloa District has limitation in availability of water for irrigation and livestock rearing activities. Hence it is very essential to harvest runoff water during rainy season to utilize that for dry season. In this view, some Non Government Organizations (NGO) constructed Runoff harvesting tanks in this area to collect runoff water. However, after the project has over no one has monitored the use of those harvesting tank to increase the sustainability. This study was conducted with the aim of acquiring relevant information from rural community and to find out the sustainability of runoff water harvesting tank in Vellaveli areas of Porathivu Pattu Divisional Secretariat division of the Batticaloa district. Information were gathered through questionnaire survey, personal interview and direct observation from 100 small holder farmers who are using runoff water harvesting tank. Stratified Random Sampling method was used in this survey and the descriptive statistics were used to analyse the results using Statistical Package for Social Sciences (SPSS).

The results shows that most of the farmers (96%) are mainly depends on Runoff tank for the irrigation to the highland crops and these tanks are found to be the most useful water source in these area. It was also found that water availability in the tank mainly depend on the area of crop extent, livestock number, family size and water use pattern. However, the capacity of runoff water harvesting tanks in this area is insufficient to store runoff water to meet water demands throughout the year. Lack of awareness, inefficient use of water (14%) and supplementary water source in the same land (30%) were the main reason for the improper use of some runoff harvesting tank in the study area. Therefore, it is recommended that, proper awareness should be developed in areas before and after implementing runoff harvesting tank and the people should be trained about the operation and maintenance of runoff tank after construction.

INTRODUCTION

Sri Lanka is an agricultural country and rain is considered as the primary source of water for domestic as well as for irrigation. Irrigated agriculture, which represents the bulk of the demand for water in this country, is also the first sector affected by water shortage and increased scarcity. Rain water is the primary source for irrigation through the different collection methods such as rain water harvesting at major and minor tanks. Rain water harvesting has been revived in Sri Lanka since 1995 with the Community Water Supply and Sanitation Project (Ariyananda, 2000). Collection of Runoff water also plays a major role inimproving the crop environment, increase labor efficiency, enhance sustainability, improve productivity, and to minimize risks from unpredictable climatic conditions (Koen,2010). Further, the current policy of the irrigation sector emphasizes the development of new water resources and rehabilitation and improvement of existing reservoirs and scheme to improve the productivity in the agriculture sector. Under the Eastern revival programme, several schemes have commenced in Ampara, Batticaloa and Trincomalee districts(Central bank of Sri Lanka, 2009).

The present study was conducted at some areas of the Porathivu pattu Divisional Secretariat areas of Batticaloa district. Annual rainfall in the study area is distributed to few months and generally do not receive rainfall for more than five months in a year. Hence, water shortage is the major problem in this area especially for vegetable crops and the people in the area are mainly depend on the groundwater as there are few minor irrigation tanks which do not hold enough water for agricultural activities. Groundwater too is limited in the study area and the wells get dried during the dry period (May to August) and the rural population is unable to maintain even a small vegetable garden for their own consumption. By considering the above problems some NGOs working in this study area constructed some runoff water harvesting tank to utilize the runoff water as supplement to the ground water supply for irrigation. Sri Lanka has been practicing runoff water harvesting system for irrigation purposes in a systemic and scientific manner (Shanthi de Silva, 2005). However, nowadays it is a question that, whether it is efficiently utilized by the farmers in all the agricultural

villages? By considering the above, a study was carried out in some rural areas of Batticaloa district with the aim of analyzing the efficiency of runoff water harvesting system and its sustainability for the house hold farming.

METHODOLOGY

The study was conducted at five (05) villages namely, Kalumunthanveli, Kanthipyram, Vamiyadiyoothu, Thumpankerny YFS and Thumpankerny villages of Porathivu Pattu Divisional Secretariat in Batticaloa district (Figure 1) during December 2010 to May 2011.

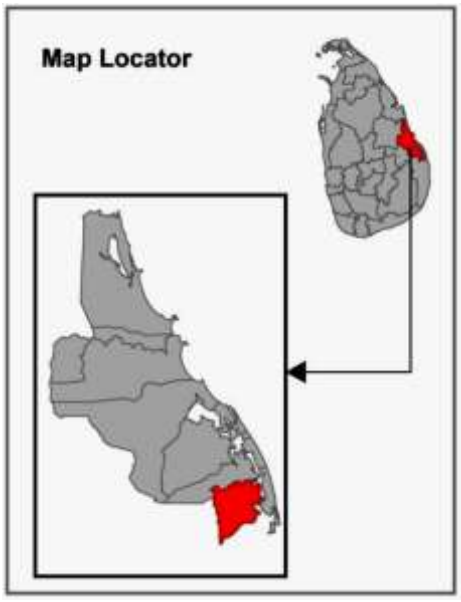

Figure 1a - Map locator (Manmunai South West DS division)

Figure 1b - Location of study area (Villages)

The relevant data were collected from primary as well as secondary sources. The primary data were collectedthrough formal household questionnaire survey, key informant discussion and direct observation among 100 beneficiaries of Runoff harvesting tank project. The secondary data were obtained from the Irrigation Department, Department of Agriculture, Meteorological Department of Batticaloa, Agrarian service center, Kachcheri Batticaloa, Central Bank Report (2009), Census and Statistical Report (2009), and published literatures. Questionnaire was pre tested by drafted questionnaire and personal interviewing of randomly selected 20 farmers in the study area. Then the data were collected among 100 households using questionnaire survey. Purposive sampling and stratified random sampling techniques were used as the major methods of sampling. The filled questionnaires were checked for completeness, coded and data were analyzed by using SPSS (Statistical Package for Social Sciences) version 11.5, MS Excel version 2007 soft ware for windows.

RESULTS AND DISCUSSION

Socio economic and livelihood condition of the people at study area

Agriculture is the main income generative activity in the Porathivupattu area, of which 75% of the respondents involved in farming because they had much of experience in both crop cultivation and livestock husbandry also it is their conventional way for main income generation. Among, smallholder farmers, many of them (61%) are involved in paddy, vegetable and livestock farming and only 9% of the respondents are involved in horticultural farm. Meanwhile 21% of the respondents were also occupied in farming activities as daily wageworkers, and rest of them 4% are engaged in other jobs in private sectors and occupied in foreign employment. As far as the education is concerned, about 38% of small holding farmers are primary educated and about 28% of the respondents are illiterate. Only 2% of the farmers got the tertiary level of education. Further, the study revealed that, around 55% of farmers owned 0.5 to 2 acres of land area whereas only 4% of farmers owned land area above 5 acres for their cultivation or farming activities.

Source of water for irrigation

According to the data collected in the study area, all the people residing in this area are involved inatleast mono crop cultivation for their main or sub income. Most of the beneficiary farmers (96%) are using runoff water tanks while 3% of the farmers are mainly using wells or irrigation cannels for irrigating their high land crops.

Usage of Runoff harvesting pond at study area

The Table 01 shows, all the farmers are using runoff water ponds for irrigation purpose.However,97% of the beneficiaries reported that the water from this pond cannot be used for drinking purpose due to its quality parameters such as colour, total suspended solids, taste and turbidity. Other than the irrigation,some of them are utilizing this pond water for bathing (22%) and washing purposes (27%).

Table 1 - Purpose of using runoff harvesting pond

Purposes	Utilization (%)
Only for irrigation	100
Washing	27
Bathing	22
Toilet flushing	39
Drinking	3
Others	15

Unavailability of water at runoff ponds

The study area receives rainfall through the North-East monsoons (between October and February), on shallow cyclonic depressions and disturbances and to some extent by South west monsoon. Data on water availability at runoff harvesting pond also collected in this study and the results are shown in table 2.

Table 2 - Experience of water scarcity in the runoff harvesting pond

Period (months)	Percentage (%)
No water scarcity	4
1 -2	9
3-6	82
7-8	5
Total	100

The table 02 shows that, most of the farmers (96%) had experienced water scarcity problem because of the continuous usage of stored runoff water from runoff pond, in which 82% of farmers reported that they are usually facing water scarcity problem for 3 to 6 months due to the drought and access of stored water. On the other hand 5% of farmers are facing severe water scarcity for about 7 to 8 months. Water availability in the runoff tank was higher (70% to 100%) during December to April due to the North east monsoon rainfall. They also reported that the water availability in the runoff tank is declining to 50% during the month of September. Efficient water use and selection of irrigation method will help to save some water at the harvesting pond. However, higher temperature, changes in water quality and evaporation rate influence the storage period of water in the runoff harvesting pond. As far as capacity of tank is concerned, 13% of the farmers are affected by the lack of water during drought period because of the less capacity of the storage pond.

Though most of the farmers are presently involved in small scale vegetable cultivation, many of them (46%) are preferred to grow perennial tree while, 21% of the farmers preferred to grow both perennial and horticultural crops whereas only 4% of them preferred to cultivate the horticulture crops as mono crop. Reason for choosing Perennial crops is the water scarcity is severely affecting the vegetable crops compared with perennial crops which can withstand in dry periods to some extent.

Management practices of runoff tank

Most of the farmers in the study area are using runoff water for irrigation but, they are not considering the purity and quality of the water because, they have lack knowledge about the quality and poor facilities to test that water. Maintenance of runoff tank at regular intervals is very important to obtain good quality water as well as to ensure the sustainability of the tank. The runoff water ponds should be cleaned periodically to maintain the quality of the water for irrigation and other purposes.

It seems that the bottom of the tank has several sediments. About 81% of the tanks contained sand particles on the bottom with other particles because runoff water carry the sand particles by their velocity and about 37% of the tank has peat on the base with other particles. This will affect the storage capacity of the tanks. Eventhough, there are some

management methods found in cleaning the runoff ponds (Table 03), it should be followed in proper way and the sediment ditch has to be cleaned periodically.

Table3 - Cleaning method of runoff harvesting pond

Cleaning method	Yes (%)	No (%)
Using sand collection pit	53	47
Cleaning before rainy season	63	37
Using sand and gravel filter	5	95
Adding chlorine	8	92
Removing silt	58	42
Other methods	1	99

Furthermore, the Table 3 indicated that, 63% of the respondents were cleaning the runoff tank before rainy season, other than this, removing silt (58%) and use of sand collection pit (53%) are commonly practiced at the runoff harvesting pond to increase the efficient collection of water. Some of them are constructed drainage channel towards the runoff tank to collect more water during rainy season to increase the water level in tank. Meanwhile most the sample respondent using the control measureslike fencing around the tank (56%) to provide adequate protection for children and animals to avoid the accidents. Other than this, 25% of the farmers using adaptation like introducing fish (25%) as prey on mosquito larvae in the runoff tank to avoid the breeding of mosquito during the storage period of runoff water. Ranatunge, (2000) also reported that, the Mosquitoes breeding is also found some tanks (Ahaspokuna) in Kandy and it could be prevented by raring fish in the tanks. And also 66% of the farmers are using vegetative cover around the runoff tank to protect soil from soil erosion. These practices have to be monitored periodically, at the same time trainings on management aspects can improve the efficient use of these runoff ponds in the study area.

CONCLUSIONS

The runoff water harvesting is a good tool for improving irrigation water supplyin the study area. The quality of runoff water for irrigation can be ensured by sand collection pit, mud collection pit, net cover in the inlet and good management system. Properly harvested water can be used for irrigation without any threat. Mosquito breeding can be prevented by using fishes. Efficient water use from the runoff tank can be ensured by regular monitoring and the selection of proper irrigation method.

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Theimpact ofextensiveagriculture on groundwater chemistry inthe eastern part of Sri Lanka

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ABSTRACT

Ampara District is one of the biggest agricultural area of the eastern province of Sri Lanka. Itcontributes more than 20% of the country's annual rice production. However, the excessive use ofagrochemicals and fertilizers by the farmers has created an emerging threat on the waterquality of groundwater in the area. The lands of Sammanthurai, Karathivu, Ninthavur,Addalachchena, Irrakkamam and Navithanveli DSD's are covered mostly with large paddy landscultivated in both of Yala and Maha seasons. Therefore the vulnerability of groundwatercontamination in these areas is enormously high and the agricultural drains have also affected onthe groundwater in the downstream areas too. This problem should be highly concerned since therural community of the area is entirely depend on the extraction of groundwater through dugwells. These shallower level groundwater aquifers are being contaminated rapidly and respondimmediately upon the any bad agricultural or pollution activity at the surface level. Oncethe dee per groundwater aquifers in the hard rock are contaminated, the reversible process or theremedial measures are hard to overcome the situation. Up to now, none of the organization orresponsive bodies has been acted to assess the present status and impact levels on thegroundwater due to these improper agricultural practices. This study deals with the assessment ofgroundwater quality through systematic monitoring network in dry & wet periods to identify theimpact levels due to the above mentioned reasons.

The monitoring points for sampling were selected based on the field inspections & availableinformation of topography, geology, landuse, hydrology & hydrogeology, pollution pathways oragricultural drains. The sampling was carried out at sixty five (65) identified locations from the dugwells representing the shallower aquifer and fifteen (15) tube wells representing the deeperaquifer for both dry and wet season of the year 2011/2012. All the samples were analyzed underSL Standards at the Chemical laboratory of Water Resources Board.

Analysis results indicated, the Phosphate (PO_4) values of shallow groundwater exceed thepermissible level (> 10mbgl) in most of the areas and especially at the locations of Samanthurai,Malwatte and Part of Karativu area. The highest level of 25 mg/l is observed in Karativu area. Ingeneral, the PO_4 varies from 0.6 mg/l to 25mg/l in dry season (August 2011) and indicating thevery lower values of 0.2mg/l to 3.3mg/l during the wet period possibly attributed to dilution in thegroundwater by recharge process and surface runoff removal before entering to the groundwater.The pattern of fertilizer application cannot be deemed out for this variation but requires carefulsurvey. PO_4 contamination is not highly affected in deeper groundwater sources despite there aresome anomalies could be identified within the permissible levels. In dry period (October 2011),04 locations shows exceeded values of PO_4 out of 18 sampling location and analyzed resultsvary from 0.1mg/l to 2.6mg/l. In wet period (February 2012) it also shows 04 locations out of 15sampling locations as exceeded values of PO4 and almost all samples are reaching theirpermissible level of PO_4.

According heavy metal analysis, the Cd level is appeared to a considerable level (vary between0.6ppb and 4.1ppb) in the shallow aquifer at dry season despite the permissible is 5 ppb. The Mncontent of shallower groundwater is higher atfour locations exceeding the permissible levelsduring the dry period. During the wet period, Mn content in groundwater declines to a level belowdesirable level in the shallow groundwater. However, there are no Mn values encountered indeeper groundwater exceeding the desirable level in both dry and wet periods. The Cd level isalso within the standards even there is some indication of Cd encountered at considerable levelsindicating a possibility of a contamination in deeper groundwater.

The other chemical parameters including EC, TDS, and Alkalinity etc. are within the acceptablelevels in most of the monitoring locations and there are certain anomalies observed in somelocalities possibly due to site specific characteristics and not in regional scale. These aredescribed in detail at the results section of this paper. In conclusion, the groundwater isobviously been contaminated in the area due to the impact of excessive applications of fertilizersand the impact level is at incipient to intermediate level and therefore immediate awareness ofcommunity, corrective measures and regulatory mechanism implementation is vitally important.

INTRODUCTION

Ampara district is a one of the largest agricultural area in Sri Lanka and it is contribute 20% ofannual rice requirement for the country. Despite the large agricultural areas, the excessive use ofagrochemicals and fertilizers by the farmers has created an enormous impact on the waterquality of groundwater. The lands of Sammanthurai, Karathivu, Ninthavur, Addalachchena,Irrakkamam and Navithanveli DSD's are covered mostly with large paddy lands cultivated in bothof Yala and Maha seasons. Therefore the vulnerability of groundwater contamination in theseareas is higher and the agricultural drains have also affected on the groundwater in the lowlandareas too. This problem should be highly concerned since the rural community of the areaentirely depend on the extraction of groundwater through dug wells. These shallower levelgroundwater aquifers are being contaminated rapidly and respond immediately upon the anybad agricultural or pollution activity at the surface level. Once the deeper groundwater aquifersin the hard rock are contaminated, the reversible process or the remedial measures are hard toovercome the situation. Up to now, none of the organization or responsive bodies has beenacted to assess the present status and impact levels on thegroundwater due tothese improperagricultural practices.

Considering the necessity of the assessment of impact due to specified causes, this study wasfocused to deliver the present status of groundwater quality of the area including the follow upactivity of implementing a long term surveillance based monitoring network under Dam Safetyand Water Resources Planning Project(DSWRPP).

District is located at eastern part of the country and geomorphologicaly it is almost flat terrain.Study area is covered by 06 divisional secretariats of Karathivu, Ninthavur, Addalachchena,Irrakkamam, Navithanveli and Sammanthurai. Most of the selected area covered with paddylands and other cultivated plants such as sugar cane and wheat. The area belongs to Gal Oyariver basin and few numbers of tanks existed in study area. The approximate land area is 400 $km^2$and area of surface water bodies are around 15 km^2.

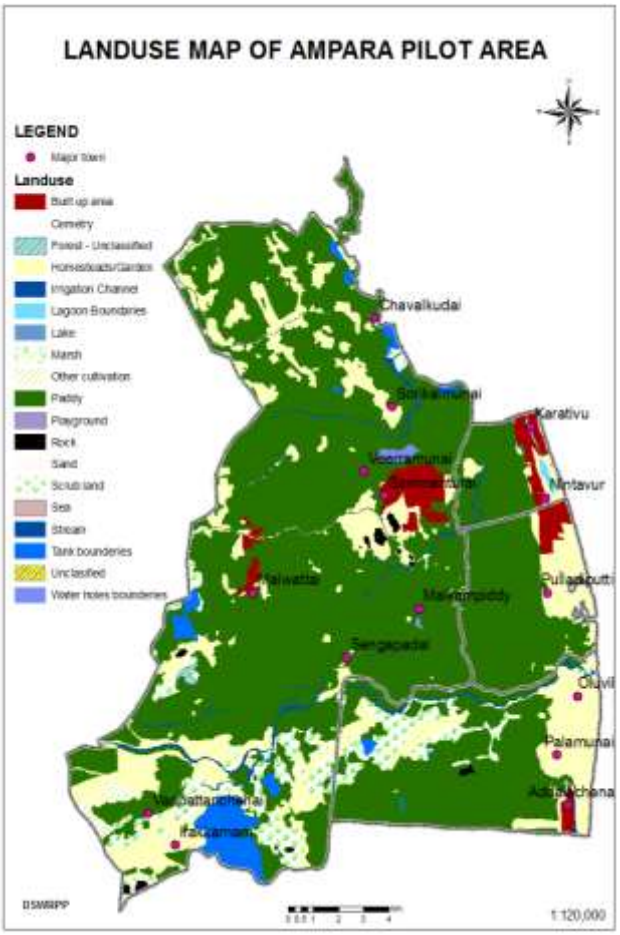


Figure 1 - Landuse pattern of study area

GEOLOGICAL SETUP OF THE AREA

The study area belongs to Vijayan complex and the main lithology of the Vijayan and VanniComplexes are amphibolite-facies metapelies, mafic to intermediate rocks, calc-silicates,granitic rocks and migmatites (Cooray, 1961, reprinted 1995 b, 1984). According to the drilllitholog of existing tube wells, a thin soil layer is underlain by massive basement roc. Figure 2 isshown the general lithology of the study area.

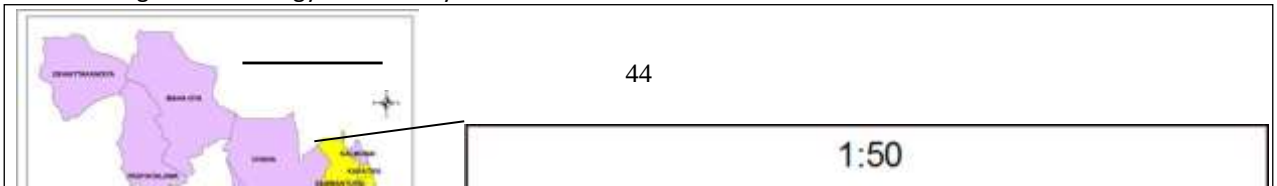


Figure2 – Generalgeological formation ofthearea

METHODOLOGY

The preliminary data and information of the area were collected from various organizations andstudied for the selection of monitoring point. The sampling was performed on theseselected points for the chemical analysis work to obtain the water chemistry spatially as well astemporally. Base maps of Landuse, Geology and DEM maps were prepared with the use ofArcGIS 10 software.

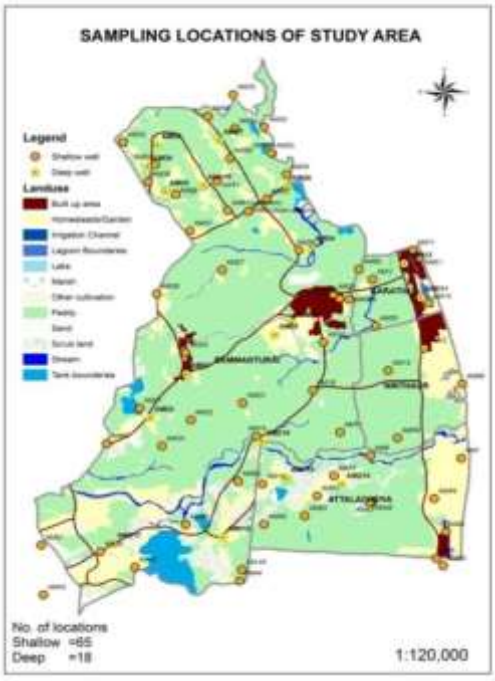


Figure 3 -Sampling locations of study area

Initially, based on the field inspections & available information of topography, geology,landuse, hydrology & hydrogeology, pollution pathways or agricultural drains and chemicalrecords of the previous studies and information on the issues identified in the area wereconsidered for the in-situ testing of Electrical Conductivity (EC), total Dissolved Solids (TDS),Salinity, NO3 and PO4. Once these basic parameter assessment in the field, the finalmonitoring point was identified for further full chemical analysis, heavy metal analysis (Mn, Cd,Pb and Cu) and bacteriological analysis if required.

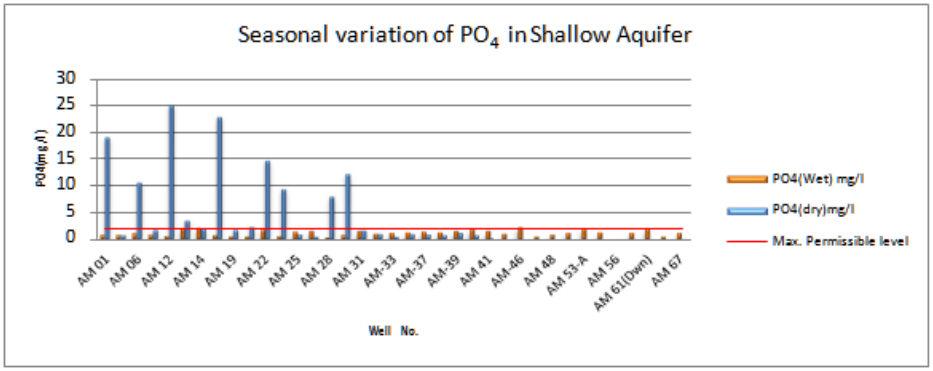
The sampling was carried out at sixty five (65) identified locations from the dug wellsrepresenting the shallower aquifer and fifteen (15) tube wells representing the deeper aquifer forboth dry and wet season of the year 2011/2012. All the samples were analyzed under SLStandards at the Chemical laboratory of Water Resources Board.

RESULT AND DISCUSSION

According to the samples analysis result of shallow and deep aquifers during dry and wetperiods, there are some anomalies detected in several chemical parameters such as EC,salinity, PO4, F, and Mn. In certain urbanized areas of the study area indicated high values ofNitrate (Sammanthurai town and Central camp town).

It is reported that that excessive application pesticides and weedicides on the cultivation lands is ageneral practice adopted by the farmers. This may directly affect on shallow water sources anddeeper groundwater bodies as well. Except the areas having pipe born water facility, the otherremote community still totally relies on the shallower water sources "open dug wells". The areais in semi-arid climatic condition thus low rainfall distribution and highevapotranspiration resulting enrichment of mineral content in groundwater and otherchemical substitutes as well.

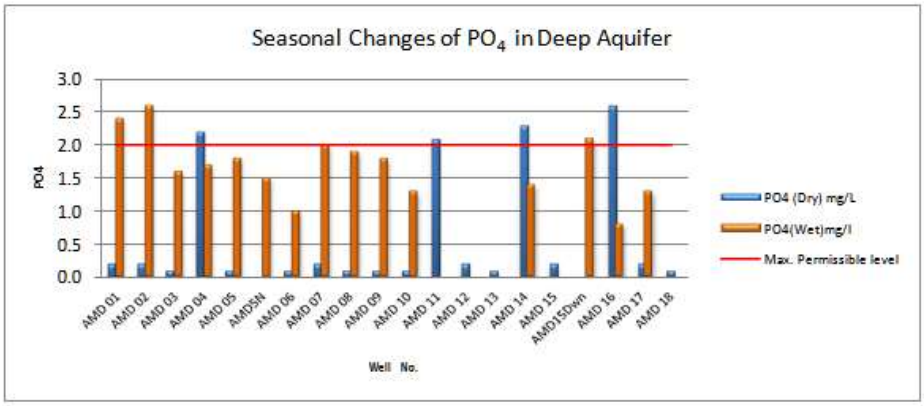
The PO_4 is the one of major issue identified in the pilot area from the analysis results. Almost allover the area of monitoring locations indicates high PO4 in groundwater both during dryand wet periods. The Graph 01 shows the seasonal variation of PO_4.



Graph 1 - Seasonal changesofPO_4 inshallowaquifer

The Phosphate (PO4) values of shallow groundwater exceed the permissible level (>2mg/l) in mostof the areas and especially at the locations of Samanthurai, Malwatte and Part of Karativuarea. The highest level of 25 mg/l is observed in Karativu area. In general, the PO4 varies from0.6 mg/l to 25mg/l in dry season (August 2011) and indicating the very lower values of 0.2mg/lto 3.3mg/l during the wet period possibly attributed to dilution in the groundwater byrecharge process and surface runoff removal before entering to the groundwater. Thepattern of fertilizer application cannot be deemed out for this variation but requires careful survey.PO_4 contamination is not highly affected in deeper groundwater sources despite there are someanomalies could be identified within the permissible levels. In dry period (October 2011), 04locations shows exceeded values of PO4 out of 18 sampling location and analyzed results vary
from 0.1mg/l to 2.6mg/l. In wet period (February 2012) it also shows 04 locations out of 15sampling locations as exceeded values of PO4 and almost all samples are reaching their permissiblelevel of PO_4.

The area was covered by 70-80 % of paddy land and farmers used various pesticides andweedicides (Nomini, Solito, He-Coper, M-08, and Bandi pohora, etc.) for their cultivations. Thesepesticides may have a strong impact on the increase of PO4 in groundwater. PO4 directly impact tohuman health such as Urolithasis (Urine stones), skeletal etc.

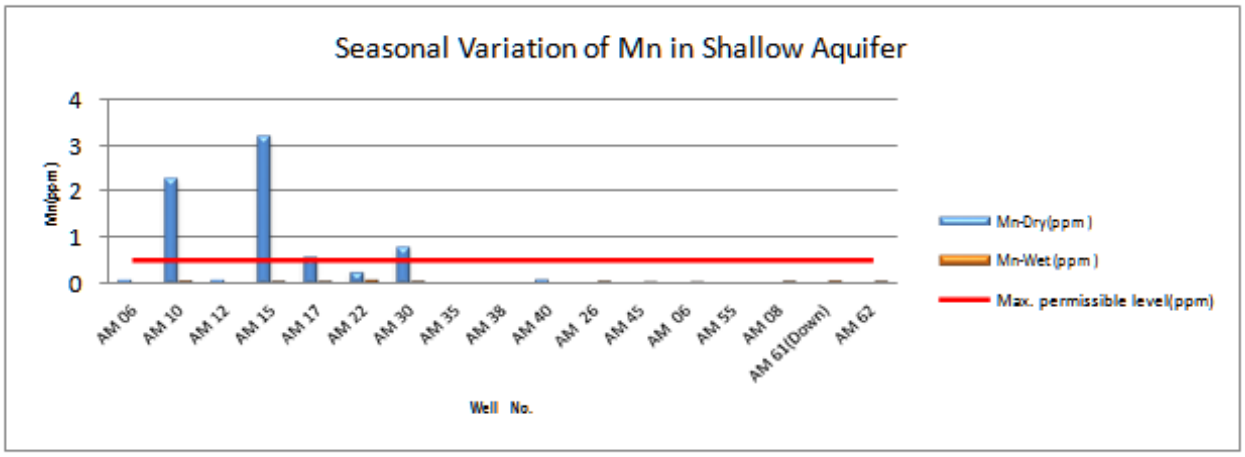


Graph 2 - Seasonal changesofPO_4 in deep aquifer

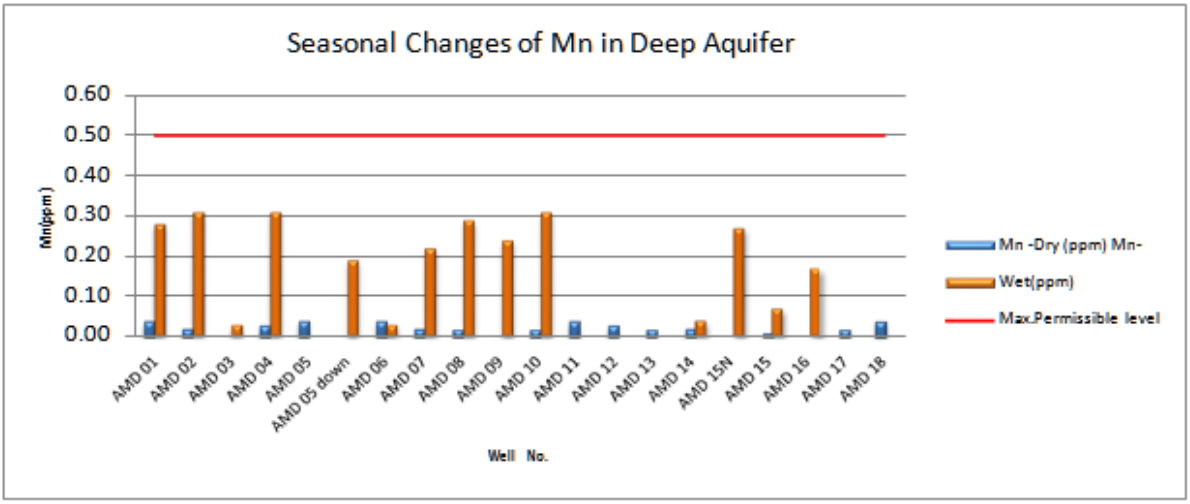
Mn, Cu, Pb, Cd and As were analyzed under heavy metal analysis. The result indicates high Mn andCd values in shallow aquifer water sources during dry season. These anomalies may occur due toMn rich parent rock weathering or due to pesticides / weedicides. In dry season, 10 samplesselected for heavy metal analysis in shallow aquifer. The result reveals that 40% of samplesexceeding maximum permissible level of Mn (0.5ppm). But in wet season, samples show slightly low values of Mn than dry season.

When considering deep aquifer samples, it is shown some different behaviors compare to theshallower aquifer. In wet season, samples were shown quit high values than dry season.Similar variation could be seen for PO_4 amount in groundwater of the area. This may result due toleaching and percolation of high Mn and PO_4 enriched shallower water to the deeper aquiferwith the rainfall recharge during wet period. In contrary, the shallower aquifer may indicate low Mnand PO_4 during wet season due to flushing off enriched and accumulated substitutes in dryperiod. The graphs 03 and Graph 04 are illustrated Mn variation of shallow and deep aquifer inboth dry and wet season.

However, these Mn values in deep groundwater aquifer are still within the tolerable levels (notexceeding the desirable level) in both dry and wet periods.



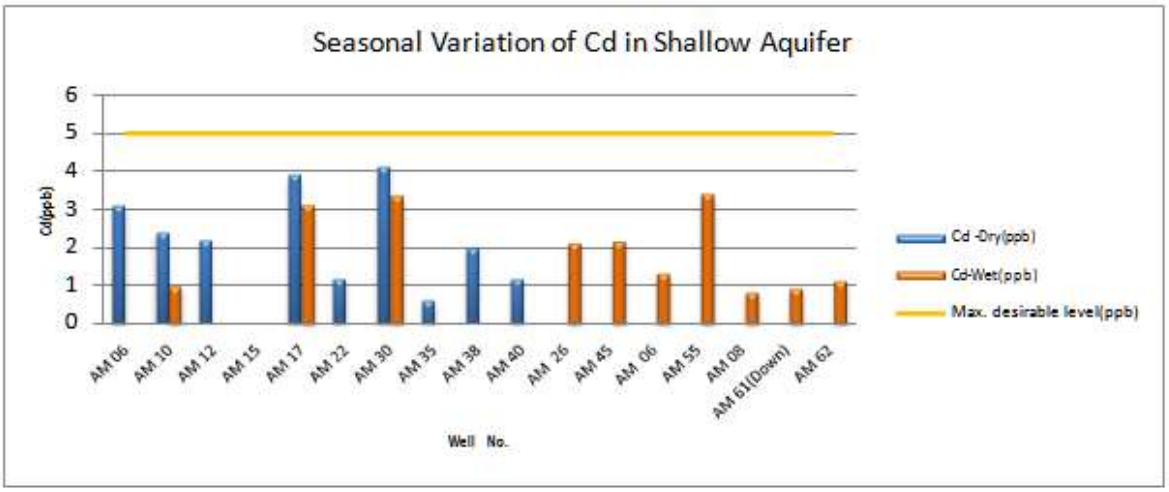
Graph 3 - Seasonal changesofMninShallowaquifer



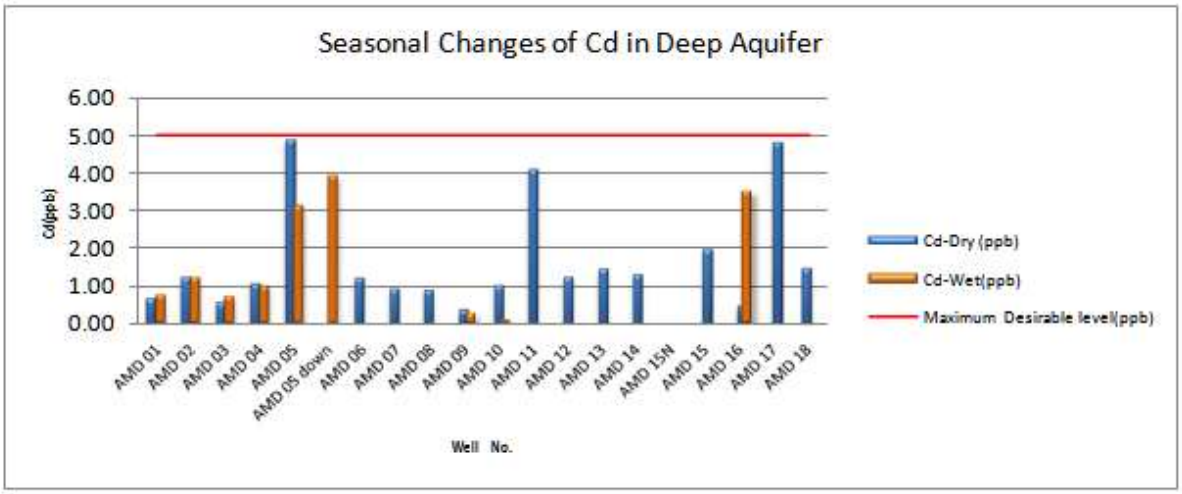
Graph 4 - Seasonal changesofMnindeep aquifer

In wet season, samples are shown lower Cd levels than dry season in both deep and shallowaquifers. Cd level is appeared to a considerable level (vary between 0.6ppb and 4.1ppb) in theshallow aquifer at dry season despite the permissible is 5 ppb. The Cd level is also within thestandards even there is some indication of Cd encountered at considerable levels indicating apossibility of a contamination in deeper groundwater.

Groundwater can be contaminated by Cd due to parent rock weathering or usage of pesticides andweedicides as mentioned above. When it considers deep aquifer, Cd increase could occur due toboth of above mentioned reasons. But in shallow aquifer, it may be largely affected by agriculturalpractices in general. The graphs 05 and Graph 06 are shown the seasonal changes of Cd in deepand shallow aquifer in the area



Graph 5 - Seasonal changesofCdinShallowaquiferlevel(ppb)



Graph 6 - Seasonal changes of Cd in Deep aquifer

CONCLUSION

This was a pilot study to identify the effect of extensive agriculture for the groundwater chemistry ineastern part of Sri Lanka. According to the results of water samples, groundwater of the study areais polluted due to heavy agricultural practices. Mainly in shallow aquifer groundwater is highlyaffected by PO4, especially in alluvial deposits of Gal Oya river zone. Mn and Cd are also showingsomewhat high values in study area.

It is obvious that the groundwater is being contaminated in the area due to the impact ofexcessive applications of fertilizers and the impact level is at incipient to intermediate level.Therefore immediate awareness of community, corrective measures and regulatory mechanismimplementation is vitally important.

Based on the output of this study, the final long term monitoring network is to be established as afollow up activity under Dam Safety and Water Resources Planning Project (DSWRPP).

ACKNOWLEDGMENTS

All the supporting staff of Water Resources Board and DSWRPP officials (Dam Safety & WaterResources Planning Project) is greatly acknowledged.

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Importance of water as a construction commodity

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ABSTRACT
Water is an inevitable gift from nature. At present, clean and drinkable water continues to be a serious global issue faced by many countries. Protection and conservation of water is one of the fundamental principles concerned in sustainable construction. Reviewing the past literature, many studies discussed that, water is one of the lesser acknowledged areas specially in the construction sector even considerable water researches done and being focusing in the field of agriculture, livestock, irrigation, household, textile, foods, manufacturing in the industrial sector.However, during the construction, water is used for several purposes not limited to mixing mortar and concrete, curing work, dust controlling, soaking materials, washing and cleaning. And also quality and quantity of water has much effect on the strength of mortar and cement concrete in construction work. On the other hand construction worksalso impact on the quality of water. It is apparent that without water no construction work can start and also there is no substitute for water. Today, use of portable water and wasteful misuse of water could be seen all the time in many construction projects. Therefore, it is crucial to study the real value of water as a construction commodity.

Since this research is at the initial stage, key literature findings and discoveries of preliminary interviews conducted among the selected industry practitioners were discussed in the paper.It was found that addressing the topic on water usage in the construction sector is hidden to many parties both in construction industry and for relevant government authorities. Moreover,Professionals identified that construction guidelines focused on water handling and consumption alone are inadequate. On the other hand the volume ofwater used for the construction sites is currently unknown and no best practices are evolved about water usage on construction sites in Sri Lanka.

INTRODUCTION

Water is a valuable resource, critical to economic development (Horne, 2012). The efficient management of water resources is a growing necessity (Gonzalez-Gomez, et al., 2011). According to Leonardo da Vinci, water is the driver of nature. Water is by far the commonest substance on earth, but 97% of the total is seawater which is unfit for human use (Economist, 2003). The remaining 3% of the world's water resources, only about 1% is readily available for human consumption (McWhinney, 2006). This 1% is utilized for agriculture, industrial sectors, domestic and all other non-domestic purposes as well.It is now increasingly being recognised that water is likely to be a major critical issue of the world (Biswas and Seetharam, 2008). Organisation for Economic Co-operation and Development (OECD),2008) identified that, 47% of the world population will live in regions with severe water stress in 2030. Therefore, as a valuable and scarce input there is a growing pressure on water and this is one of the challengeable areas faced by the world very soon.

Many studies hitherto have discussed that water is one of the lesser acknowledged areas in the construction sector. Quantity and quality of water uses vary from activity to activity and change according to the construction process and delivery. Eventhough resource optimisation is one of the main objectives under the sustainable concept, less attention is paid on water management during the construction due to the perception that water has no value since it is a natural resource and personal attitudes like spending time on water management is not cost effective. Because of that, significant wastage and misuse of water could be observed in many construction sites. However, water is a variable in the cost estimation. On the other hand, at present for many construction activities use portable or virtual water during the construction process.With the speedy industrialisation and population growth many new constructionprojects could be seen. Therefore, it is worth to investigate the water usage patterns in the construction industry, understand water demand and supply, its value –costs and benefits, use of sources, and management process during the construction as a finite resource.In Sri Lanka no body conducted any research on this area so far. Thus, this paper will address "do stakeholders realise the value of water in the construction sector?"

LITERATURE REVIEW

Global view on sustainable water resource

The influences and the linkage of the built- environment to the sustainability are highly acknowledged in the literature. In essence, built-environment facilities are required to drive towards sustainable developments to meet the future

challenges. An objective of sustainability is to avoid or minimise any damaging future consequences from current consumption and investment activities (Fawcett, 2012). Many green building assessments discussed and identified protection and conservation of water is one of the fundamental principles concerning sustainable construction. According to the Center for Environmental Systems Research (2000), many countries have severe water stress and water pollution. Countries like Australia, China and Middle East do not have enough water but countries like Canada, Ireland and Austria have more water than usage (Economist, 2003).Water is valuable and scarce input for Australia. Horne (2012) mentioned according to Australia's approach to water policy, waterneeds to be priced properly and managed actively to be used effectively. In the UK water resources are under pressure and current levels of water abstraction are unsustainable in many places (Strategic forum for construction: water, 2012). According to (Biswas and Seetharam, 2008), increasing water pollution is a major issue for nearly all Asian developing countries and it is likely to be a critical unless the present perceptions and attitudes change radically. Furthermore, the same authors stated that the social, economic and environmental future of Asia is likely to depend on how efficiently and equitably this resource will be managed in the coming years. Economist (2008) stated that climate change, droughts, growing population and increasing industrial demand are straining the available supplies of freshwater. In many Asian countries agricultural water use accounts for nearly 90% of the total water use however, this percentage has been declining steadily in recent years, in contrast industrial water use has been increasing (Biswas and Seetharam, 2008). This statement is very much inline with the statement of 'although agriculture is the largest consumer of water resources, per capita consumption growth, industrial activity, the use of water for energy production, the construction sector and tourism and leisure activities have all exerted additional pressure on available water resources' (González-Gómez et al.,2012). These all the facts show water source will be a big threat in the future if not taken long term plans.

Water input in Construction Industry

Chen (1998) argued that there could be no economic activity without construction. Of course construction industry is a major contributor to economic growth (Chan, 2009).The World Bank Report (1984 cited Rameezdeen et al., 2008) mentioned that construction industry is not characterised as a single sector and it has strong linkages with other sectors of the economy. Guggemos and Horvath (2006) stated that in many studies, the impacts from the construction phase are ignored or simply approximated, because the analysis is complicated or the impacts are thought to be small. In general, the contributions from the construction phase have been found to be on the order of 0.4 -12% due to the overwhelming impacts from the lengthy use phase (Junnila et al., 2006 cited Guggemos and Horvath, 2006).

McComack et al., (2007) argue that water used to operate buildings significantly and consume considerably in the extraction, production, manufacturing, delivery of materials to site and the actual on-site construction process. During the construction, water is used for several purposes not limited to mixing mortar and concrete, curing work, dust controlling, soaking materials, washing and cleaning (McComack et al., 2007; Utraja, 2010; The Workplace Health and Safety Queensland, 2007). The stratergic forum for construction (SFfC) water subgroup has identified that dust suppression, cleaning and commissioning and test as most water wasting activities as shown in Table 1 (McNab et al., 2011). Moreover, same authors identified that there is little consistency throughout the construction sector in relation to water managementthrough observations based on the nine case studies conducted by the SFfC group. Domestic and welfare water consumption is another high water using activity and this water requirement is unique at construction sites.

Table 1 - High priority activity on water use

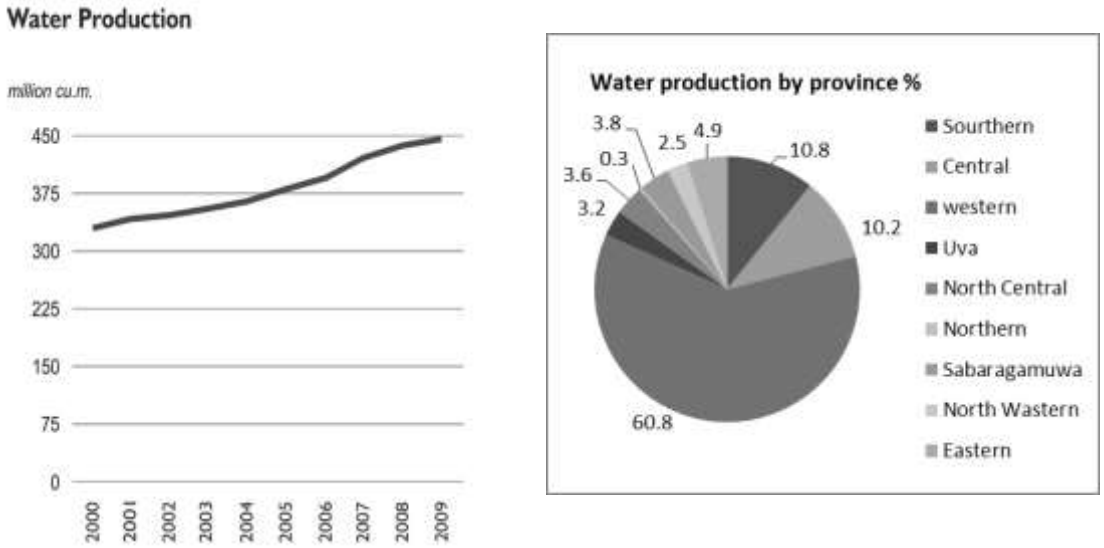
Water Using Activity	High Priority Activity
Dust Suppression	General, Site roads, wheel washes
	Hydro-demolition with high pressure water
Cleaning	Ready mixed concrete wagons
	Site/general cleaning
	Specialist/ High pressure cleaning
Commissioning and test	Building plant/Services

Source :McNab et al.(2011)

Utraja (2010) mentioned quality and quantity of water are important parameters that impact on strength of some construction works. Moreover, findings of McCormack et al., (2007) shown that, there is a considerable amount of water embodied in building materials. Steel and concrete had the most significant amount of embodied water. And also the findings suggested that policies focused on operational water consumption alone are inadequate. According to Goodrum (2008), the amount of water consumed by the construction industry has not been adequately measured.

Water Situation in Sri Lanka

Sri Lanka is a tropical Asian country. Supply of water is very seasonal. Pipe born water, dug well, tube well, streams, irrigation tanks and rainwater harvesting are main water supply sources in Sri Lanka (NWSDB, 2009). Available quanity and quality of water is vary from disrict to district. Pipe borne water demand is continuously increasing due to high population growth and rapid urbanisation. Water production and water production by province from 2000-2009 is illustrated in Figure 1.According to Figure 1, western province shows higher water production which is equal to 60.8%. Southern and Central provinces represent 10.8% and 10.2% respectively. Converting naturally available water to drinking water involves expenditure for power, chemicals, staff, maintenance and repair (NWSDB, 2009).Therefore, purifying water is expensive process and it should be used with carefully. According to the NWSDB (2009), pipe-borne water coverage in Sri Lanka is around 34%, with the rest of the population depending on local sources such as wells, hand pumps, tube wells, small scale rural water supply schemes, rainwater harvesting tanks and surface water bodies.



Source: Annual Report: NWSDB (2009)

Figure 1 - Water production and production by the province

Based on the National water supply and drainage board (NWSDB) annual reports and cooperate plans, supplying safe drinking water for customers is not an easy task in future. According to the Centre for Environmental Systems Research (2000), water stress was around 40% in Sri Lanka. This percentage is going up due to population growth and industrialisation. Even though presently people think water as a cheap material in Sri Lanka, and water usage on construction sector is negligeble, definitely these attitudes will change among the individuals in near future and water topic will be a challenge to the country.

RESEARCH METHOD

Mainly, literature review conducted and key words like water efficiency, conservation, delivery, consumption, quality, sustainable, and construction were used to search literature from various sources. Meantime, preliminary interviews were conducted to get impartial opinions of key representatives who have more experience and representing different disciplines from the construction industry. Qualitative interviews conducted through face to face interviews and few interviews conducted via telephone to collect data. Six voices involved with the unstructured interviews to elicit views and opinions.

Findings of preliminary Interviews

The unstructured interviews were conducted with parties from four different disciplines including engineering, quantity surveying, project management and environmental economics prior to initiate and develop the detailed questionnaire survey. Many respondents said that water related research is not at all conducted so far in the construction sector in Sri Lanka. Based on the opinions, it was found that the importance of this topic is hidden to many parties both in construction and for relevant government authorities. Most of the time, there are no proper practices conducted in the industry while handling water and less priority has been given for the best use of it. One of the respondents highlighted that one project was delayed due the unavailability of water. Even Sri Lanka has seasonal climate, today no one cannot expect same pattern due to the global issues. Another respondent mentioned that water was one of the critical factors while making decision to start some projects. Moreover, it was also highlighted that in Sri Lanka, some projects didn't start due to water issue. This supported and proved that it is worth while studying "value of water in construction sector".

Environmental economist stated that when bowsers were used to bring water for the construction activities specially in dry and rural areas, water is taken from rivers, lakes, streams, etc. But nobody worries about the water quality and the impact on the quality of water on construction activities. Another important thing highlighted was when taking water through bowsers at some considerable period, there is a big damage to the ecosystem. Lands near rivers, streams and road ways turn to muddy areas. Therefore, this provides areas that needed to pay more attention by the stakeholders. Moreover, one respondent said that water is a big issue for the Middle East countries where almost all water is supplied through bowsers for many construction projects. But not like Sri Lanka there is no issue with quality as well as no impact to the environment. Authorised places are available to fulfil the industry requirements. Another facts identified through preliminary survey was construction guidelines focused on water handling, measuring quality and usage alone are inadequate and also it is important to educate and improve the awareness of best practices of water handling among the stakeholders including site- labours at construction sites as essential.

Due to the limited space, and poor quality of water of alternative sources, many construction projects depend on the public main specially around the urban areas. Eventhough other sectors talk about rainwater harvesting, rarely practiced in construction projects. However, based on the preliminary survey it was found that the NWSDB does not give permission to use drinking water for the construction work except exceptional situations. As found from the survey, lack of understanding of where water is used and where water is wasted are major challenges faced by the industry. Moreover, many intervieews stated that the volume of water used for the construction sites is currently unknown and no best practices is evolved about water usage on construction sites.

CONCLUDING REMARKS

Water is integral to the economy. Today finding freshwater becomes a global issue and water stress is high in many countries . Therefore, efficient water management is a necessity in every sector. Due to speedy industrialisation more construction works both building and civil engineering projects taken place in everywhere. It is obvious without water no construction works can be started and also there is no substitute for water. Literature findings show, water is one of the areas given less priority and have ignored the value of it in the construction sector. However, there is a big impact of quantity and quality of water used on strength of products during the construction. It was found that providing safe water to cater the future demand is a big challenge for Sri Lanka as well. This paper addressed the importance of the study through literature review and findings of preliminary interviews. Detail questionnaire survey will be designed incorporating essential gaps identified through literature and preliminary findings as the next step of the study.

FUTURER RESAERCH AGENDA

This paper shows the importance of addressing the value of water in construction industry through findings of preliminary interviews. At the end of the research project, the reseach findings will be critically answered the following questions systematic way. How does the construction water fit into sustainable development? What are the immediate and long-term costs and benefits in terms of sustainable aspects? What is the impact of water scarcity to construction industry? How stakeholders' and workers' attitudes and behaviour on water management during the construction process? How much construction projects use water? What are the policies available for water management? How to use water efficiently during the construction? How to calculate the economic value of water as a construction commodity? Finally, come up with the water management protocol for efficent water mangement ofboth building and civil engineering constrcution projects.

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Geographical distribution of chronic kidney disease of unknown origin in Sri Lanka in the region of irrigation reservoirs

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ABSTRACT

The investigators in Sri Lanka have noticed frighteningly high incidence of an apparently new form of chronic kidney disease of unknown etiology (CKD-U) in some agricultural areas of Sri Lanka. A steady increase has been observed within last fifteen years. Histopathological studies have revealed a tubule interstitial nephritis at early stage of the disease which is suggestive of a toxic etiology. Researchers who investigated the disease proposed number of risk factors including high level of fluoride in ground water , leaching of heavy metals such as cadmium from agrochemicals into water sources, exposure to inorganic pesticides and usage of aluminium containers for cooking. However, the lack of sufficient epidemiological studies made the identification of the etiological agent difficult. Aim of the present study is to investigate the geographical distribution of CKD-U using modern GPS and GIS mapping.

Community based information of 11630 patients were collected and used for GIS mapping using ARC GIS 9.2 software and 1197 households of CKU-u patients for GPS mapping in Padaviya and Nikawewa areas.
GIS mapping indicated five high prevalent areas in the region namely Medawachchiya (identified 20 yrs ago), Padaviya (identified 18 yrs ago), Girandurukotte (identified 12 yrs ago), Medirigiriya (identified 8 yrs ago) and Nikawewa (identified 5yrs ago). Low prevalence of the disease was noted in communities who consume water from natural springs for drinking. In all five areas the distribution is related to stagnant irrigated water. Most of the affected villages are located below the level of the reservoirs and canals. GPS mapping showed most of the cases are located below the level of some reservoirs and some are related to the irrigation canals.

All the high prevalent areas are clustered around reservoirs of the irrigation system. The epidemiological data on geographical distribution infers that while older foci of CKD-U are persisting, there is an emergence of new foci of CKD-U with the time. The presence of the affected villages located below the level of the reservoirs and canals indicated the possibility of irrigated water draining to the shallow wells of the households which is the source of drinking water. A similar pattern of distribution of endemic nephropathy was described in Balkan region along the Danubi river in low altitude areas where water stagnates.

INTRODUCTION

Chronic Kidney Disease (CKD) is defined as either kidney damage or decreased kidney function for a period of three months or more (1). It is characterized by progressive destruction of renal mass with irreversible sclerosis and loss of nephrons over a long period of time depending on the underlying etiology. CKD is a slow progressive disease, which requires dialysis or transplantation at the end-stage. It is an emerging health problem all over the world(2). The disease is often associated with poor prognosis and it incurs economic burden on the patient, family, community and the country as a whole. Common causes of CKD include diabetes mellitus, hypertension, urological diseases and glomerular nephritis. Toxins, collagen vascular disease and infections are the rare causes of CKD.

Sri Lanka is an island in the Indian Ocean below the southern tip of India with a special topography. The island with a landmass of 65,525 km^2 has a central massif with its tallest peak rising 2500 meters above sea level. One hundred and three river basins spread radially from the central hills outward to the coastal plains. The island receives an average of 1800 mm rainfall from the two distinguished monsoons. The region in the south–west quadrant (wet zone) receives annual rainfall of 2200 mm covers only one third and the balance with a rainfall about 2000mm encompass 2/3 of the country (dry zone). The dry zone of the country is characterized by intricate network of man made reservoirs and canals that provide water for paddy cultivation and for human and livestock use from pre Christian era up to date. However, CKD is abundant only in one part of the dry zone namely North Central Region of the country.
In early nineties investigators in Sri Lanka have noticed an alarmingly high incidence of a new form of chronic kidney disease of unknown etiology (CKD-U) in North Central Region of the Sri Lanka. This kidney disease was not related to any

of the known causes such as diabetes mellitus, hypertension & infection (3). However, histopathology of affected kidneys showed tubulo interstitial nephritis, which is suggestive of a toxic etiology. Researchers who investigated the disease proposed number of risk factors including high level of fluoride in ground water (4) heavy metals such as cadmium (5) , exposure to inorganic pesticides (6), usage of aluminium containers for cooking and orchratoxin (7) etc.

Although many studies on the etiology of the disease were carried out by different research groups, a comprehensive epidemiological study has yet been reported. As such, identification of the etiology has become a difficult task.

Geographic information systems (GIS) and geographic position system (GPS) are computer-aided database management and mapping technology that organizes and stores large amounts of multi-purpose information. Health mapping has evolved from Dr. John Snow's cholera death mapping (8) in mid-nineteenth century to the latest Internet-based mapping and GISis particularly useful to health professionals and administrators in planning and day-to-day management (9). It offers powerful tools to determine geographical distribution and variation of diseases, and their prevalence and incidence. GIS has been successfully used in the management of many vector-borne diseases (10-11).

In this study, we attempted using GIS and GPS technologies to study the geographical distribution of chronic kidney disease of unknown origin, which is an important non communicable health problem in Sri Lanka. The present study was carried out to with the aim of studying demographic characteristics of the patients, geographical distribution of the disease, location of households of the CKD-U patients in relation to reservoirs, irrigation canals and the topography of the affected area that would help identifying potential etiological factor/s, which could be associated with the disease.

METHODS

In first part of the study Geographical Information System (GIS) mapping was used (ARC 9.2 software) to study the geographical distribution of the disease. Information was collected with reference to basic demographic data (age & sex) and respective addresses of 11630 chronic kidney disease patients who attended to Hospitals and community renal clinics (Figure2) that were especially established to follow up CKD-U patients in high prevalence areas. Community based data collection was carried out with precautions to prevent counting the same patient twice or more. The patient density per each Gramaniladhari division(GN) was calculated using the ARC GIS 9.2 software. Subsequently the patient density was expressed in relation to the 1000 population in each Gramaniladhari division (12). Based on the findings of the GIS mapping, two locations, one area with a large reservoir (Padaviya) and another area with multiple small reservoirs (Nikawewa) were selected for further studies. Geographical Position System (GPS) mapping was specially used to study the location of households of the CKD-U patients in relation to reservoirs, irrigation canals and the topography of the two selected areas. There were 1100 and 97 reported patients from Padaviya and Nikawewa respectively. Homes of these registered patients were visited to record the GPS coordinates, collect demographic data and to reconfirm the diagnosis using documentary evidence. Due to unavailability of patients, migrations, lack of information or subjects, which do not fulfill the diagnostic criteria, the sample was restricted to 863 during home visits. (796 and 67 patients from Padaviya and Nikawewa respectively). The diagnostic criteria used for CKD-U includes absence of Diabetes Mellitus, hypertension, urinary tract infections or other renal diseases in the history, presence of urinary protein one plus or more in sulphosalicylic acid test on two occasions and presence of radiological / pathological evidence of chronic kidney disease.

RESULTS

The demographic information showed that the male: female ratio of the disease is 2.4: 1. CKD-U is more prevalent in the age group over 40 years with a mean age of 54.7 $\pm$ 8 yrs (figure 1). Out of the total, 90% of the patients were farmers. The source of drinking water was shallow wells (92%), tube wells (7%) and water reservoirs (1%). CKD-U was present even among patients who consumed boiled water exclusively for lifelong drinking. Clustering of the disease was observed in 30% of the families.

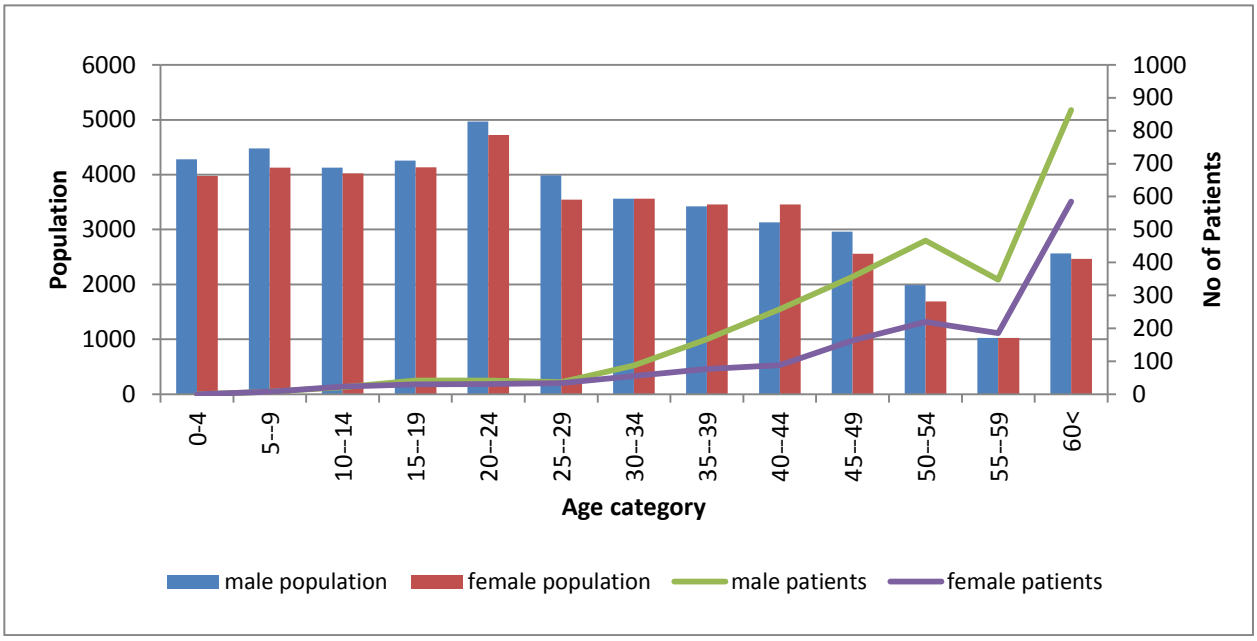

Figure 1 -Age and sex distribution of CKD-U patients

The epidemiological data indicated three high prevalent areas (Figure 2) in the region namely Medawachchiya (identified 20 yrs ago), Padaviya (identified 18 yrs ago), Girandurukotte (identified 12 yrs ago). In addition two smaller foci had been identified in Medirigiriya (identified 8 yrs ago) and Nikawewa (identified 5yrs ago). Epidemiological data infers that there is an emergence of new foci with the time while older foci are persisting. Analysis of water resources shows that the affected areas are fed by the reservoirs of the irrigation system. Low prevalence of the disease was noted in communities who consume water from natural springs for drinking (some villages of Kebithigollewa (figure 3)). Figure 4 shows the distribution of patients in Girandurukotte mainly a paddy farming area that is supplied by the two reservoirs namely Ratkinda and Ulhitiya. The disease is reported only in the villagers who live in the left bank of the Mahaweli river supplied by the two reservoirs while those who live in the right bank supplied by the natural springs are not affected Similarly. Figure 3 shows distribution of patients in Padaviya-another affected paddy farming area supplied by the Padaviya reservoir and the patient distribution in Medawachchiya area where high density of smaller reservoirs is seen. GPS mapping shows that most of the affected villages are below the reservoir or canals. Area with the lowest altitude is affected by the disease (Figure 5).

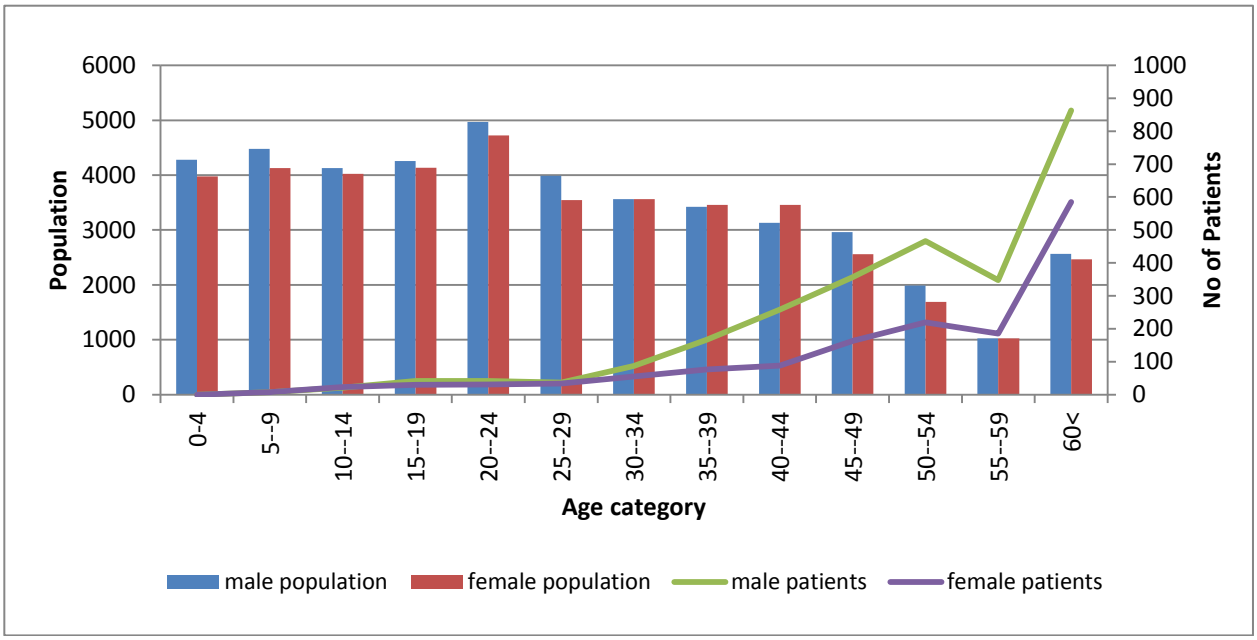

Figure 2 - Geographical distribution of CKD-U patients in Sri Lanka with hospitals/renal clinics

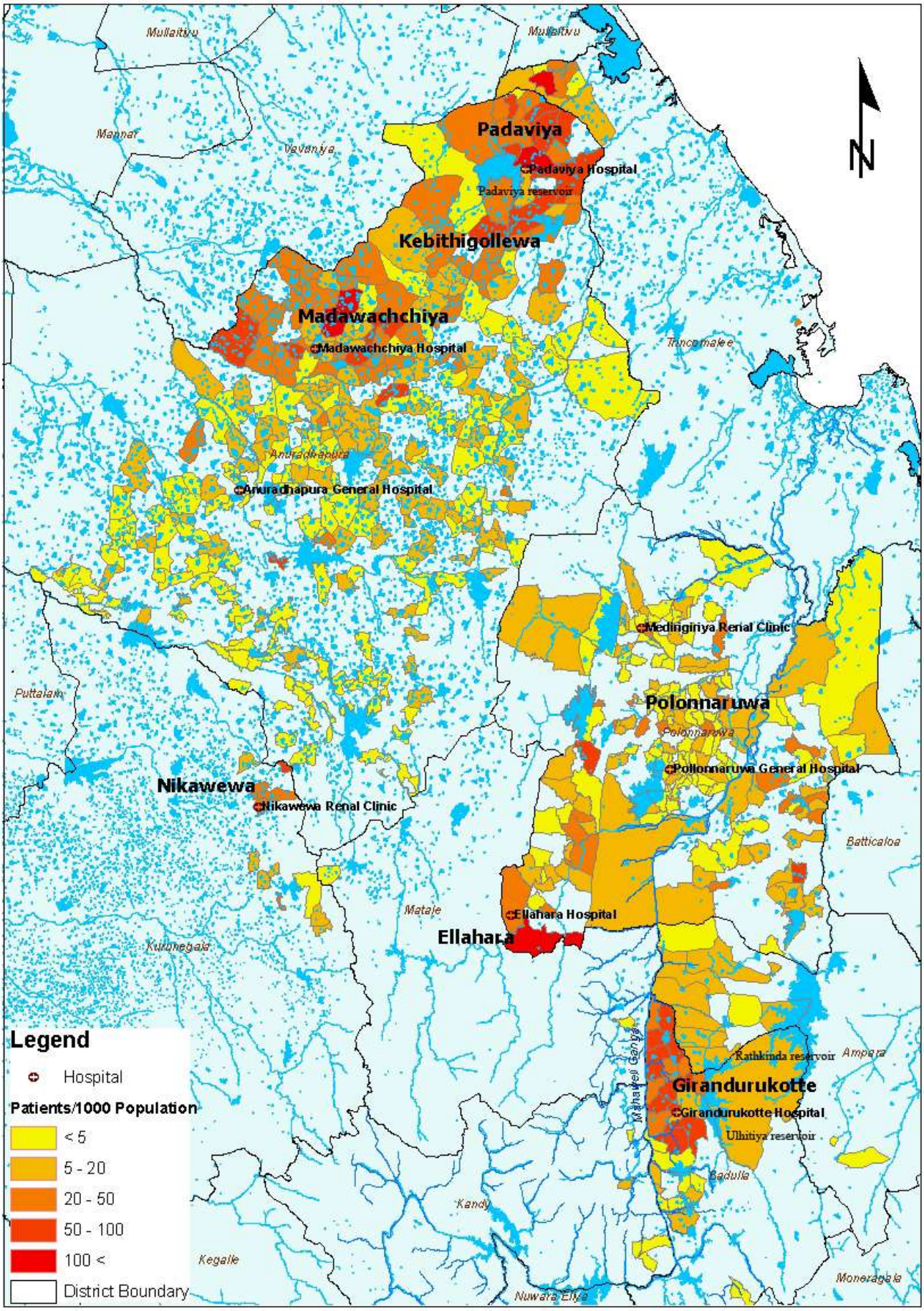

Figure 3 - Distribution of CKD-U patients in Padaviya and Medawachchiya

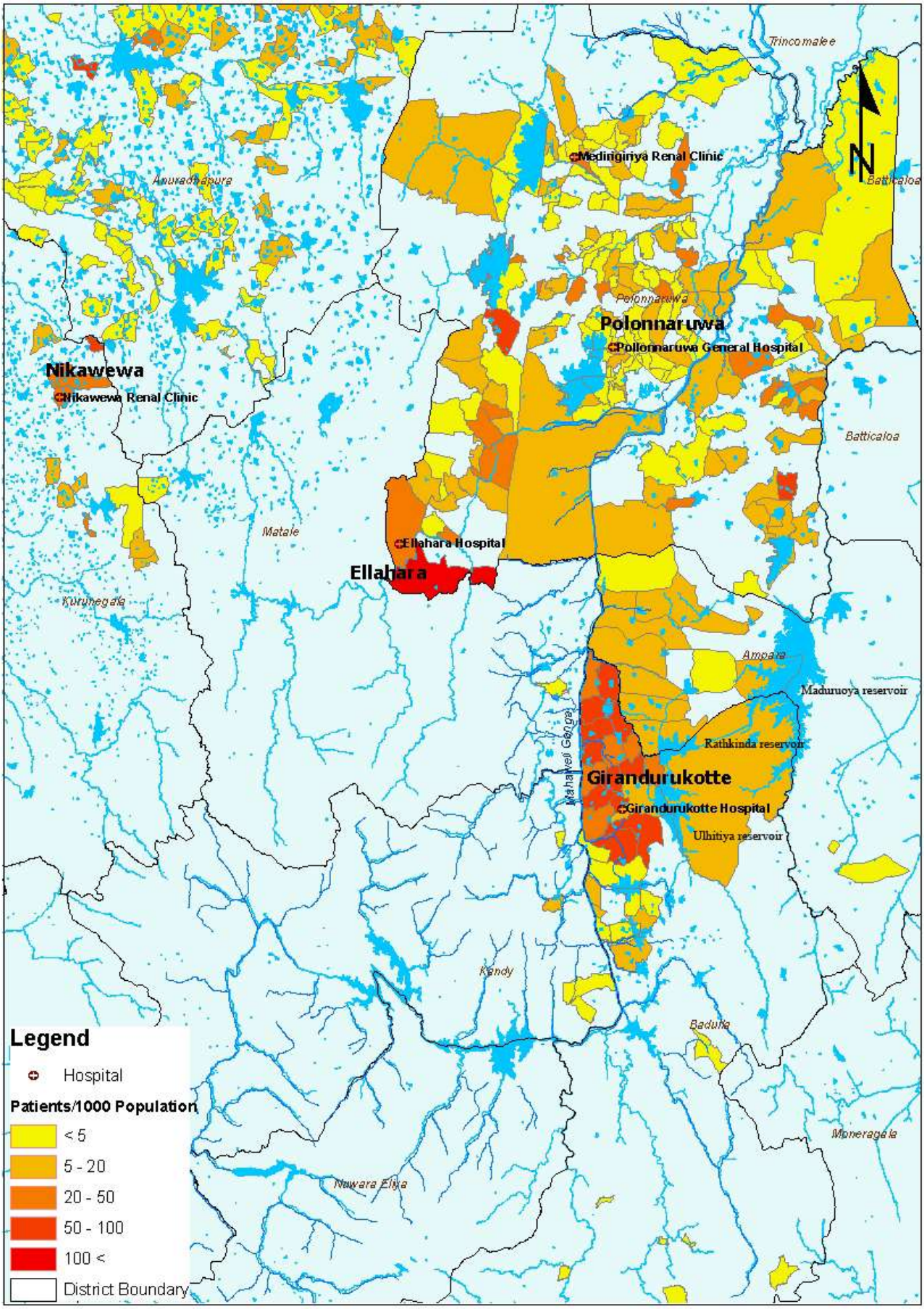

Figure 4 - Distribution of CKD-U patients in Girandurukotte

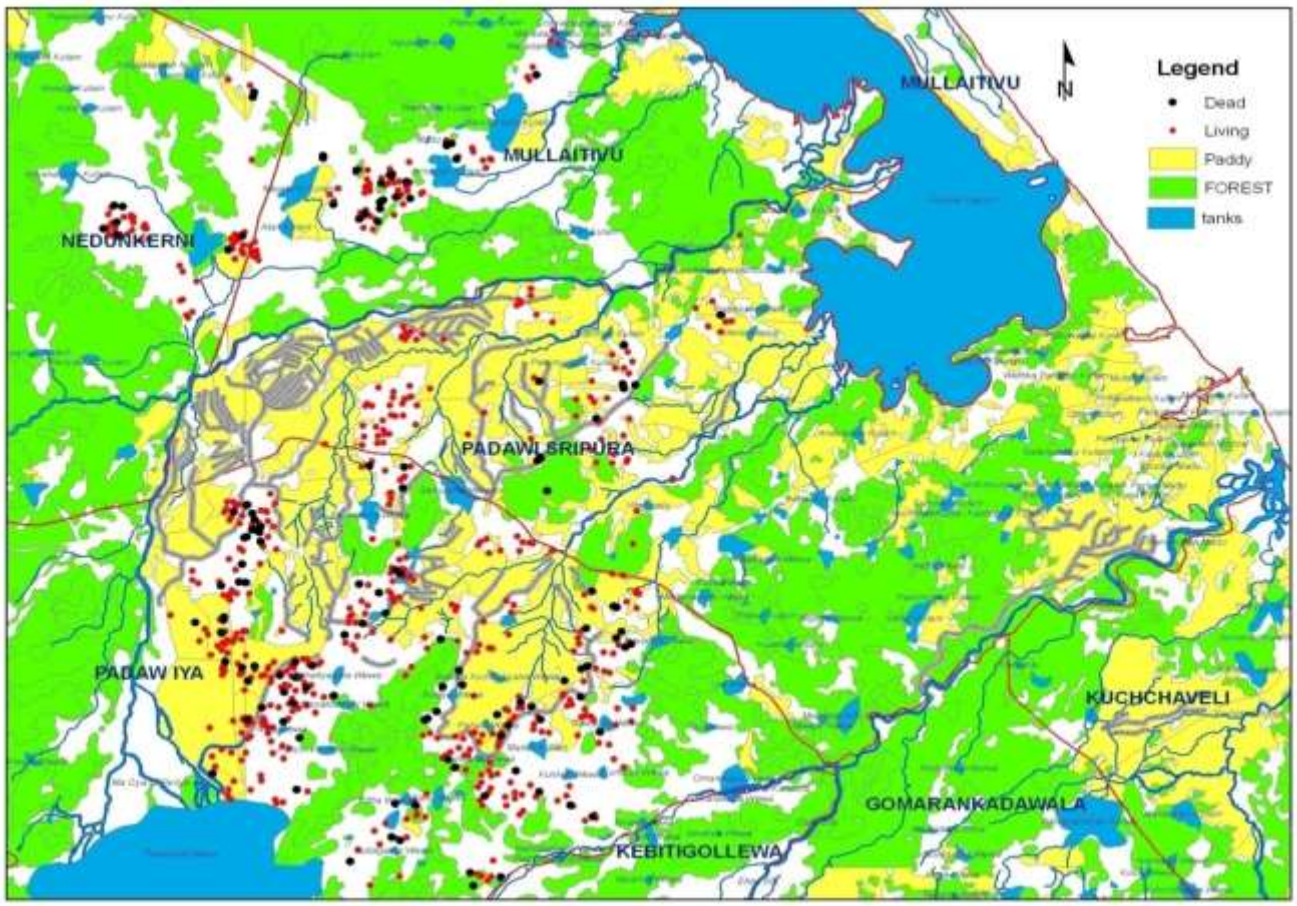

Figure 5 - Location of the households of CKD-U patients in Padaviya

DISCUSSION

The geographical distribution of the CKD-U shows that the disease is confined to some areas of the dry zone prominently in the North Central Region (NCR), which includes villages of North Central, North Western and Uva provinces. Though the populations at risk are scattered in the North Central Region, large number of patients have been detected in Medawachchiya, Padaviya and Girandurukotte. In addition, two other small disease foci had been identified in Medirigiriya and Nikawewa areas. It has been observed that all five regions affected with the CKD-U encompass a well developed irrigation system comprising of either one or two large reservoirs (Padaviya & Ratkinda /Ulhitiya) or cluster of small reservoirs (Medawachchiya & Nikawewa). Water from these reservoirs is mainly used for agricultural purposes. However, the people who live in these areas consume water from shallow wells for their all other daily needs except bathing. These shallow wells are purposely positioned close to the irrigation canals and most are downstream of the canal so that the dwellers can gain water without digging too deep. Water levels of these shallow wells are proportionate to the water levels of the canals indicating that the ground water table is recharged from irrigation canals & reservoirs. Therefore, the ground water level is fluctuated proportionately with the water levels of the reservoirs and canals. This shows that there is a definite seepage of water from these canals to the shallow wells. As such, it is clear that almost all these shallow wells are fed by irrigation canals and not by natural springs. It has been observed that the prevalence of the disease is comparatively low in the villages where natural spring water is available for drinking & cooking.

Observations of the study reveals that the exposure to the etiological agent remains unchanged and new disease foci are reported to be emerging. Therefore, prospective surveillance studies and regular screening programmes are essential to combat this devastating disease. The reported familial occurrence of the disease with no evidence of clear Mendelian inheritance could be due to exposure of the siblings to the etiological agent rather than direct genetic/inherited background for the disease. Similarly, familial occurrence & location of the affected house holds in the lowest lying area has been observed in Balken nephropathy (13,14,15,16,17,18) too, where the causative agent is supposed to be toxic in nature. Disease preponderance in males may be due to their frequent exposure to the etiological agent than females. This could also be due to another unknown contributory factor that operates in males which increases the risk of the disease.

CONCLUSION

The characteristic geographical distribution of the disease related to stagnant irrigated water indicates the possibility of an environmental factor related to water in the pathogenesis of the disease. The use of water from the shallow wells for

drinking by the affected population indicates the possibility that the etiological agent is water soluble. Presence of the disease in patients who consume boiled water for life long drinking indicates the possibility of heat stable nature of the etiological agent. In order to identify this agent further studies are needed. These studies should be focused on the onset of the disease and respective environmental factors that were associated with the emergence of the disease. The potential environmental factors should be correlated with the incidence of the disease in order to get a clear understanding of the disease. A study to find evidence of disease in the domestic farm animals may pave the way to identify the etiology of the disease. Multidisciplinary studies involving environmental, hydro/geological, epidemiological, occupational and toxicological studies needs to be planned for the precise identification of the etiological agent. Identifying the factor(s) responsible for CKD-U will lead to a deeper understanding of the pathogenesis of this disease and to a better understanding of kidney disease mechanisms. Unraveling the etiology of CKD-U will also allow appropriate preventive measures to be taken in the afflicted areas, such as by treatment of the drinking and cooking water or changing the main water supply.

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Studying the effect of super water absorbent polymer and watering capacity on growth of tomato under plant house

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ABSTRACT

Supper Absorbent Polymers(SAPs) have been used as water retaining materials in agricultural and horticultural fields, because when they are incorporated in to soil, they can retain large quantities of water and nutrients. The stored water and nutrients are released slowly if required by the plants to improve their growth under theconditions of limited water supply.

The aim of this preliminary study is to evaluate the effect on some morphological parameters of tomatoes by applying imported starch acrylic acid graft copolymers named GAM-sorb, from Vietnam. Experiment using plastic potswas done inthe plant house ofthe Department of Agricultural and Plantation Engineering of the Open University of Sri Lanka. Soil used in the experiment was sandy loam. The two factor factorial experiment was carried out in completely randomized design with 3 replicates. Factors were water capacities in three levels, 75% Filed Capacity (FC) of water, 50% FC and 25% FC together withsuper absorbent polymers in four levels (Low level (L)4.5 g,High level (H)9 g, Intermediate high level (M) 13.5 g, Double High level (DH) 18g in each level per 6kg of soil.Control was carried outwithout super water absorbent. Fifteen treatmentsconsisted of combination of above two mentioned factors. Minitab 14 package was used for data analysis. The analyzed data revealed that effect of three water rates were significant ($p<0.05$) for moisture content of soil, leaf area, number of flowers per plant, plant height and root dry weight. Except plant height, different rates of polymer were significant for other measured parameters. Interaction effects of above two mentioned factors were not significant. The results showed that all measured parameters were highest at combination of DHSAP(18 g): water 75%FC compared to control: water25%FC. Best soil moisture retainingability and growth parameters in sandy loam soil were prominent in combination of higest (DH)SAPrate and higest water rate (75% FC) added tomato plants.

INTRODUCTION

Supper Absorbent Polymers (SAPs) are compounds that absorb water and swell in to many times than their original size and weight. They are lightly cross linked networks of hydrophilic polymer chains. The network can swell in water and hold a large amount of water, while maintaining physical dimension structure (Buchholz and Graham, 1997, Mahdavinia et al 2004). It was known that commercially used water-absorbent polymeric materials employed are partial neutralization products of cross linked polyacrylic acids, partial hydrolysis products of starch acrylonitrile copolymers and starch acrylic acid graft copolymers.

Most authors agree that when super water absorbent polymers are incorporated in the soil, the following can be observed; control of soil erosion and water runoff (Wallace & Wallace, 1990), increasinginfiltration capacity (Zhang & Miller, 1996), increasing soil aggregate size (Wallace et al, 1986), reducing soil bulk density (Al-Harbi et al, 1999), increasing water retention (Johnson, 1984; Bres et al, 1993), improvingthe survival of seedlings subjected to drought (Huttermann et al, 1999)), lengthening shelf-life of pot plants (Gehring et al, 1980), improving nutrient recovery from applied fertilizers (Smith et al, 1991; Bes et al, 1993), improving nutrient uptake by plants grown in poor soil, minimizing nutrient losses through leaching under highly leached conditions, (Mikkelsen, 1994) and reducing irrigation frequency (Taylor et al, 1986).

SAPs are mostly used in arid and semi arid regions of the World to overcome water scarcity problem. We introduce SAPs to urban agriculture, because urban agriculture contributes to minimize the problems of food security and food safety in the World. The present trend in Sri Lanka is more and more urban people to practice crop cultivation. When urban people focus on crop cultivation, they are confronted with severe water scarcity problems especially in Colombo area,mainly due to heavy evaporation rateduring the day time Further, highly polluted environment in urban city limits increases the temperature, hence increasing soil water evaporation. This will result in wilting of plant leaves during the day time. Therefore, watering in the morning as well as in the evening is inevitable. However, frequent watering requires labour, time and money, in addition to water that may waste away during application. Apart from above, during the rainy

seasons and when frequent watering is practiced, nutrient deficiency problems are prominent among the cultivated crops due to wash off of soil nutrients and fertilizers, followed by soil degradation. The present study focused to evaluate the application of SAPs under urban agriculture.

METHODOLOGY

The study was carried out in the plant house of the model farm that belongs to Department of Agricultural and Plantation Engineering, of the Open University of Sri Lanka. Soil in the tested area was sandy loam and organic matter content, electric conductivity, and pH value were 5%, 1.32 mS and 6.81respectively. Factorial experiment was carried out with Completely Randomized Design. Treatments were consisted of combination of four rates of SAPs low level (L) 4.5 g, high level (H) 9 g, intermediate high level (M) 13.5 g, double high level (DH) 18 g and the control (C) which is without adding SAP. Each pot was added with 6 kg of soiltogether with the polymer. Three water rates: 75%% of Field Capacity (FC), 50% of FC and 25%of FC were maintained for each of above polymer rates. Each treatment was replicated three times. Volume of water required to fulfill the field capacity was measured using pressure plate. Soil moisture stress was recorded using digital moisture meter (in kPa) one week after transplanting andduring this period watering was done up to the field capacity**.** Soilmoisture content was measured three days after harvesting followingby drying in an oven at 105^0C until itreached at a constant weight.Number of flowers per plant was recorded at one week interval.Plant height was measured from colar region to the epic at three growth stages; seedling stage at two weeks after transplanting, at first flowering and then at harvesting. Leaf area was measured in five (05) randomly selectedmature leaves per plant using Leaf Area Index. Root dry weight of each plant was measured after oven drying to a constant weight at 60 ^{0}C.Statistical analysis was carried out through Minitab software version 14.

RESULTS

According to the Figure 1, a primary horizontal andprimary vertical axis showed the variation among the condition of pot soils each treatment separately vs. moisture stress. Secondary horizontal and secondary vertical axis showed variation of polymer rates and average moisture stress in each polymer rateone week after transplanting. Moisture stresses of all pots during the seven days after transplanting were between 1.11 kPa to 1.57 kPa**.** Out of them DH, M and H SAP rates showed the lower average moisture stress when compared to the control among them. DH had the lowest moisture stress.

As per the results indicated in table 1, there wasa significant different ($p<0.05$) between meanmoisture content of soil, leaf area, number of flowers per plant, root dry weight againstdifferent rates of SAP. However, plant height was not significant. Further,there was a significant differencebetween plant height, moisture content of soil, leaf area, number of flowers per plant and root dry weight ($p<0.05$) against three water rates.According to the results in table 2, SAP rates, moisture content of soil, leaf area, number of flowers per plant, plant height and root dry weight in double high (DH) level with SAP added were the highest when the lowest occurred at the control. Moreover, water rates were highest in moisture content of soil, leaf area, number of flowers per plant, plant height and root dry weight at water 75% FC compared to water25% FC.

Interaction effects were not significant for all above parameters.However, least square-means ofsoil moisture content, leaf area, number of flowers per plant, plant height, and root dry weight were highest in SAP(DH): water 75% FC as shown in figures 2,3,4,5 and 6. At the same time lowest least squares-means of moisture soil content, leaf area, number of flowers per plant, plant height and root dry weight were observed in control which were not added with SAP: water 25% FC. Since least square-means of soil moisture content, leaf area, number of flowers per plant, plant height and root dry weighthave increased at SAP (DH): water75% FC, control without adding SAP: water75% FC and SAP(DH): water 25% FC compared to control: water25% FC. These results were evident in table 2 as well.

DISCUSSION

SAPs have been used in agricultural and horticultural fields (Johnson 1984; Mikkelsen 1994;Yazdani etal,2007) due to theirability to retain water and nutrients for long time when incorporated into the soil. The stored water and nutrients are released slowly in requiredamounts tothe plant thatimproves its growth under limited water supply condition (Huttermann et al, 1999).Results of the present studyindicated clearly a remarkable increase in soil moisture retaining ability and at the same time improvement of some morphological parameters of tomato with limited soil-water supply. Among the applied SAP rates,DH had the lowest moisture stress confirming to the application of SAP at high rates were more effective than M and H SAP rates. This result indicates the requirement of SAP to a considerable level for better water retaining.

Researchers have elucidated that soil properties and its management have major influence on root and plant growth (Klepper, 1991; Sainju et al, 2001;Anikweet al, 2003). Sainjuet al, 2000 mentioned that optimum root growth and distribution within the soil profile play a major role in water and nutrient up take. The result of the present study is in line with above findings, by indicating a clear direct relationshipbetween tomato root and plant growth. The

remarkabledevelopment of roots was brought upby sandy loam soil amended with gel polymers,and therefore enhanced plant growth. According to the present study plant height, moisture content of soil, leaf area, number of flowers per plant and root dry weight have increased in highestSAP and highest water added DH SAP: water 75% FC compared to the treatment which wasnot added with SAP and lowest water rate from FC (control: water 25% FC). These results are in line with the Ghasemi et al, 2008 reported the best amount of super absorbent (0, 0.2, 0.4, 0.6, 0.8 and 1% of weight) and *Chrysanthemum morifolium*Ramat reaction to it, in different irrigation intervals (2, 3, 4 and 5 days). They announced that using these hydrophilic gels had positive and significant effect on number of flowers per plant area of leaves, plant height, root dry weight, root/shoot proportion, and coverage area in drought stress. The best performance in all indices was related to 0.8% treatment compared to control (without SAP) and also according to their study, water deficit reduces growth parameters.

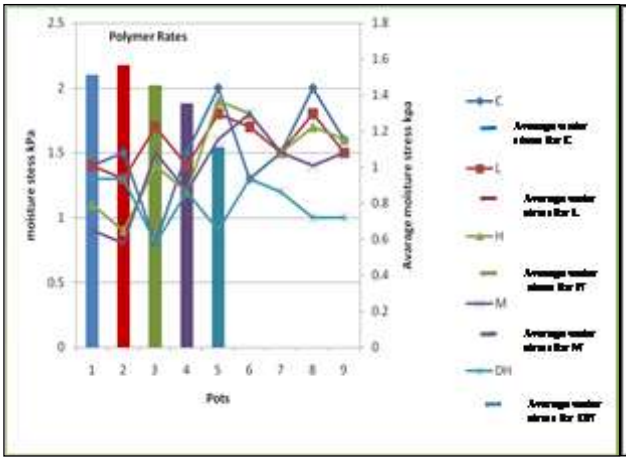

Figure 1 - Variationof moisture stress

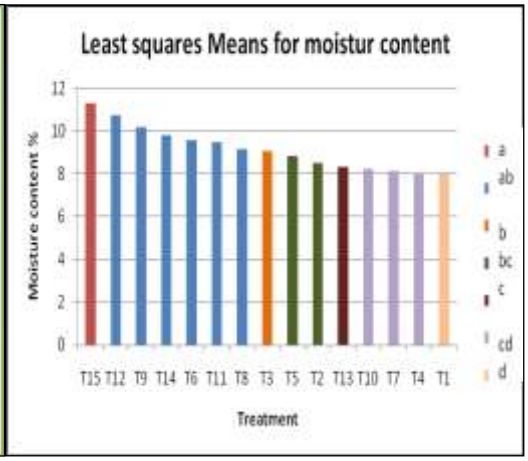

Figure 2 - Variation in soil moisture content in different treatments

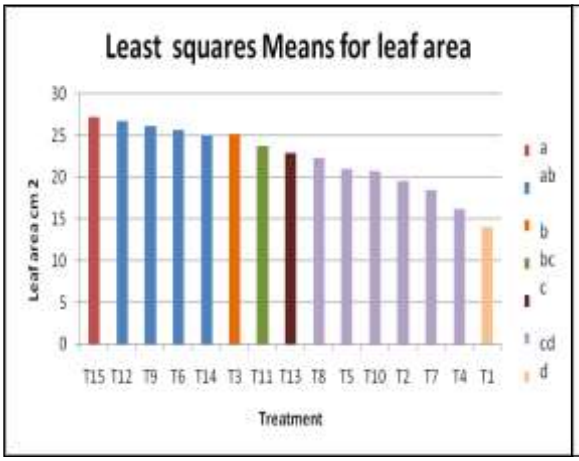

Figure 3 - Variation in leaf area in different treatments

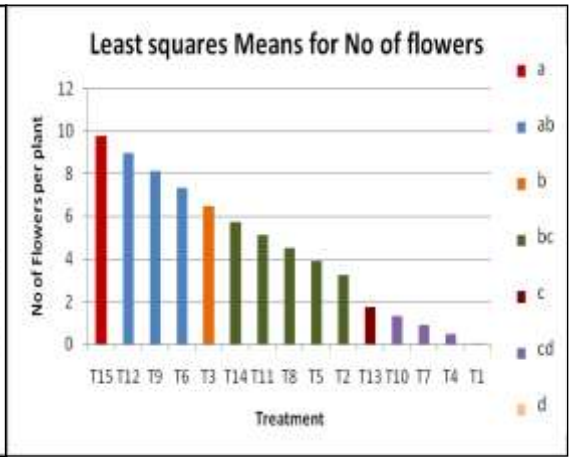

Figure 4 - Variation in number of flowers in different treatments

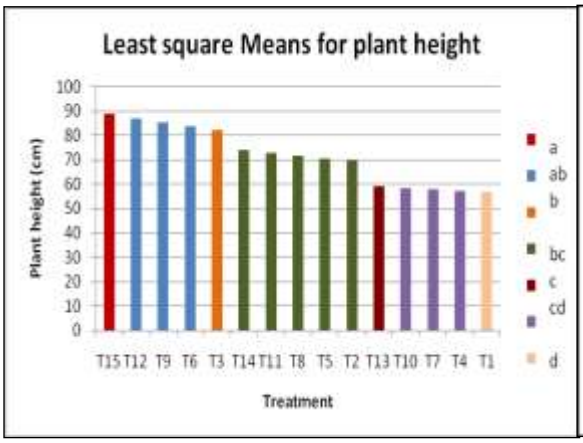

Figure 5 - Variation in plant height in different treatments

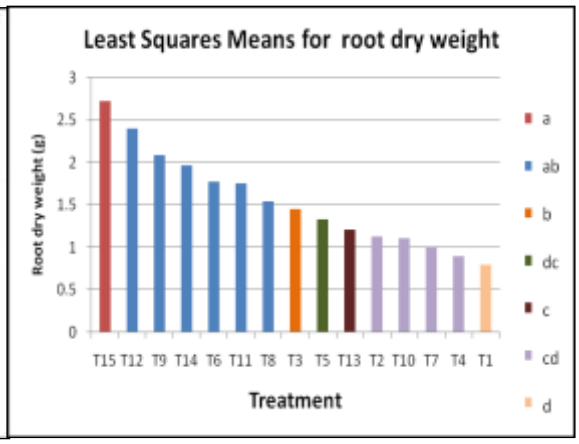

Figure 6 - Variation in root dry weight in different treatments

Table 1 - Variations of SAP andWater rates

Term	Moisture content %	Leaf area cm^2	No of Flowers	Plant height cm^2	Root dry Weight(g)
SAP rates	0.009	0.002	0.008	0.124	0.003
Water rates	0.000	0.000	0.000	0.000	0.000
SAP rates*Water rates	0.114	0.105	0.466	0.576	0.205

Table 2 - Variations of least square means for moisture content of soil, leaf area, number of flowers per plant, root dry weight of tomato with different rates of SAP and water

Term	Moisture content (%)	Leaf area ($cm^{2)}$	Number of Flowers per plant	Plant Height (cm)	Root dry Weight (g)
SWA rates					
Control (C)	8.51	19.56	3.27	69.51	1.12
SAP (DH)	9.81	25.09	5.76	73.91	1.96
Water rates					
Water 25%FC	8.15	18.47	0.88	57.84	1.00
Water 75%FC	10.17	26.17	8.14	85.58	2.09
SWA rates*Water rates					
T1 - C: water 25%FC	7.97 d	14.00d	0.03d	56.61d	0.79 d
T2 - C: water 50%FC	8.51 bc	19.56 cd	3.27 bc	69.51bc	1.12 cd
T3 - C: water 75%FC	9.04 b	25.11 b	6.50b	82.41b	1.45b
T4 - L: water 25%FC	8.06 bc	16.24 cd	0.46cd	57.23 cd	0.90 cd
T5 - L: water 50%FC	8.83 bc	20.94 cd	3.89 bc	70.61 bc	1.33 bc
T6 - L: water 75%FC	9.60 ab	25.64 ab	7.32 ab	83.99ab	1.77 ab
T7 - H: water 25%FC	8.15 cd	18.47 cd	0.88 cd	57.84 cd	0.10 cd
T8 - H: water 50%FC	9.16 ab	22.32cd	4.51 bc	71.71 bc	1.54 ab
T9 - H: water 75%FC	10.16 ab	26.17 ab	8.14ab	85.58ab	2.09 ab
T10- M: water 25%FC	8.24 cd	20.71cd	1.30cd	58.46 cd	1.10 cd
T11- M: water 50%FC	9.48 ab	23.71 bc	5.13ab	72.81 bc	1.75 ab
T12- M: water 75%FC	10.73ab	26.71 ab	8.97 ab	87.16 ab	2.40 ab
T13- DH: water 25%FC	8.33 c	22.94 c	1.72 c	59.08 c	1.21 c
T14 -DH: water 50%FC	9.81 ab	25.09 ab	5.76 ab	73.91 bc	1.96 ab
T15 -DH: water 75%FC	11.29 a	27.24 a	9.79 a	88.74 a	2.72 a

SAP - super absorbent polymer, C-control, L- Low level, H-High level,M- Intermidiate high level DH- Double High level,FC-Field Capacity.

CONCLUSIONS

Best soil moisture retainging ability and growth parameters in sandy loam soil were prominent in combination of higest SAP (DH) rate and higest water rate (75% FC) added tomato plants. Other SAP rates as well as water rates added tomato plants grown in sandy loam soil showed lower gorwth performances and at the same time showed lower ability to retaining the soil moisture.

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Impact of climate change: Socio economic impacts of drought on farmers in Hambantota District

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ABSTRACT

Climate change is the fundamental development challenge in the 21st century. Global warming and adverse impacts of climate change will reverse the development efforts of the mankind. Increase of temperature, changes in rainfall patterns and intensity and frequency of natural disasters like drought, floods, tornados and landslides will adversely impact on socio economic establishment of the society. Poor developing nations are more vulnerable to adverse impacts of climate change, and island nations like Sri Lanka face great difficulties to achieve their socio economic goals within this changing climate.

During the last few decades, temperature level and rainfall pattern in the island have significantly changed and the increase of intensity and frequency of extreme rainfall events like droughts and floods are more visible. Increase of extreme rainfall events will create adverse impacts on socio economic stability, food security, natural environment, public health, human settlement and finally on the development goals of a country. Since Sri Lanka is a tropical island and largely dependent on the monsoon rains, changes in rainfall will lead to hydro-meteorological disasters like drought. Dry zone of the island which receives less than 1750mm rainfall is more vulnerable to drought. Nearly 70% of paddy which is the staple food of the island and most other field crops are cultivated in dry zone of the island. Hambantota district which is the 6th largest paddy growing district has recoded large amount of droughts throughout the history.

Standard Precipitation Index was used to identify drought events and analysis of monthly rainfall at Hambantota, Agunakolapalassa, Ambalantota, Bataatha and Mahalewaya during the past thirty (50) years (1961-2010). It shows that there are severe droughts occurred throughout the period. Although there are large scale irrigation development projectsunder way, some parts of the district is suffering from water scarcity and droughts. Farmers are the most vulnerable group while rain-fed cultivations are adversely affected than the irrigated cultivation during the drought periods. Therefore socio economic conditions of the farmers in four (4) rain fed villages closer to above rainfall stations namely Mahara-Baragama, 4 Kanuwa-Kaliyapura, Yaya 19-Hungama and Debokkawa are correlated with the drought events. It is seen thatthe farmers are adversely affected during droughts and their livelihoods and socio economic status are in danger. Drought and water scarcity are the main reasons behind theirpoor, stagnated life style. Reasons such as lack of education qualifications or training for engaging inanother job or vocation, and non availability of any other choice, ensures that these farmers stick to the same livelihood. However there is no improvement in their lives and the present generation is not willing to accept the agriculture as their livelihood under prevailing socio economic conditions in the area.

INTRODUCTION

Climate Change, Drought and Drought Identification

Global climate has been changing mainly due to rapid increase of emission of greenhouse gases through the anthropogenic activities. Fourth Assessment Report (AR4) of the Intergovernmental Panel on Climate Change (IPCC) has documented that the global temperature has increased by about 0.74^0C during the period 1905 - 2006. It is also indicated that there is a strong possibility of changing global climate pattern with the climate change.

Recent analysis of temperature data in Sri Lanka shows, temperature has increased by 0.2 degree Celsius per decade during the period 1951-2008 (Premalal, 2010). With the increase of temperature, extreme climatic conditions related to temperature and precipitation also have been established in Sri Lanka (APN Report). Even though there is not much change of annual total rainfall, the variability was more visible during the recent past. It resulted in more drought events and consequently more flood events.

Droughts and Floods are major hazards related to water in the world. Every year many people die and bring economical losses over most of the countries from droughts and Floods. The damages and the economical losses due to the flood and droughts are very high and it affects very large number of people each year (Wilhite, 2000). Every year Sri Lanka

experiences droughtand/or floods and damagesto the properties and human lives is a common occurrence. Agriculture and water sectors are the most vulnerable sectors and considerable damageis caused to the agricultural sector. Both droughts and floods occur due to the irregular patterns and deficit or excess of rainfall and also as a result of high intense rainfall.

Droughts and floods are extreme climate events that percentage-wise are likely to change more rapidly than the mean climate (Trenberth et al. 2003). Drought is the single most important climatological hazard, often aggravated by human actions. Drought may start at any time, last indefinitely, and reach varying levels of severity (Premalal,1998). The occurrence of dry spell or droughts is not normally expected to be a characteristic feature of the climate of tropical islands.

The recorded history of drought in Sri Lanka dates way back to pre-colonial era. Premalal, 1998 has documented that, droughts were reported even in 161-137 BC. However at present vulnerability is very high from the drought due to many sectors such as agriculture, water, power are largely dependent on the rainfall and in addition peoples livelihoods are strongly dependent on the rainfall. Therefore even a slight negative anomaly in rainfall will affect the people and the economy of Sri Lanka.

Most recent destructivedrought was reported in year 2001. This much affected and the damage was very high especially in the dry zone and intermediate zone and also economic loss to the country was significant.The total affected families from the drought are reported to be more than 800,000 in the year 2001 (http://www.desinventar.lk/).To minimize the damages from droughts and floods, accurate Seasonal Weather Prediction capability has to be developed to issue early warnings for the relevant sectors. However it is hard to develop seasonal weather prediction tools to generate accurate seasonal weather forecast. Therefore drought monitoring will fulfill the above requirement.

Drought is a complex phenomenon which occurs spatially and temporarily in all over the world. Generally drought is in-cooperate with rainfall anomaly, evaporation, soil structure and vegetation etc. Therefore predicting drought condition is adifficult task. Many methods are being used in different parts of the world for drought forecasting and drought monitoring. One of the common methodsused by USA for drought prediction isPalmer Drought Severity Index (PDSI). PDSI was developed by W. C. Palmer in 1965 (Palmer, 1965).Palmer recognized the need for a better monitoring tool that could identify drought in terms of its intensity, duration, and spatial extent. Palmer based the PDSI on anomalies in the supply and demand concept of the water balance equation. Inputs into the weekly or monthly calculations include precipitation, temperature, and the local antecedent soil moisture conditions. The data are standardized to account for regional differences so that PDSI values can be compared from one location to another. The PDSI calculations are complex, and 68 terms are actually defined as part of the calculation procedure (Soulé 1992).

A simple method for calculating drought was introduced by T.B. McKee, N.J. Doesken, and J. Kleist at Colorado State University at 1993.It is known as Standard Precipitation Index (SPI). The advantage of the use ofSPI is that it is less complex than the Palmer Severe Drought Index (PDSI). The SPI was designed to quantify the precipitation deficit for multiple time scales. SPI was used to identify drought years in this study. SPI is calculated based on precipitation only. The SPI calculation for any location is based on the long-term precipitation record for a desired period.

Socio Economic Conditions in the Study Area

Mahara-Baragama, 4 Knuwa-Kaliyapura, Yaya 19-Hungama and Debokkawa villages were chosen for this study. The main economic source of the people in these areas is agriculture farming. About 50% of farmers are above 55 years old and 70% of them have experience onagricultural farming formore than 30 years. Average number of members in one family is about 5 and the education level of them is well below average. Approximately 15% of them have never had any formal education. Most have been educated up to primary level only.

The people living in the area are very much vulnerable to drought conditions, and therefore they have no satisfaction in agriculture. The only hope for these farmers appears to be to try to educate their third generation to be able to find fixed income sourcesto the family. 90% of them have permanent shelters but donot have adequate house hold items. Even though they buy their household during bumper harvest periods, they are eventually compelled to sell these during the unproductive drought periods. Therefore no house hold items clearly explain the frequent drought conditions in the area.Drinking water is one of the other majorproblem. Only a few people have access to tap water. Others depend on ground water and inmost of the places ground water is saline.

Water plays a vital role in any society. For farmers, water is among the basic needs to continue their only livelihood. Although Hambantota farmers are eager to cultivate in both the Yala and Maha seasons, due to lack of water they are unable to do so. During Yala season, only few paddy farmers are able to cultivate their fields while highland farming is

impossible. Although water is available in some areas, water salinity is a significant problem and farmers are unable to cultivate in those areas. Water salinity has largely affected paddy cultivation than highland crops.

DATA AND METHODOLOGY

The aim of this study isto evaluate the socio economic condition during the drought periods in Hambantota district. Primary and Secondary data were used to identifythe correlation between Socio Economic condition during the drought periods.Field survey has been conducted to identify Socio Economic conditions in the people living in the areas ofMahara-Baragama, 4 Knuwa-Kaliyapura, Yaya 19-Hungama and Debokkawa. Main livelihood of the people living in the area is agriculture. Agriculture in the study area is highly dependent on rain water.Despite there being large scale irrigation development projects, some parts of the district continue to suffer from water scarcity and droughts. Farmers are the most vulnerable group while rain-fed cultivations are being adversely affected than the irrigated cultivation during the drought periods.Socio economic data for the above area were collected for last ten years, because it is not easy to obtain correct information from the people during the past years. Therefore memorized period for the people is considered as past 10 years for this study.

Rainfall data were collected from the Department of Meteorology, very closer to the study area as a secondary data. The rainfall stations considered for this study are Ambalantota, Hambantota, Bata Ata, Angunakolapelessa and Mahalewaya.The method used to identify drought period is Standard Precipitation Index (SPI). For better results, more than 30 years data are needed, because calculation of the SPI for a specific time period at any location requires a long-term monthly precipitation database with 30 year or more of data(Hayes, et al. 1999). Therefore 50 years' data were used for this analysis. The probability distribution function is determined from the long-term record by fitting a function to the data.

SPI values were worked out for the 50 years rainfall data. One method to calculate SPI is the fitting of long-term record to a normal distribution, so that the mean SPI for the location and desired period is zero (Edwards and McKee, 1997). Positive SPI values indicate greater than median precipitation, and negative values indicate less than median precipitation. Because the SPI is normalized, wetter and drier climates can be represented in the same way, and wet periods can also be monitored using the SPI (Hayes, 2006). Other method is to fit the data in to a gamma distribution,as the gamma distribution has been found to fit the precipitation distribution quite well. This is done through a process of maximum likelihood estimation of the gamma distribution parameters, α (shape parameter) and β (scale parameter). In simple terms, the process described above allows the rainfall distribution at the station to be effectively represented by a mathematical cumulative probability function. Therefore, based on the historic rainfall data, an analyst can then tell what is the probability of the rainfall being less than or equal to a certain amount. Thus, the probability of rainfall being less than or equal to the average rainfall for that area will be about 0.5, while the probability of rainfall being less than or equal to an amount much smaller than the average will be also be lower (0.2, 0.1, 0.01 etc, depending on the amount). Therefore if a particular rainfall event gives a low probability on the cumulative probability function, then this is indicative of a likely drought event. Alternatively, a rainfall event which gives a high probability on the cumulative probability function is an anomalously wet event.

SPI value	Condition
2.0 or more	Extremely wet
1.5 to 1.99	Very wet
1.0 to 1.49	Moderately wet
-0.99 to 0.99	Near normal
-1.0 to -1.49	Moderately dry
-1.5 to -1.99	Severely dry
-2 and less	Extremely dry

For this study SPI was calculated for different time scales, as one month, three month and six months, because long term departure of rainfall gives better results. A three months or six months time scale is better for the prolonged severe drought because it embodies previous months' rainfalls too. However, finding the best time scale will be important to have a proper output. Results for the rainfall stations for the period 1961-2010 is shown in the figures 1 to 5. Severe droughts were marked to distinguish from the others.

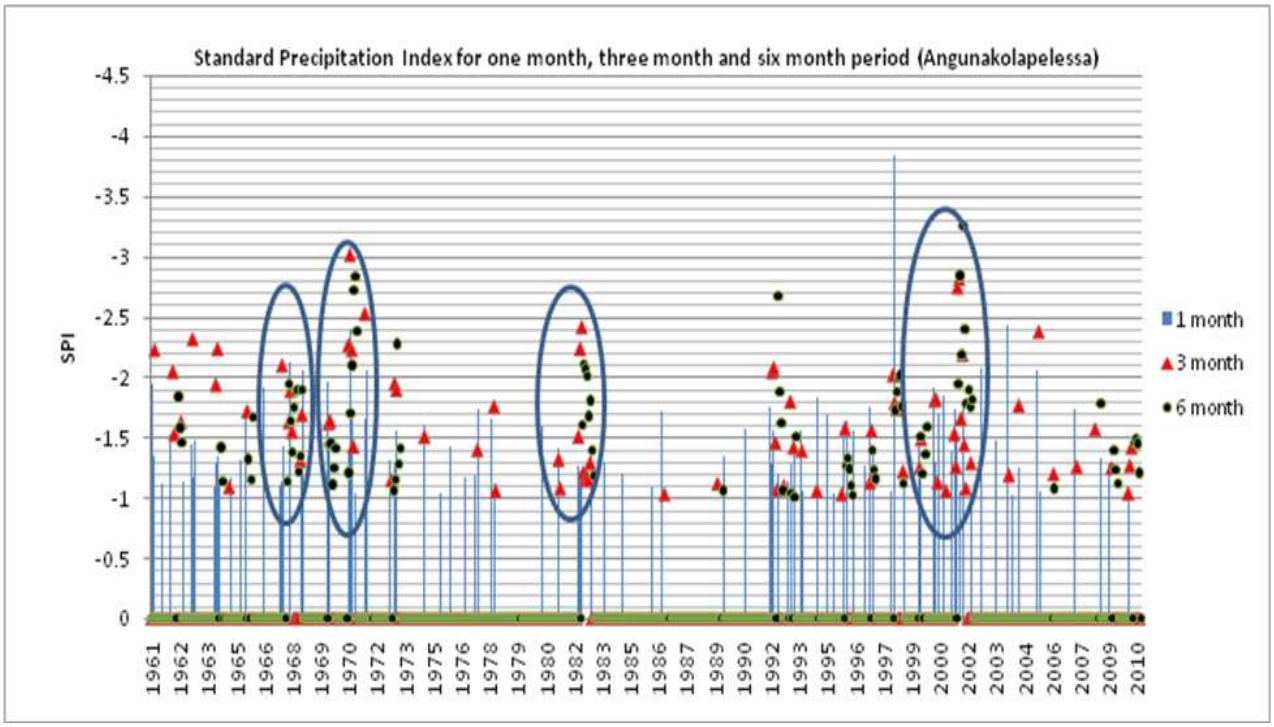


Figure 1 - Standard Precipitation at Ambalantota for the periods 1 month, 3 month and 6 month

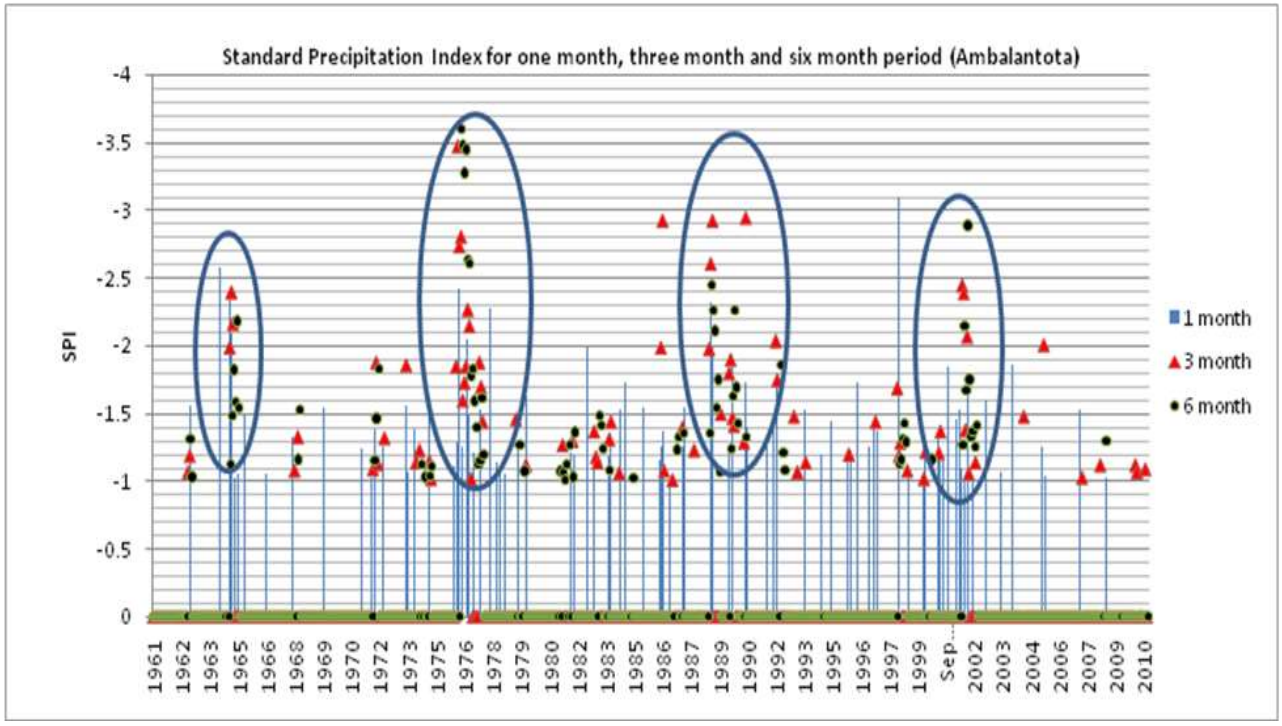


Figure 2 - Standard Precipitation at Angunakolapelessa for the periods 1 month, 3 month and 6 month

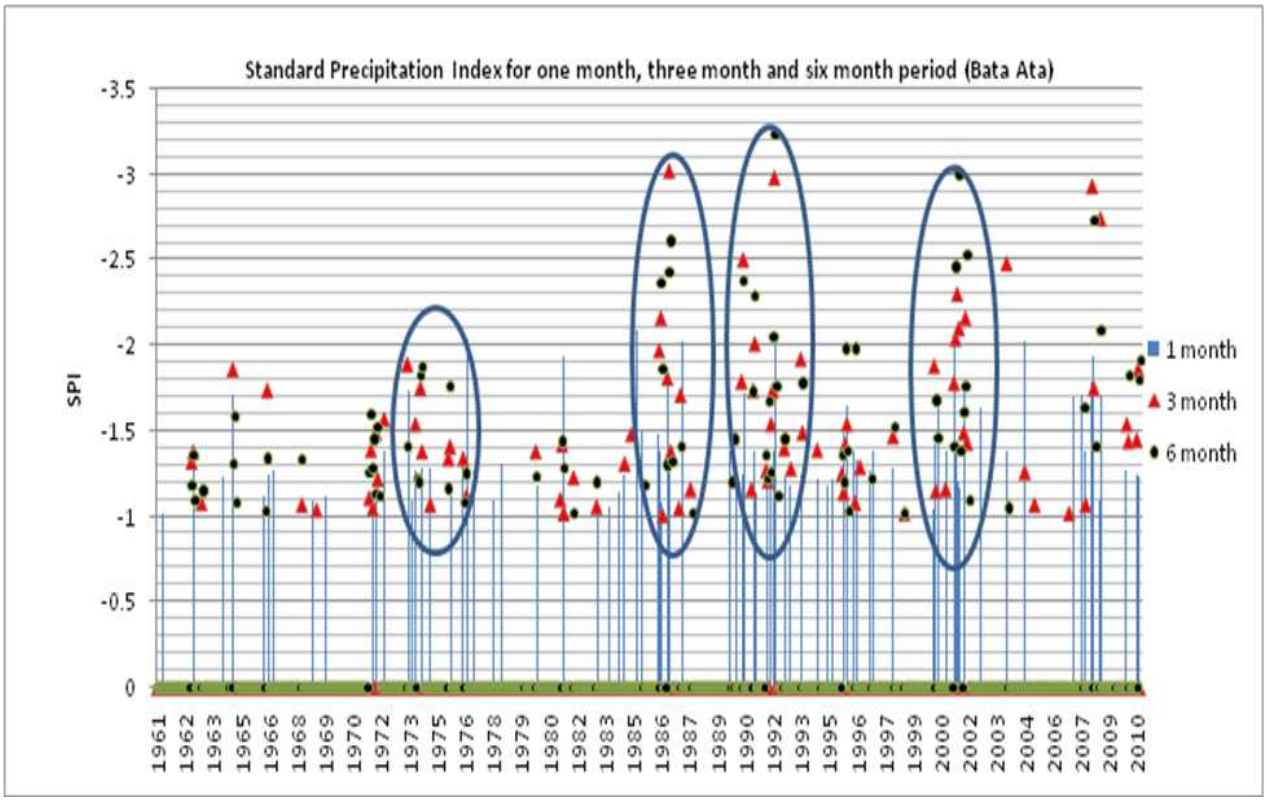


Figure 3 - Standard Precipitation at Bata Ata for the periods 1 month, 3 month and 6 month

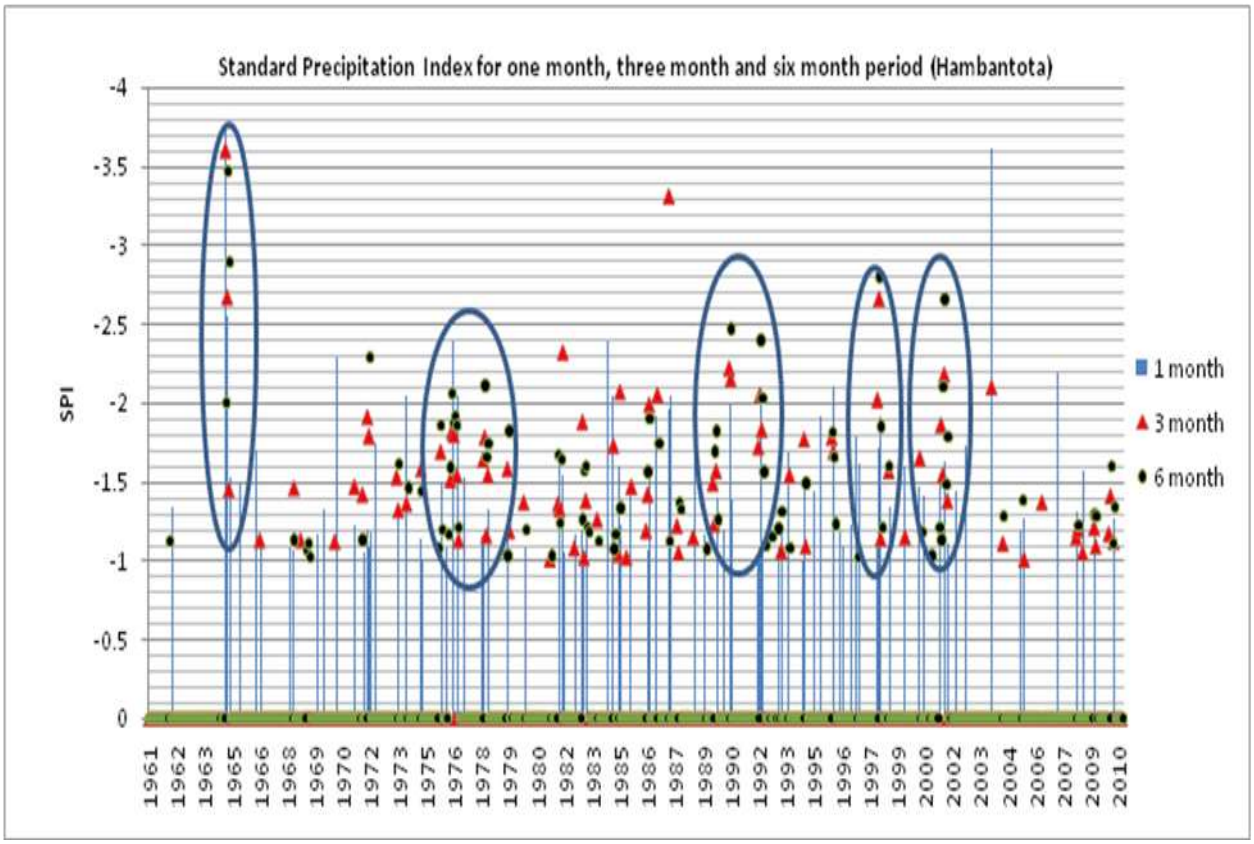


Figure 4 - Standard Precipitation at Hambantota for the periods 1 month, 3 month and 6 month

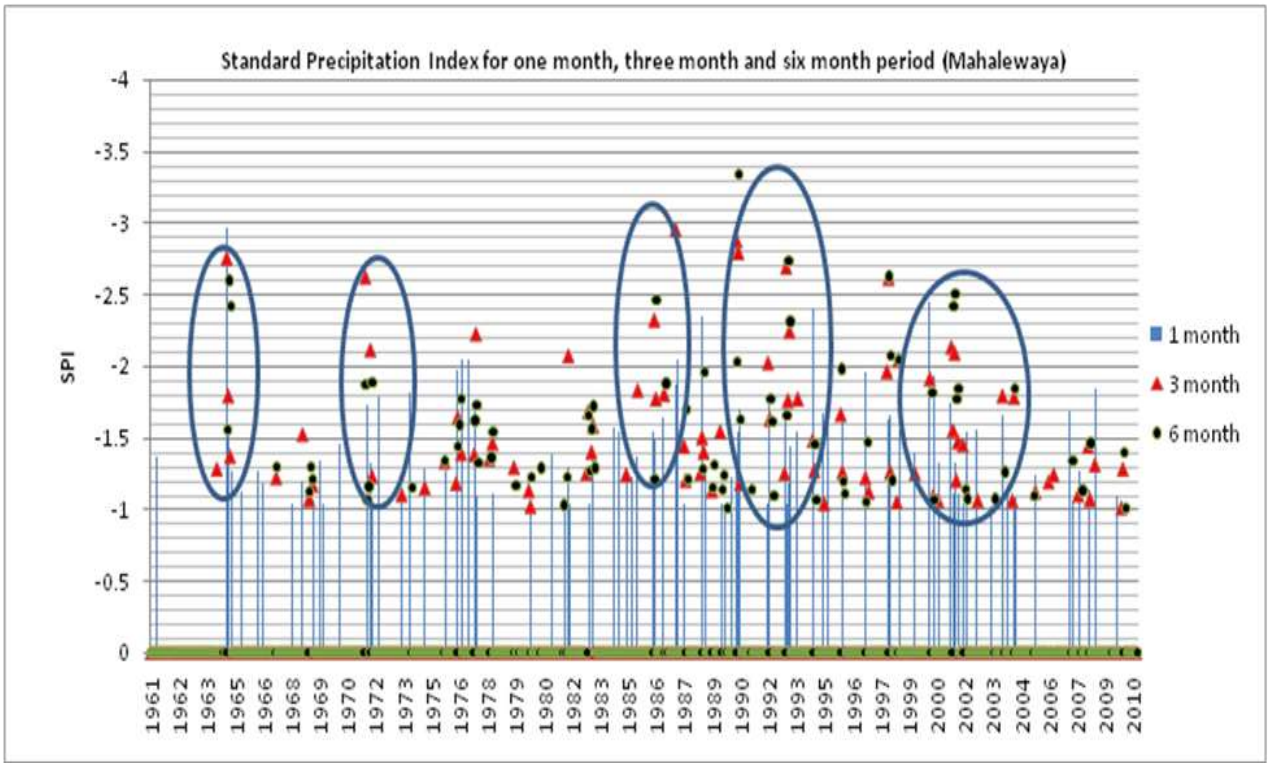
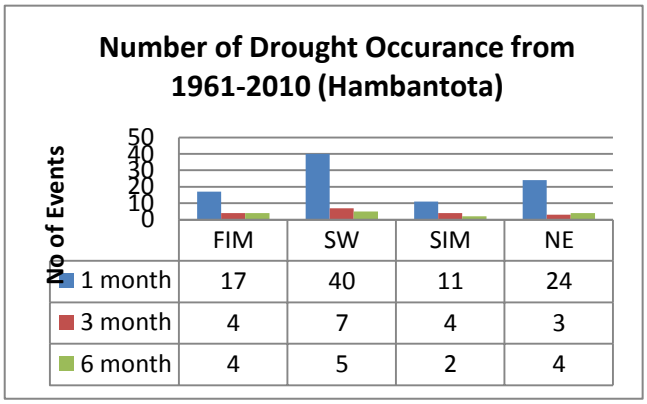


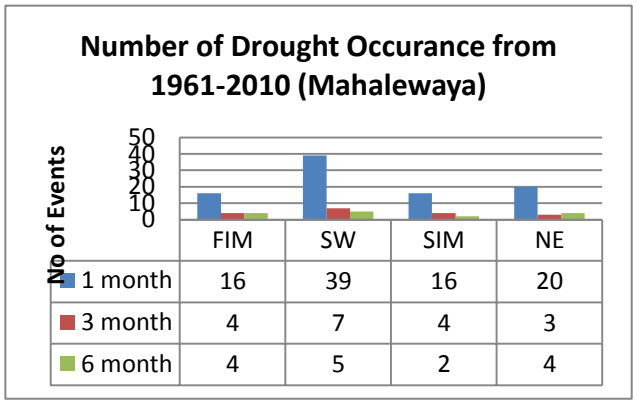
Figure 5 - Standard Precipitation at Mahalewaya for the periods 1 month, 3 month and 6 month

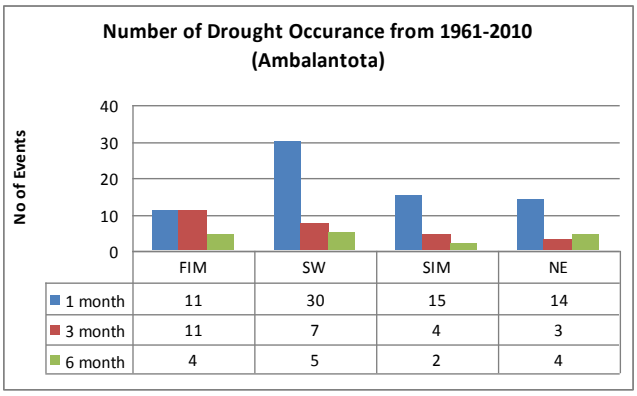
It is clear that short term rainfall departure is very common in Hambantota area. Therefore one month analysis of SPI does not give a clear picture about the severe drought situations in Hambantota. If one month rainfall anomaly is continued further, analysis of three month will give a negative value. If the 3 months SPI gives a higher negative value (-2 or -3), that clearly indicatesa long term drought condition. If the analysis is extended further for 6 months,negative values of SPI indicate prolonged drought conditions very clearly. Data are summarized below by considering these drought conditions at Hambantota area.

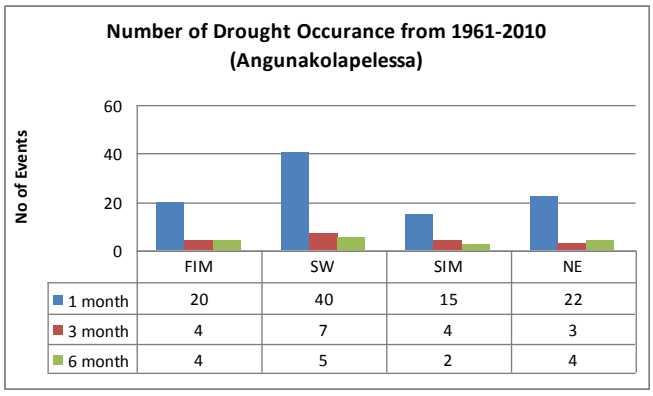
	Short Period			Medium Period			Long Period		
	Moderate	Severe	Extreme	Moderate	Severe	Extreme	Moderate	Severe	Extreme
Ambalantota	1968		1964			1972	1981-1984		1976-1977
									1988-1990
									2000-2002
Angunakolapelessa		1968					1995-1997	1981-1982	1969-1970
								1992-1993	1999-2002
Bata Ata	1972						1980-1981	1973-1974	1986-1987
								1975-1976	1990-1991
								1992-1993	1991-1992
								1996-1997	2000-2002
Hambantota			1965		1972		1986-1987	1982-1983	1976-1978
							1992-1993	1985-1986	1997-1998
								1989-1990	2001-2002
Mahalewaya			1965		1972			1976-1978	1985-1986
								1982-1983	1992-1993
									1994-1995
									2000-2002

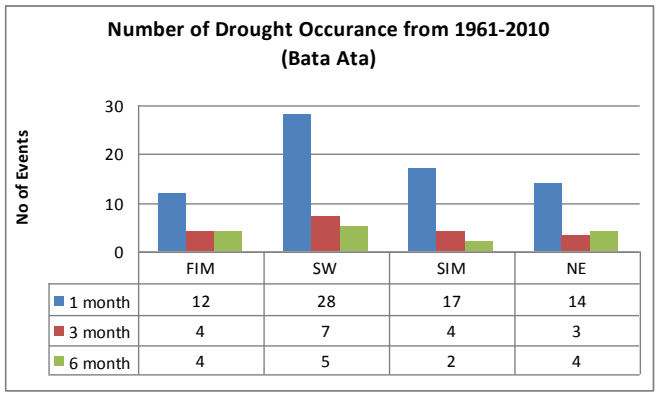
The analysis is further extended to identify the probability for having drought conditions for different climate seasons, because it is very useful to correlate people's perception with the drought periods or frequency of occurrence of drought. Peoples are much aware about the seasons, it did give rainfall at exact time. According to the results it is seen that the highest probability for having drought condition prevails during Southwest monsoon season. The rainfall during the southwest monsoon is very low compared with the northeast monsoon season. Therefore drought condition is common in this area during the southwest monsoon period, even for low negative rainfall anomaly.











According to the analysis of drought using SPI, it is clear that Hambantota area and suburbs are subject to frequent drought conditions. Considering the general background of the people, they are heavily dependent on the rainfall for their cultivation. Farmers and their cultivation are highly sensitive to two main monsoons. According to the people in the area, north east monsoon is the lifeblood of Hambantota farmers, but according to the analysis of drought periods, it is clear that most short and long period droughts have occurred during southwest monsoon periods. According to the people's perception in the area, they experience delay in rainy season and also changes in the volume of the rainfall. This indicates the occurrence and severity of drought in the area.However changes in climate factors have adverse impacts on rainfall in the area and it leads to adverse impacts on livelihood of the farmers. About 75% of the farmers interviewed said that the rainfall is not prevalent duringthe expected duration of time and this adversely affects their cultivation. They believe that lack of water management, limited amount of reservoirs, lack of maintenance of existing irrigation facilities and lack of rain water harvesting are also responsible for severe hardships and damage caused during the drought periods experienced in the area.

Although the farmers in these areas are not educated, through their life experiences they are used to hard and dry condition of climate in their villages and are able to make maximum use of the available resources. They are very close with the natural environment and are very sensitive to the changes in the natural environment. More than 80% of farmers in all these villages interviewed said that they experience changes in the climatic conditions. They said that the monsoon rainfall pattern has changed. They further experience an increase in the temperature. They believe it is because of delay in monsoon rainfall. Some said that the reason is delayed rainfall and not receiving the expected volume/amount of rainfall. In addition, few of Hungama farmers said that they experience in increase of extreme rainfall events like droughts, floods and tornados compared to the past.

CONCLUSION

Although drought is a common phenomena in the area, there is no responsible agency to conduct drought monitoring, adaptation and mitigation strategies to minimize the impact. Farmers cultivate their lands on the expectation of receiving irrigated water and rainfall according to the cropping calendar. There is no drought prediction system and awareness creation program on the changing weather patterns or upcoming droughts. Therefore farmers spend their time and money on agriculture activities even during the dry period without being aware or being warned of an upcoming drought, and eventually end up with the crop being destroyed. Only a few farmers mentioned that they receive agriculture advisory services, and that too is very limited. Therefore farmers heavily depend on subsidies and drought relief from the Government and other agencies during drought. However only a very few farmers receivethe benefits of these subsidies and drought relief programs.Only 20% of farmers in Debokkawa received the drought relief. 90% farmers in Hungama and 65% farmers in Kaliyapura didn't receive any drought relief.

Although any responsible agencies have never implemented drought adaptation/mitigation programs in the area, farmers themselves with their traditional knowledge and experience practice some strategies to minimize the adverse impact of drought. Therefore educating and implementing adaptation strategies and implementing an early warning system for drought in the area will very much benefit the people and the economy.

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Impact of agricultural activities on groundwater quality and its suitability for drinking in Valikamam area, Jaffna Peninsula

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ABSTRACT

Jaffna Peninsula is underlain mainly by Miocene limestone considered to be a good aquifer for groundwater storage and release. The Chunnakam aquifer in Valikamam area is the main limestone aquifer of Jaffna Peninsula. The objective of this study was to assess the impact of agricultural activities on groundwater quality in this study area. Groundwater samples were collected from forty fourwells to represent different uses such as domestic, domestic with home garden, public and farm wells and different cropping systems such as paddy, banana, high land crops and mixed crops. The data was for the period January to April 2011, whichrepresents a critical period covering the end of wet season to beginning of dry season. Important drinking water parameters, namely pH, electrical conductivity (EC), chloride, nitrate-N, fluoride, calcium, magnesium, carbonate, bicarbonate, sodium and potassium were determined to map the spatial variation of drinking water quality of the aquifer using GIS. Information on land use and agricultural practices such as fertilizer applicationand irrigation were obtained through a questionnaire survey and direct observations. High concentrations of nitrate–N, salinity development along coastal area and low levels of fluoride were the problems identified compared to Sri Lankan drinking water standards. The study showed that the level of nitrate-N concentration of water was influenced by different agronomic practices. Excessive irrigation and excessive application of nitrogen as inorganic fertilizer were found in the Valikamam area of the Chunnakam aquifer. Fertilizer application and irrigation practices were decided by the farmer based on their own experience and hardly any extension service exists to advise the farmer on these aspects. However, long-term monitoring is essential to make a firm conclusion and devise protective measures.

INTRODUCTION

The Jaffna Peninsula lies in the northern most part of Sri Lanka. It has four main types of aquifer systems, namely Chunnakam, Thenmaradchi, Vadamaradchi and Kayts (Punthakey and Nimal, 2006). Limestone is the main aquifer type in the Jaffna Peninsula. Groundwater is an extremely valuable resource in the Peninsula and pollution of groundwater is a matter for serious concern. Agriculture is the main source of livelihood for 65% of the population and about 34.2% of the land is cultivated intensively with high value cash crops such as red onion, chillies, potatoes, tobacco, vegetables, banana and grapes for commercial purposes (Thadchagini and Thiruchelvam, 2005).

In some parts, the density of wells was reported to be up to 75agricultural wells per 100 ha (Balendran et *al.,* 1968). Fertilizer and pesticide residues leached from agricultural fields often contribute significantly to groundwater pollution. The high nitrate levels recorded in well waters of the Peninsula's agricultural areas is very likely related to the intensive cultivation practiced in that region. Pollution of groundwater by nitrate has been receiving attention in the Peninsula since early 1980s (Maheswaran and Mahalingam, 1983; Dissanayake and Weerasooriya, 1985; Nagarajah *et al*., 1988; Maheswaran, 2003 &Mikunthan and Silva, 2008). Though many studies have been carried out on groundwater quality in the Peninsula, no systematic studies have been carried out so far to characterize the drinking water quality of aquifers in the Jaffna Peninsula. Hence, the objective of this study was to assess the impact of agriculturalactivities on groundwater quality and its suitability for drinking in Valikamam area, Jaffna Peninsula.

METHODS AND MATERIALS

Description of the study area

Jaffna Peninsula experiences the major rainy season during the North-East monsoon from October to December and the minor rainy season during the South-West monsoon in April and May (Mapa *et al*., 2010). The major soils in the Peninsula are the calcic red-yellow latosols which are shallow, fine textured and well-drained with very rapid infiltration rates (De Alwis and Panabokke, 1972).

Selection of wells

Forty four wells were selected for water quality monitoring in a systematic manner to represent the entire Chunnakam aquifer. Selected wells are under usages such as domestic, domestic and home gardening, public wells for drinking purpose and farm wells. Of the selected wells, twenty four (24) were farm wells from different cropping systems namely high land crops (chilly, onion, brinjal, and tobacco), mixed crops (high land crops with banana), banana and paddy.Figures 1 show the locations of the wells selected for monitoring.

Collection of water samples and analytical techniques

The data used in this study covered the period from January to April 2011 representing a critical period covering the end of wet season to beginning of dry season. Samples were analyzed for pH, Electrical Conductivity (EC), nitrate-N, fluoride, calcium, magnesium, chloride, carbonate, bicarbonate, sodium and potassium concentrations. The procedures of the analysis were based on Sri Lankan standard 614. Spatial distribution maps for different parameters were developed by ArcGIS 10 using IDW interpolation technique.

Field data collection

A questionnaire survey was carried out to collect information regarding cropping pattern and fertilizer usage in the study areas. Recommended rates of fertilizer for each crop were obtained from the fertilizer recommendation for horticultural crops - 2007, Department of Agriculture, Peradeniya. Rainfall data during the study period was obtained from the Meteorological Department, Thirunelveli.

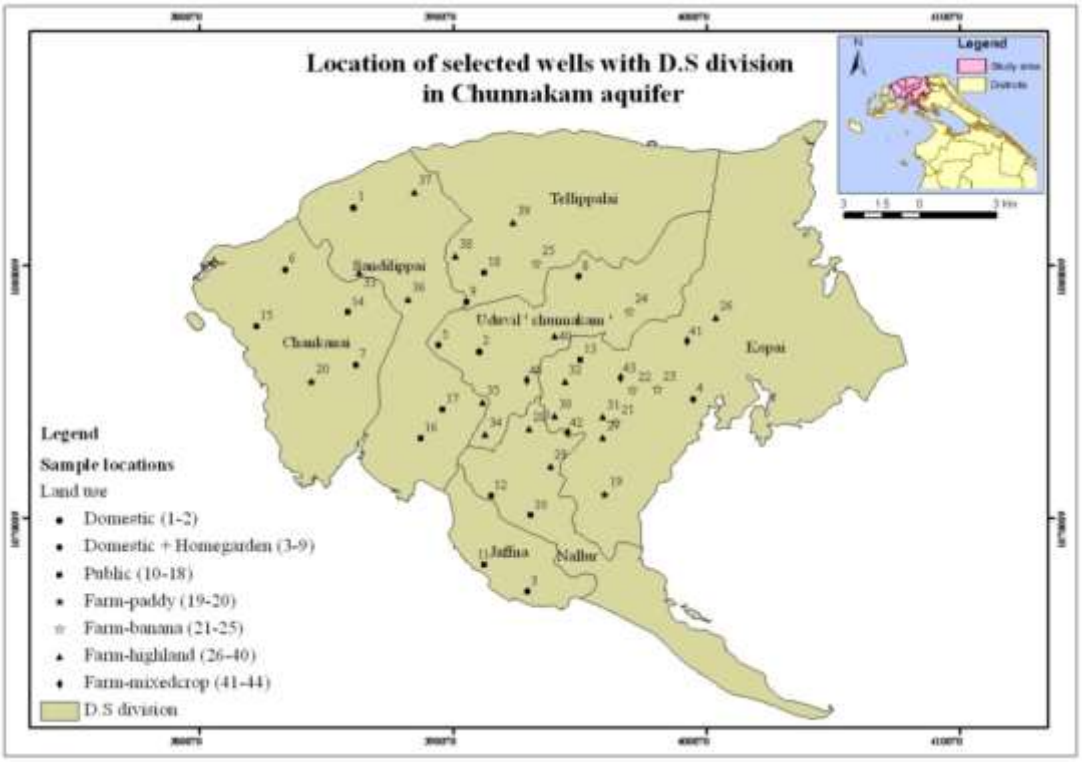


Figure 1 - Location of selected wells with DS divisions in Chunnakam aquifer

Calculation of crop water requirement

Environmental parameters required for the estimation of reference crop evapotranspiration, i.e., monthly average mean temperature, humidity, wind speed and sunshine hours, were obtained from the Meteorological Department, Thirunelveli.The type of crop, frequency of irrigation, rate of pumping and duration of pumping were obtained through direct observation during the questionnaire survey. Crop coefficients for required crops were taken from Allen et al. 1998. The time required to fill a 50 liter bucket was used to measure the rate of pumping during irrigation.The CROPWAT 8.0 decision support tool, developed by the Land and Water Development Division of the Food and Agriculture Organization of the United Nations (FAO), employing Penman-Montieth method was used to calculate the reference crop evapotranspiration (ETo) values. Crop evapotranspiration was calculated by multiplying the reference evapotranspiration by the respective crop co-efficient.

RESULTS AND DISCUSSION

General

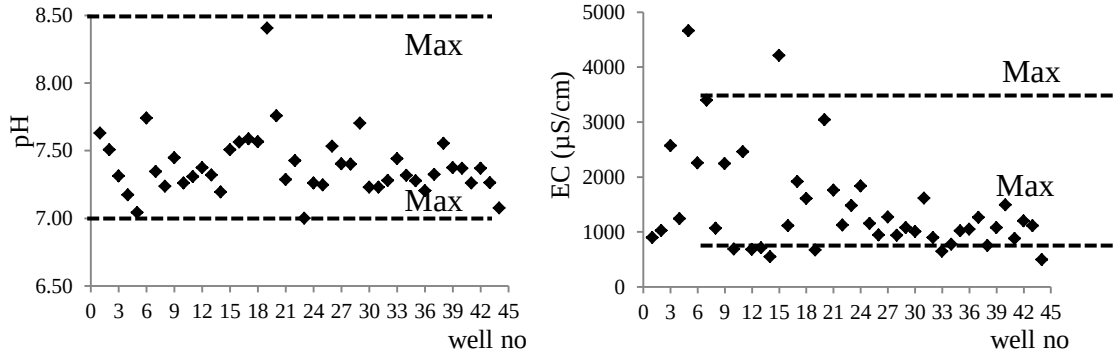
Size of the farm lands in the Chunakam aquifer area ranges form 0.1 – 1.5 ha. In intensified agricultural areas, farmers practice year round cultivation with no fallowing in between the cropping cycles. Pumping is done for approximately

three hours on a daily basis or may be with two shifting. The depths of most of the wells are ranging from 2.5 m to 10 m. Most of the farmers have their own wells and in some cases a well is shared by three or four farmers. Timing of crop, irrigation, fertilizer application and all the cultivation practices are decided by the farmer with their experience.

Drinking water quality of selected wells

pH

The average pH values of water samples were within the range of 7.0 to 8.41 indicating a slight alkalinity (Figure 2a). Puvaneswaran (1986) and Rajasooriyar et al. (2002) reported that the pH value of water in the Jaffna Peninsula region is greater than 7.0. According to Sri Lankan Standard Institute (SLSI) guidelines, the desirable level of pH for drinking water could vary from 7.0 to 8.5. Thus, groundwater in the study area could be considered as being acceptable for drinking in this respect.

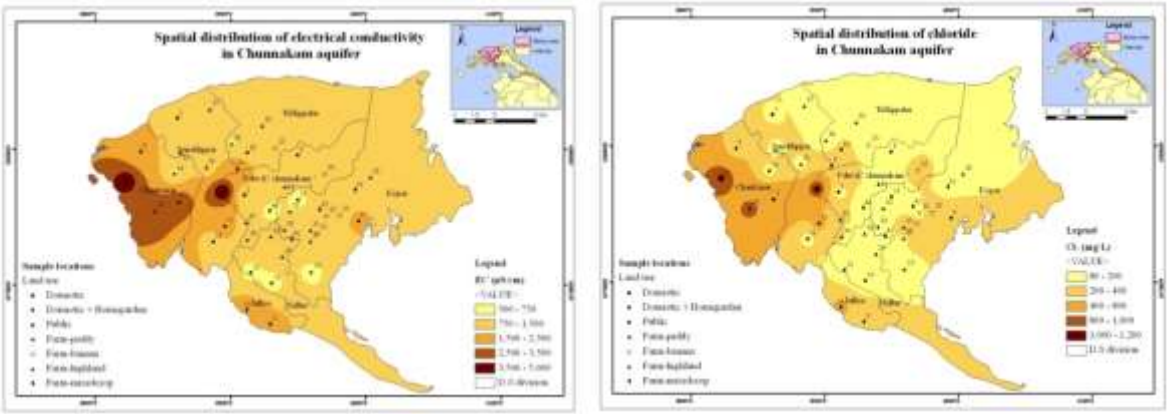


(a) (b)

Figure 2 - Average pH and EC

Electrical conductivity (EC)

The EC of the water samples is an indicator of their salinity. The average EC values ranged from 500 to 4660 µS/cm (Figure 2b). However, 95% of the wells were within the limits of SLSI permissible levels. As shown in Figure 3a, the groundwater of Chunnakam aquifer is characterized by the occurrence of high EC contents with widely differing concentrations among individual wells during March 2011. Higher EC was clearly shown to be more common closer to the coast, and decreasing inland. Well-5 and 15 had relatively high EC values of above 4000 µS/cm which was above the SLSI guideline for drinking water of 3500 µS/cm. The trend of EC generally reflects the chloride concentration available in groundwater and enriched by the discharge ions of sodium, calcium and magnesium(Jothivenkatachalam *et al*., 2011).



(a) (b)

Figure 3 - Spatial variation of EC and Cl^-

Chloride

The average chloride concentrations of water samples of all wells were between 80 mg/L to 1100 mg/L(Figure 4a). All values of measured wells were below the permissible level of SLSI guideline for drinking. The high chloride concentration of 1100 mg/L was observed in a public well (well-15 at Moolai) which is located closer to coastal line. Of the forty four wells measured, 66% showed chloride contents less than 200 mg/L and 34% were within the range of 200 mg/L to 1200 mg/L. High concentration of chloride was observed in well- 5 and 15. However, these two wells are still used for drinking purposes.

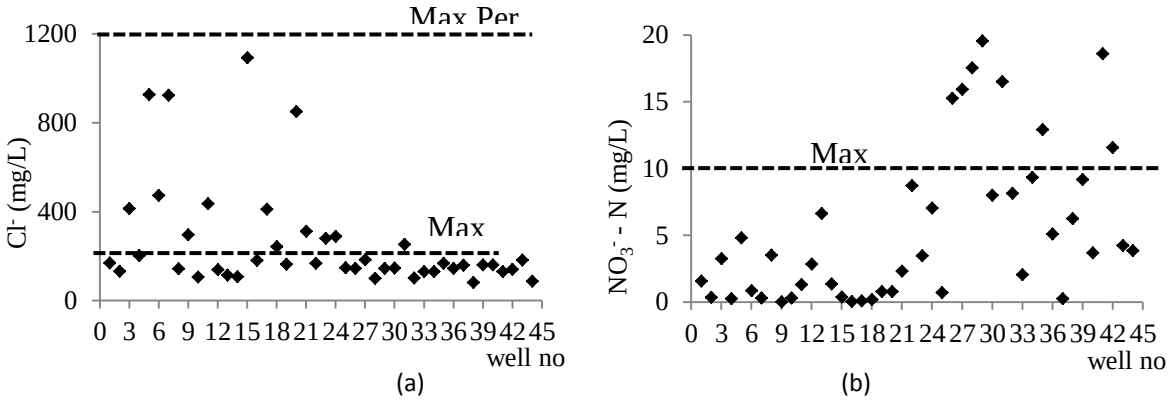


Figure 4 - Average Cl^- and NO_3^- as N

The spatial variation of chloride concentration during March in Chunnakam aquifer is shown in Figure 3b. High concentration of chloride was observed closer to the coast, and decreasing inland. The patterns of EC and chloride concentration are a clear indication of the influence of sea. Rajasooriyar et al., (2002) mentioned that high chloride concentration in some selected coastal locations provide evidence for seawater intrusion.

Nitrate–N

The average nitrate- N concentration ranged from undetermined value to 19.6 mg/L (Figure 4b). All domestic, domestic with home garden and public wells could be recommended for drinking as the average values of nitrate-N were below the SLSI guideline for drinking water. Among the selected farm wells, 31% exceeded the SLSI guideline of 10 mg/L and not suited for drinking. Gunasegaram (1983) studied extensively groundwater contamination in the Jaffna Peninsula and found that the nitrate levels exceeded standard limitsdue to the mixing up of abundant nitrogenous waste matter and synthetic and animal fertilizers reaching the shallow groundwater table. Mageswaran and Mahalingam (1983) also reported high nitrate-N content in the well water and soil.However, the violent conflict that lasted for more than 25 years after this period could have reduced the intensity of agriculture in these areas and stabilized or reduced the nitrate-N concentrations.

Nitrate as N content was below 10 mg/L in January, March and April in domestic, domestic with home garden and private wells and did not have the problem of nitrate for drinking purpose. Figure 5 shows temporal fluctuation of nitrate-N concentration in groundwater in different agricultural land uses such as paddy, banana, highland crops and mixed crop. Groundwater within the intensively cultivated area had nitrate-N concentrations in between undetermined value to 35 mg/L. High nitrate –N concentration of ground water was observed at high land crop land use and followed by mixed crops during January. Concentration of nitrate-N in paddy and banana land use had less than the SLSI guideline for drinking water. The high nitrate- N value of 35mg/L was observed during January at Thirunelvely and Neervely which are highland and mixed crop respectively. Even though these wells are used for agricultural purpose, people who are working in the field use the well water for drinking. Jeyaruba and Thushyanthy (2009) also noted that the level of nitrate-N concentration of water was influenced by cropping systems.Cultivation of banana is normally under basin irrigation with organic fertilizers. Premanandarajah *et al.* (2003) mentioned that the addition of organic manure increases nitrogen retentions capacity and reduces nitrate loss by leaching in sandy soils. Since nitrogen retention increases with organic fertilizers, this could reduce leaching of nitrate-N to groundwater in banana land use. Hence one of the ways to reduce nitrate pollution of groundwater is by incorporating organic manures.

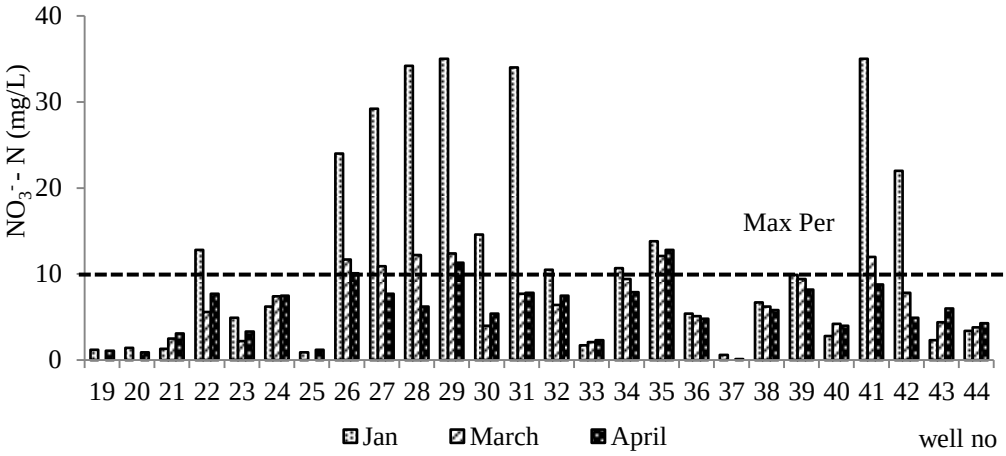
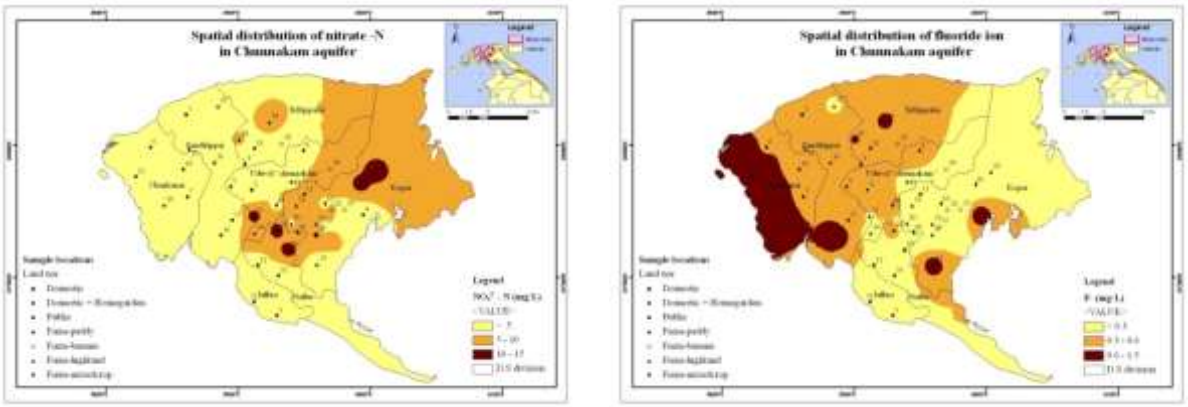


Figure 5 - Temporal fluctuation of NO_3- as N in farm wells

A general decreasing trend in nitrate-N concentration was observed from January to March. During rainy season, the soil is wetted enough up to the water table to facilitate the leaching of nitrate. In addition the Peninsula experienced heavy rainfall during *Maha* 2010 which resulted in high groundwater table in January. This in turn would have resulted in dissolving nitrate-N that was accumulated in the upper soil layers. Nandasena *et al.* (2005) reported that the rainfall influences the distribution of nitrate-N in the groundwater by raising or lowering of the groundwater table.



(a) (b)

Figure 6 - Spatial variation of NO_3^- as N and Fluoride ion

Spatial variation of nitrate-N concentration in Chunnakam aquifer during March 2011 is shown in Figure 6a. Here 14% of the wells were above acceptable level of SLSI guideline for drinking. These farm wells come under intensified agricultural area. Of these farm wells, well 26, 27, 35 and 39 are used for drinking purposes by farmers. Dissanayake and Weerasooriya (1985) pointed out that Jaffna Peninsula has the highest nitrate content among the groundwater of Sri Lanka. They also mentioned that the major factors responsible for the poor water quality in the Jaffna Peninsula are abundant use of agricultural fertilizers mainly urea, usage of cattle manure and discharge of human excreta in the form of soakage pit.

Fluoride

The average concentration of fluoride changed from un-determined value to 0.74 mg/L(Figure 7). Results revealed that 95% of the wells including domestic wells had water with less than 0.6 mg/L which could lead to deficiency of fluoride. The recommended level of SLSI guideline for fluoride in drinking water is 0.6 mg/L to 1.5 mg/L. Rajasooriyar *et al*., 2002 stated that fluoride concentrations in 95% of the wells from Valigamam region were less than 1 mg/L due to the result of solubility which controls causing calcium fluoride precipitation. The spatial variation of fluoride concentration in Chunnakam aquifer is shown in Figure 6b.

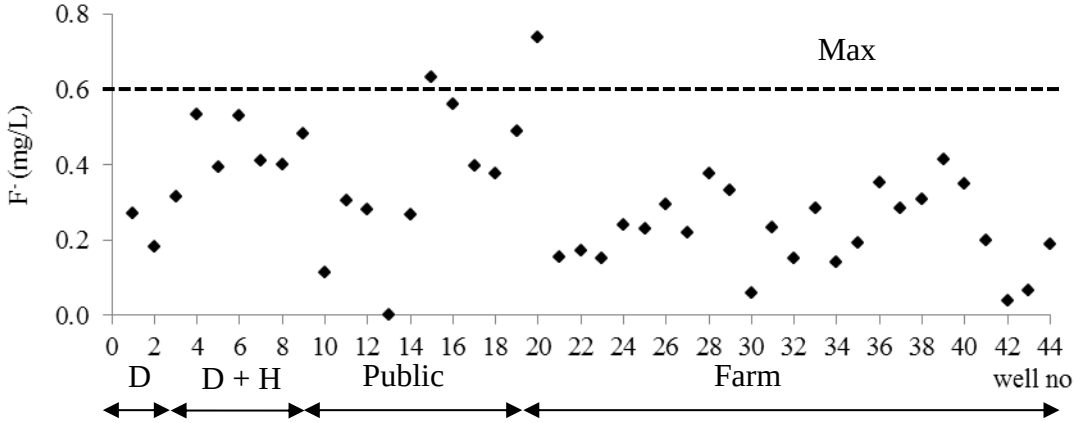
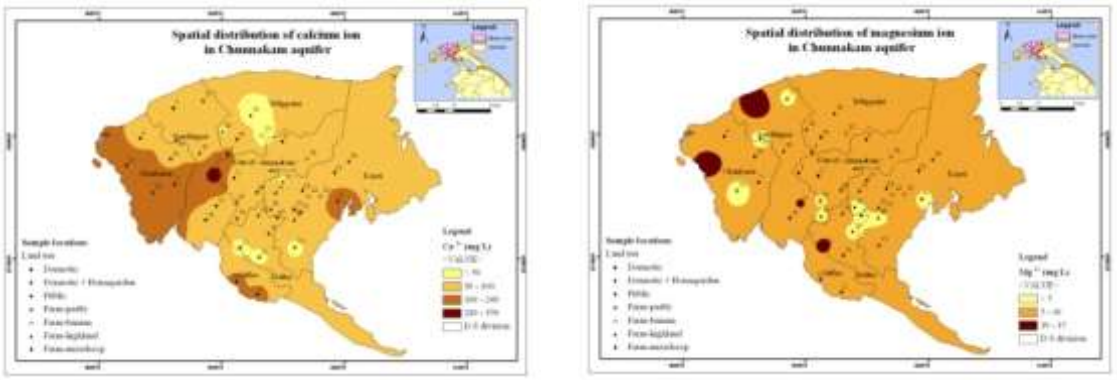


Figure 7 - Average concentration of fluoride ion

Calcium and Magnesium

The average calcium concentration varied from 50 to 340 mg/L. Based on average calcium concentration, 98% of the measured wells were below the SLSI guideline of 240 mg/L for drinking. The distribution of average concentration of magnesium in the studied area ranges from 5 to 25 mg/L. Figures 8a and 8b shows the spatial variation of calcium and magnesium ions during March 2011 in Chunnakam aquifer, respectively. The higher values of calcium by the end of wet season are observed near the coastal regions. The spatial variation of magnesium ion during March showed that all measured wells were below the SLSI guideline for drinking (140 mg/L).

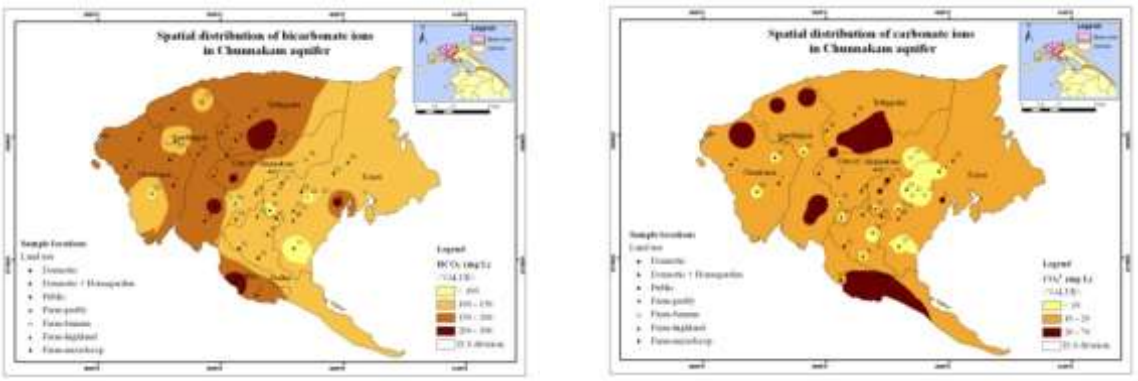


(a) (b)

Figure 8 - Spatial variation of Calcium and Magnesium ions

Bicarbonate and Carbonate

The average concentration of bicarbonate and carbonate values of selected wells varied from 100 mg/L to 350 mg/L and from 3 mg/L to 52 mg/L, respectively. The spatial variations of bicarbonate and carbonate for the selected wells during March were shown in Figures9a and 9b, respectively. Limestone aquifer is rich in carbonates. Hence waters flowing through limestone bring the carbonate to the groundwater which increases the alkalinity. Highly alkaline waters are unpalatable and may force consumers to seek other water sources.

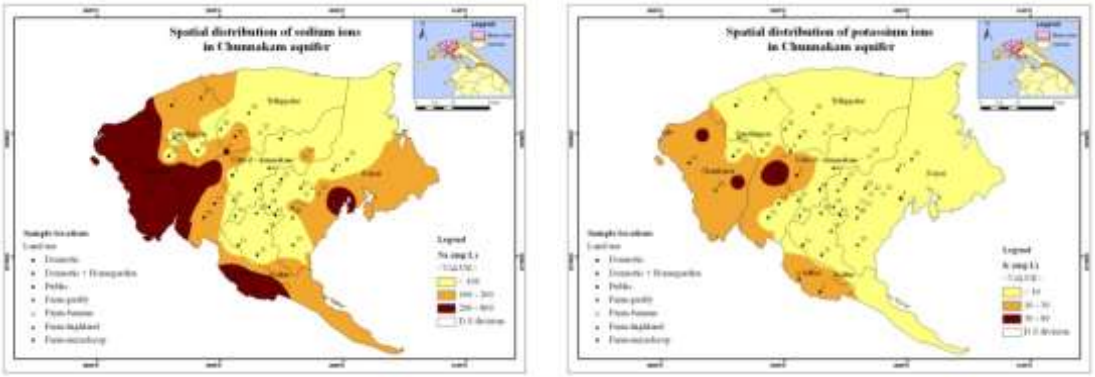


(a) (b)

Figure 9 - Spatial variation of bicarbonate and carbonate ions

Sodium and Potassium

The distribution of average concentration of sodium and potassium in the studied area ranges from 20 mg/L to 740 mg/L and from 0.5 to 112 mg/L. The spatial variations of sodium and potassium for the selected wells during March 2011 are shown in Figure10a and 10b, respectively. No health-based guideline value is proposed, however, sodium may affect the taste of drinking water at levels above about 200 mg/l (WHO 2011). The higher values of sodium are observed near the coastal regions of Chunnakam aquifer and could be related to seawater intrusion. The above result is similar to the spatial distribution of EC and chloride (Figure 3a and 3b).



(a) (b)

Figure 10 - Spatial variation of sodium and potassium ions

Crop Water Requirements (CWR) and Water Use

At the time of the study (March 2011), banana, cassava and cabbage were already established in the field. Tobacco and onion were found in late stages. No rainfall was obtained during the month of March 2011 in Jaffna Peninsula. Therefore, irrigation water is the only source for crop.Average depth of irrigation water (mm/day) was calculated for each crop and compared with the CWR. Based on this analysis, the amount of irrigation water applied by farmers was higher than CWR for each crop. Hence excess irrigation which ranged from 5.33 - 10.89 mm/day was found in Valikamam area in Jaffna Peninsula. This amounts to 131 to 229% application in excesses of the net water requirement.

Application of Nitrogen as inorganic fertilizer

From the questionnaire survey, the amount of nitrogen applied as inorganic fertilizer (mainly urea) for onion, carrot, cabbage, beetroot and tobacco were calculated. Application of excess nitrogen (kg/ha) was calculated from different between the average amount of nitrogen applied by farmer and the recommendation of nitrogen (kg/ha) for each crop except tobacco. Table 1 shows the excess amount of nitrogen application for each crop in the studied area.

Table 1 - Excess amount of nitrogen application for each crop

Crop	Avg. nitrogen Applied (kg/ha)	Recommended nitrogen (kg/ ha)	Excess nitrogen (kg/ha)
Onion	178.1	70	108.1
Carrot	230	150	80.0
Cabbage	142.6	150	-7.4
Beetroot	246	180	66.0
Tobacco	262.9	No recommendation	-

Based on this study excess amount of nitrogen as inorganic fertilizer was applied for onion, carrot and beetroot. Application of nitrogen was lower than recommended level for cabbage. Department of Agriculture, Peradeniya has no fertilizer recommendation for tobacco. Inorganic fertilizer application practices were decided by the farmers by themselves with their own experience. In addition to the inorganic fertilizer, farmers have been using organic materials such as biomass and cattle and goat excreta which are rich in nitrogen. Leachate of nitrate-N from these sources could have accumulated in these wells.Farmers have the practice of keeping cattle and goat in the field during off season. 66.7% of the farmers practiced paddock system with cattle's ranging from 1- 30. The excreta and urine of animals gets incorporated in the field thus resulting in high nitrate-N in soil.

Based on analysis of CWR and amount of nitrogen application for each crop, it can be concluded that the use of large quantities of inorganic fertilizers and manure together with excessive irrigation were considered to be responsible for the high nitrate content. In a survey carried out in 1982, three-quarters of the wells sampled had a concentration in excess of recommended guideline value of 50 mg/L nitrate and some were in excess of 175 mg/L nitrate (Nagarajah *et*

al., 1988). The study area contains red yellow latosol which is highly porous and having an infiltration rate of 430 mm/h conducive for the free leaching of nutrients to the shallow groundwater (Joshua, 1973).

CONCLUSION

High concentrations of nitrate–N and EC and low levels of fluoride were the identified drinking water problems in the study area. The level of nitrate-N concentration of water was influenced by cropping system as high nitrate-N concentration of groundwater was observed at high land crops land use followed by mixed crops when compared to banana and paddy.Based on this study excess irrigation and excess amount of nitrogen as inorganic fertilizer application were found at Valikamam area of Chunnakam aquifer in Jaffna Peninsula.Therefore, awareness should be created on the hazards due to the excessive use of chemical fertilizers in agriculture. Recommendations should be made based on continuous monitoring.

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The significance of addressing water related issues through a right-based approach in Sri Lankan context: Right to water

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BACKGROUND

Water is one of the nature's miraculous gifts for the entire creature; notably, mankind. Throughout the human civilization water has played afundamental role as a social and environmental resource in numerous fields such as agriculture, energy, health, biodiversity and ecosystems (Scanlon, Cassar& Nemes 2004). Particularly, in the modern context, water has been recognized as an economic assert in consequence of economic value in all its competing usages,while identifying it as an essential element to sustain life, development, and the environment (Dublin principles 1992).At the same time, water has to be considered as one of the limited and vulnerable resources of the world due to various reasons (Dublin principles 1992).Amongst them, the rapid increment in the demand for water parallel to the growing population and intensified development activities and the continuous water pollution can be highlighted. This vicious circle has resulted in impending the water crisis which has adverse impacts on all aspects of human life. Moreover, it would makewater one of the most endangered basic human needs for the present and future humanity. The emerging catastrophe can be logically pictured by the estimate that 'by 2025 about two thirds of the world's population-roughly 5.5 billion people-could be living in areas facing moderate to severe water stress' (UN, Fact Sheet No.35, p. 36).At variance withthe prevailing global situation, the estimates for Sri Lanka suggestthat 'water demand in 2025 will be less than half of the available water resources' (Samad 2005, p. 126).Being so, it has been predicted that fortunately, 'Sri Lanka will face slight or no scarcity, either physical or economic, even by 2025 in terms of water' (Samad 2005, p. 126). In view of this, Sri Lanka is apparentlyhaving satisfactory water resources per capita (Lanka Jalani).At the same time, Sri Lanka is relatively known as an island which well-endowed with water resourcesthat have developed a pleased hydraulic civilization for over 2000 years (Sri Lanka Environmental Foundation 2004, p. 41).

ISSUE ADDRESSED AND CURRENT STATUS

The above positive figures, nevertheless, should not be viewed from an optimistic standpoint. To be detailed, these positive implications, do not suggestthatthe country is free from any kind of water related malfunctions at present or in the future.Likewise, there is no sphere to be exclusive of taking water in exigent by the current generation of the country. This is due to the numerous water allied complications and premonitions therein, witnessed explicitly in the recent past through incidents that took place in the country and reports that have been put forward.

Amongst such water allied complications and premonitions, the most recent deliberated incident was the protests of farmers in North Central Province and other areas of the country such as Abilipitiya, demanding authorities to provide them with adequate water for their agricultural undertakings (ColomboPage News Desk 2012). According to the media reports farmers have claimed that although a drought is prevailing there was sufficient water for cultivation, which authorities were holding without releasing for paddy cultivation (ColomboPage News Desk 2012).Even though the accuracy of those allegations against the governmental authorities is a discrete issue which goes beyond the parameter of this paper, the gravity of those allegations cannot be undervalued in terms fulfilling their basic need of water on which their livelihood depends primarily.

In addition, the quality of the drinking water remains an issue island-wide. According to the latest UNICEF Sri Lanka briefing sheet on water sanitation and hygiene, 11 per cent of the total population of the country lack access to safe drinking water, while it is 35 percent in rural areas. As quantified by the Asian Legal Resource Centre (ALRC) in 2010, out of the 25 districts in the country, more than 15 districts are, in fact, affected from serious health problems resulting from unsafe drinking water. Hence,the lack of safe drinking water has been identified as another burning and life threatening problem of the country, particularly, in the Dry zone (Institute of Fundamental Studies 2012). As per its observations people in Dry zone face difficulties to access safe drinking water due to receiving their drinking water from the ground water sources which are contaminated with excess fluoride and hardness in the water. Consequently, extraordinary prevalence of chronic renal disease in the North Central Provinces has become one of the major health problems in Sri Lanka, while 50 per cent of schools going children areaffected with dental fluorosis (Institute of Fundamental Studies 2012). At the same time, industrial and agricultural waste and fertilizers are considered as the major causes for

contaminating of water sources of the country and this situation has led to create severe health problems amongst the people in those farming areas (ALRC 2010).

Apart from these manifest circumstances, numerous water allied complications prevailing in the rural areas of the country, notably in the Dry zone, have been frequently reported. Most of these complications can be identified as the ramifications of central problems such as lack of access to safe drinking water and the lack of proper supply of water in those areas. Amongst them, the repeatedly conveying difficulty is the need of walking long distances, possiblyquite a few times a day, in order to collect water from distant water points for fulfilling water demands of the family members livingin rural areas (Lanka Business Report2011).This troublesome and time consuming water collecting process characteristically involves the heavy burden of carrying water containers which exposes those who engage to illness like *hernia*, while precluding them using their time productively (UN, Fact Sheet No.35, p.13).

These incidences can be considered as the testimonies that reveal gradual evolvement of water as an issue which createssocial, environmental and economic complications at present and in the future Sri Lankan context. It is a tragic situation for the country like Sri Lanka which is 'known for rivers, lakes, monsoon season and has arich history in hydrology' (Lanka Business Report 2011). Being so, it is topical to find out the actual factors by which water is being thrust towards an issue which jeopardizes the long-lasting hydraulic civilization of the country.

Amongst such factors, temporal water scarcities arising out ofseasonal and regional water related variations can be initially identified as the foremost but provisional factorshave also createdwater complications in the certain parts of the country; namely,Dry zone and Intermediate zone. As already discussed, these districts of the country are currently undergoing serious water related social economic and health problems in contrast to theWet zone of the country. Nevertheless, due to the natural characteristic derived from the country's bimodal pattern of rainfall and geographical setting of such areas, these temporal water scarcities that are predominate during the dry spells have become one of the natural phenomenon that is accustomed to Sri Lankan folk culture. Being so, from ancient timesthe Sri Lankan community had employed a system through which this natural hindrance can be overcome by adapting to its underscored natural phenomenon.To be precise, from the bygone monarchism epoch the Dry zone and the Intermediate zone of the country have been equipped with various and numerous means such as lakes and reservoirs to accumulate the surface run-off water that 'remains from rainfall after evapotranspiration and infiltration losses' (Punyawardena 2004, p.16).Those ancient efforts which survived to this day were entirely focused on enabling the inhabitants of the Dry zone and Intermediate zone to efficaciously deal with the temporal water scarcity prevailing during dry spells (Punyawardena 2004, p.19).Following these footsteps even after gaining the independence a substantial amount of State investments had been assigned for the development of the water resources for irrigation, hydropower generation and domestic and industrial water supply (Bandara cited in Sri Lanka Environmental Foundation 2004), particularly focusing on the Dry and Intermediate zones of the country. In the Dry zone those efforts had been specially focused on storing run-off water for usage during dry periods in contrast to the efforts that had been oriented to supply water to places where it is not sufficient or available in the Wet zone (Punyawardena 2004, p.19).

The rationale of the above discussion firmly leads towards the assumption that the temporal water scarcities confronting the particular parts of the country is a natural phenomenon accustomed to the Sri Lankan context and a natural hindrance which can be overcome through proper governance of run-off surface water. Even though the situation is such, it is regrettable to see that inhabitants of the Dry zone and the Intermediate zone of the country, including their cultivations and livestock, are harshly suffering from temporal water scarcities, alongside other long-term aftermaths of the lack of safe drinking water such as water related health problems. Accordingly, the prevailing situation of the country, notably in the Dry zone and the Intermediate zone can be identified as a periodic water crises rather than a mere temporal water scarcity arising out of natural phenomenon accustomed to the Sri Lankan context.

Nevertheless, a vigilant academic inspection pertaining to the prevailing periodic water crises brings to mindthe fact that exterior reasons, in preference to natural reasons, havelargely influenced to metamorphose the temporal water scarcities into a periodic water crisis which has short-term as well as long-term negative effects in terms of social, economic and health. Even so, this assumption does not discard the impacts of global climate change on making water one of the threatened natural resources in the world, notably including 'South Asian countries that are likely to be exposedto more rain overall but paradoxically also to greater likelihood of spells of drought, while losing the predictability of seasonal rainfall patterns due to the change of monsoon patterns' (UNDP, HDR 2006 cited in Water Governance Facility Report No.1, p.8).

At the same time, the manner in which exterior reasons have taken priority over such natural variations and environmental changes in the process of transforming temporal water scarcities into a periodic water crisis in contemporary Sri Lankan context can be demonstrated through the already discussed incidents that took place in the country and reports that have been put forward.For instance, althoughdemands of farmers to provide them with

adequate water for their agricultural undertakingsis one of the short-term aftermaths of temporal water scarcity, it is undeniable that disappointments in governance of surface water management during the bygone dry spell has resulted in transforming such sensible demands into a widespread series of protesting which led to dispensable uprising against the governmental authorities. Likewise, the extraordinary prevalence of chronic renal disease in the North Central Provincehas been identified as one of the repercussions of reckless practices of farmers in these areas regarding agricultural waste and fertilizers such as 'usage of fertilizers combined with the use by farmers of toxic fertilizers in coconut plantations and rice paddies' (ALRC 2010 n.p.). On the other hand, the failure on the part of the State to establish 'properly functioning State monitoring mechanisms for the usage of fertilizers' has been identified as the main reason which has allowed those reckless practices to continuously abide by the framers of those areas (ALRC 2010 n.p.).Furthermore, the problem of collecting water from distant water points to fulfill the domestic water demands, depending on unsafe local sources and surface water bodieshas been pointed out as a regrettable consequence of failure on the part of 'National Water Supply and Drainage Board which has been vested with the responsibility of providing the safe drinking water through pipe-borne water coverage throughout the country' (ALRC 2010 n.p.).

Accordingly, the contribution made by the failures and underperforms of the country's relevant water authoritiesand the unsustainable, as well as reckless community practices to make water one of the vulnerable resources in the Sri Lankan context can be figured out. Consequently, on one hand, it is realistic to comprehend the influence of exterior reasons pertaining to water sector, in preference to natural phenomenon,on making the water an issue which creates social, health and economic complications, both present and future Sri Lankan context. On the other hand,this comprehension reflects the impact of the failures that stem from governance of the water sector in impending water crisis which hasa bulk of negative effects on every aspect of the Sri Lankan milieu. The latter postulationcan be further rationalized by the following scenario which reflects the crisis related to governance of drinking water sector. To be detailed, the actors involving in the contemporary drinking water sector of the country mainly include, the Ministry of Water Supply & Drainage, the National Water Supply and Drainage Board, Provincial Councils, Local Authorities (Municipal Councils, Urban Councils, and Pradeshiya Sabhas) and Community Based Organizations. At the same time, this outspread intuitional reticulation is functioning upon the national policy on drinking water which considers 'safe drinking water as a key factor contributing towards the overall economic and social development of the country, while seeing access to safe drinking water as an inalienable right of the people' (National Policy on Drinking Water, updated 2009). Moreover, all of these governmental actors are sustained by distinct pieces of legislations which separately demarcate their responsibilities and jurisdictions. Notwithstanding the presence of such enriched intuitional reticulation, by considering the best policy entourage and extensive legal background, as well as the availability of rich natural and manmade water resources, drinking water still remains an issue island-wide which pressurizes 11 per cent of the total population of the country as a result of lack access to safe drinking water, while it is 35 percent in the rural areas (UNICEF Sri Lanka).

By means of the aforesaid scenario, the impact of the failures stemming fromthe governance of the water sector on the impending water catastrophe in the Sri Lankan context can be rationally pictured, while providing an overall depiction which is common to the entire water sector of the country.Accordingly, the notion being disseminated in the international arena as to '(global) water is, in fact a crisis of governance' is pertinently suitable to describe the current water related complications prevailing in the country notably, including the situation inDry and Intermediate zones(Lanka Jalani; Second UN World Water Development Report cited in UNESCO 2006). This is for the reason that, almost all the manifesting water related complications in the current Sri Lankan context mainly reflect theaftermaths of letdowns inthe governance ofthe water sector rather than the unavailability or the scarceness of the water resources in the country.In other words, most of the water complications in the country can be considered as repercussions of the failures that stem from the governance in water sector in different avenues which have intensified the water related impacts of adaptable natural and environmental phenomenon as the disparaging external reasons therein. At this point, it is fundamental to have an indication about the governance at large, to properly understand the state of affairs described by the term of 'crisis in governance' of the water sector. Principally, the term governance means the 'process of decision-making and the process by which decisions are implemented or not implemented' (Wikipedia 2012). Accordingly, it can be deduced that the amplified water related complication in the Sri Lankan context virtually as the consequences which stem largely from the letdowns of the process of decision-making and the process by which decisions are implemented or not implemented in the water sector rather than the outcomes of adaptable natural and environmental water related phenomenon. Nevertheless, this assumption does not thrust aside the huge pressure that has been placed upon the available water recourse by the steady growth of population and the intensified development activities of the country.

To the extent thatthe Sri Lankan situation is mainly considered as a crisis in governance,the first and the foremost solution by which it can be overcome is the establishment of good governance in the water sector.This is largely due to the general assumption that good governance is the finestmethod to evade the bad governance which has lead towards the crisis in governance within a particular sector.In addition to the competency of dealing with the crisis in governance, the potential of the good governance to contribute towards meeting the constantly increasing water demandhas been identified internationally alongside with the element of managing the available water resources (Second UN World

Water Development Report cited in UNESCO 2006, p.3).However, the later element that focuses on the management of the available water resource is not within the crux of this paper since it deals with the issue of equitable allocation of scare water recourses through a human right based approach which entails sound water governance (Water Governance Facility Report No.1, P.11).Quite the reverse, the next part of the paper considers the significance of addressing water related issues througha right based approach, as a mean by which the concept of the good governance can be realized within the water sector, while diminishing the prevailing crisis therein.

Nevertheless, this discussion has to be started by mentioning a major failure of global human right agenda that happened in the twentieth century (Scanlon, Cassar & Nemes 2004). To be precise, water has not been directly referred to as a self-standing human right in the framework of leading international, as well as legally binding human right conventions(Scanlon, Cassar & Nemes 2004). Correcting this failurethe United Nations General Assembly recently adopted a resolution which explicitly recognizes water (and sanitation) as a human right (Resolution No. 64/292 2010).Even before this adoption, Kofi Annan, former United Nations Secretary-General, has very clearly stated that 'access to safe water is a fundamental human need and, therefore, a basic human right' (UN 2001).At the same time, it has been always acknowledged that safe drinking water is the birthright of all humankind – as much a birthright as clean air (Third World Academy of Sciences 2002) notwithstanding its precise repudiation as a self-standing human right by leading international human right covenants. Consequently, it can be firmly deduced that the human right to water does exist since water is one of the most indispensible components of human lives. Being so, the fact that water had not been manifestly demarcated within the international human right law and it had not been expressly acknowledged as a fundamental human right; does not set up legal hindrances upon the people of the world to invoke water as one of their fundamental human rights. However, its repudiation as a distinctive self-standing human right creates legal difficulties to directly access legal remedies by the victims of water pollution and people who are deprived of necessary water for meeting their basic needs. This is largely due to the prerequisite of linking water related allegations with another related human right or rights such as right to life, food and livelihood in order to establish the violation that have taken place or imminent infringement of their water rights. In other words, sufferers of water related problems have to 'lift their right to water from the shadow of other associated human rights'(Scanlon, Cassar & Nemes 2004).This circularity results in preventing the aggrieved parties from gainingdirect allegations on water issues,while weakening the enforcement competency of water rights as an independent and self-standing right (Scanlon, Cassar & Nemes 2004).

At variance with the universal human rights framework, certain countries have taken a farsighted verdict to directly protect water as self-standing fundamental right which is guaranteed by their national Constitutions such as Zambia (Art.112, Constitution 1996) and Gambia (Art.216 (4), Constitution 1996). Amongst them, Section 27 of South African Constitution (1996) can be highlighted as a sound constitutional provision which has explicitly enshrined the right to access sufficient water, while leading toward the ascendant of rich fundamental right jurisprudence on water rights at the national level.Most of the other national Constitutions of the world have referred to the fundamental right to clean and healthy environment (Scanlon, Cassar & Nemes, Appendix I, 2004). These references can be connoted as an indirect recognition of right to water by the national Constitutions as it is irrefutable that water is an integral pillar of the entire environment.

Even though Sri Lanka cannot be categorized under any of these two benchmarks, as already mentioned, the country's policy entourage has taken a right based approach at least towards the basic factor of water, that is to say drinking water (National Policy on Drinking Water, updated 2009). In addition, the directive principles of State policy and fundamental duties of the Sri Lankan Constitution (1978) have explicitly recognized the duty of the State to protect, preserve and improve the environment for the benefit of the community (Article 27(14)) and the corresponding fundamental duty of every person in Sri Lanka to protect nature and conserve its riches (Article 28(f)). These constitutional provisions can be considered as indirect connotations that have empowered Sri Lankans with water rights and corresponding duties therein, since water constitutes an integral part of the environment. In particular, the Sri Lankan Supreme Court also has played an imperative role in addressing water related issue in a right based approach in a legal context where even the right to life has not been expressly recognized by the Constitution (Chapter 3, 1978). The best known example is the broadminded approach taken by the Supreme Court in the case of H.B.Dissanayake vs. Gamini Jayawikkrma Perera (Thuruvilla Case S.C.F.R.329/2002), while complying with the ongoing judicial tendency of recognizing water as a fundamental human right of people which is mirrored by the progressive judicial decisions such as Subhash Kumar vs. State of Bihar (1991) AIR SC 420, delivered by the Indian Supreme Court and Bon Vista Mansions v. Southern Metropolitan Local Council, the South African (2003) 120 SALJ 41, delivered by the South African High Court.

The rationale of the above discussion perceptibly divulges the legal inclination both at national and international level toward framing and beholding water in terms of rights, rather than its conventional understanding as a basic human need. However, before discussing the manner by which beholding water from the viewpoint of right facilitates the good governance in water sector, it is noteworthy to identify the significance of addressing any particular issue in a right based approach at large. Essentially, it results in assimilating the norms, standards and principles of the international human

rights system into the plans, policies and process of matter that are being beheld from the viewpoint of rights and thus, elements such as accountability, empowerment, participation, non-discrimination and attention to vulnerable groups becomethe cohesive components of all actions regarding that particular issue (UN, Fact Sheet No.35, p. 15; Water Governance Facility 2012, p. 11).

This general perception provides an appropriate ingress to feature the basic outcomes of framing the water in terms of rights rather than a basic human need. Initially, it posits the existence of substantive right to water (Water Governance Facility 2012, p. 11; Scanlon, Cassar & Nemes 2004, p.28) which cannot be taken away from the people, since human rights are formulated in terms of the rights of individuals. Consequently, individuals become the holders of water rights, while simultaneously making the State the duty-bearer (Water Governance Facility 2012, p.11). Accordingly, substantive right to water has resulted in making accessibility to sufficient quantity of safe water as a legal entitlement of every individual instead of a privilege, while precluding water is considered as a mere commodity or a service provide on a charitable or welfare basis (UN, Fact Sheet No.35, p. 15). In addition, it posits the existence of corresponding obligations on the part of a duty-bearer basically; the State (Water Governance Facility 2012, p.11). These correlative obligations are of vital significance to build a relationship between right-holders viz. individuals and group with valid claim and duty-bearer in terms of water, while outlining the obligations of governments to respect, protect and fulfill the progressive realization of water rights (Scanlon, Cassar & Nemes 2004, p. 28; Water Governance Facility 2012, p. 11; UN, Fact Sheet No.35, p. 15). In particular, framing the water in terms of rights inherently results in equipping the right-holders with numerous procedural rights such as right to information on water, right to participate in decision-making process in water and right to judicial redress and etc. (Water Governance Facility 2012, p.11). These procedural rights are of vital significance to materialize the water right meaningfully at the pragmatic arena and to empower the right-holders to claim their legal entitlements pertinent to water, while highlighting their needs and priorities without subjecting to any kind of discrimination.All in all, framing water in terms of rights has been identified as an 'effective methodology' to enable victims of water pollution and people who deprived of necessary water for meeting their basic needs to exercise their rights, while enabling the State and other relevant duty-bearers to meet their obligation. (Water Governance Facility 2012, p.12). This conclusion orientates the paper towards its main crux; the manner by which framing the water in terms of right facilitates good governance in the water sector. At this point, it is essential to mention the major characteristics of which good governance is composed, while understanding them as a set of guideline describes the way that 'public institutions should conduct public affairs and manage public resources to guarantee the realization of human rights' (Wikipedia 2012). The concept of good governance consists of eight major characteristics (UNESCAP).These are participatory, consensus oriented, accountable, transparent, responsive, effective and efficient, equitable and inclusive and follow the rule of law.The next part of the paper serves a conceptual framework which demonstrates the extent to which these characteristics can be materialized by beholding water from the viewpoint of rights.

As already demonstrated, framing water in terms of rights theorizes the existence of a substantive right, as well as a legal entitlement pertaining to water as opposed to the existence of a mere privilege therein.On one hand, this postulation is of vital significance to formulate the foundation for fair legal frameworks on water. The presence of such fair legal frameworks has been identified as one of the essential prerequisites to satisfy the characteristic of rule of law in the context of good governance (UNESCAP). On the other hand, the above postulation results in bringing about right-holders those who can legitimately claim the water rights at the pragmatic arena. This bringing about results in stimulating the enforceability of water laws, while satisfying the other prerequisite of the characteristic of rule of law in the context of good governance; namely, the impartial enforceability of the fair legal frameworks (UNESCAP). Nevertheless, the accomplishment of the element of impartiality requires an independent judiciary (UNESCAP). Correspondingly, the enforcement of the water laws results in making duty-bearers, virtually government bodies, 'responsible for not getting in way of the realization of the water rights, not allowing others to interfere with the realization of water rights and facilitating the realization of the water rights' (Water Governance Facility 2012, p.10). As one of the consequences of these widespread and undeniable responsibilities, the relative government bodies have claimed to attempt serving all stakeholders in the water sector within a reasonable timeframe by crystalizing the characteristic of responsiveness in the concept of good governance (UNESCAP). As the second consequence, the relative government bodies are legally required to produce 'results that meet the needs of current society, while making the best use of resources at their disposal' thereby materializing the component of the effectivenessof good governance (UNESCAP). At the same time, framing water in terms of rights results in simultaneously making the State trustee of the water resource, instead of the owner, who held and uses this miraculous natural resource for the benefit of the people. This phenomenon which leads toward the 'public trust doctrine' is crucial to materialize the component of efficiency in the context of good governance which stands for sustainable use of natural resources and the protection of the environment (UNESCAP). In particular, framing water in terms of rights is of utter importance to materialize the characteristic of accountability (UNESCAP), which is one of the key requirements of establishing good governance in the water sector. Because its legal outcomes which lead toward the positing a substantive right and legal entitlement pertinent to water results in subjecting the State to widespread and undeniable legal responsibilities on water, while making the State trustee of the water resource. This enormous commitment compels 'State to give details of what it is doing and why, and how it is moving towards the

realization of the right to water for all, as expeditiously and effectively as possible' (UN, Fact Sheet No.35, p. 38); leading towards the crystallization of the characteristic of the accountability in the concept of good governance.

As already mentioned, framing water in term of rights does not posits only the existence of substantive right therein, but also empowers the right-holders with numerous procedural rights pertaining to water. Amongst them right to participate guarantees the direct or indirect involvement of the people in the process of decision making on water at the national and community levels who will be affected by such decisions and their enforcement. This assurance is of vital significance to make real the cornerstone of good governance i.e. participation. At the same time, equality amongst the participants can be also preserved since non-discrimination is one of the cohesive components of right based approach. Suchconstructive participation facilitates the reflection of concerns of vulnerable groups in the society, while ensuring the equal participation of both men and women in the process of decision making, as expected by the concept of the good governance per se.At the same time, such constructive participation ensures the preserving the inclusiveness in the water sector, while crystalizing another characteristic of the concept of good governance. This is for the reason that, such non-discriminative participation of all groups in the society on equal basis ensures that members feel that 'they have a stake in their society' mainly, in the water sector instead of the feeling and the reality that they are excluded thereof (UNESCAP).On the other hand, founding the equality and inclusivenessinthe water sectordirectstoward therealization of the other characteristic of the good governance that is consensus oriented. It emphasizes the 'mediation of the different interests in society on what is in the best interest of the whole community and how this can be achieved' (UNESCAP).The materialization of the characteristic of consensus oriented in the water sector is of utter importance within societies where numeral community groups such as farmers, fisherman and etc. upholds strong, longstanding and traditional linkages with water; likewise in Sri Lanka. In addition, in the context of good governance participation needs to be informed (UNESCAP). The realization of this attribute can be facilitated by the right to information which consists in the package of procedural rights derived from framing water in terms of rights.Because the right to information guarantees equipping the participants of the decision making process of water with sufficient and understandable information on water related issues and this empowerment results in making them cognizant participants who lead the process towards the rational decisions. On the other hand, the right to information poses a voluminous potential to make real the other component of good governance i.e. transparency (UNESCAP). Because in the context of good governance the characteristic of transparency represents the notion of free availability, adequate information and the direct accessibility through an understandable forms and media, whilst it boldly means that decision taken and their enforcement are Implemented in a manner that follows rules and regulations (UNESCAP).

All in all, the discussion on the main crux of the paper can be concluded by determiningframing water in terms of rights as one of the best deceives which can be employed to insist on good governance in the water sector in terms of law.Because, the main two intrinsic worth of approaching water through a right based approach i.e. theorizing a substantive right to water and positing bundle of procedural rights therein, is of utter supportive to make real the almost all characteristics of the concept of good governance at the pragmatic arena, whilediminishing the failures and letdowns of governance in the water sector which generate the crisis in governance therein.

RECOMMENDATIONS FOR CONSIDERATION AND PREDISPOSING

Accordingly, the first and the foremost recommendation of this paper is to frame water in terms of rights in the Sri Lankan context, which is currently hampered by the numerous water related complications that have resulted from crisis in governance of the water sector, rather than the respective natural reasons. For that purpose, it is essential to recognize water as a self-standing fundamental right protected under the Chapter 3 of Sri Lankan Constitution (1978), which can be enforced through national protection mechanisms of fundamental rights.

Potential benefits of recommendations to sector and country

Even though this recommendation is not free from pragmatic difficulties which are common to every workable solution its potential benefits to the water sector and to the country as a whole, it can be highlighted depending on three factors. Initially, the recommendation of framing water in terms of fundamental rights is of vital significance to serve as a conceptual input which disseminates a productive water discourse at national level for future legal developments in a social context where water is gradually emerging as a cause for social and health glitches. Secondly, addressing the preliminary water related issues viz. personal and domestic water uses through a right based approach under the caption of 'right to water' (ECOSOC General Comment 15 2002) propounds the conceptual platform to evolve the right-based approach towards large scale water issues such as management of water recourses, providing water for agriculture or pastoralism and sustaining ecological systems. Thirdly, framing water interms of fundamental rights results in empowering the victims of water pollution and the people of the country who are deprived of necessary water for meeting their basic needs with the legal remedies which can be achieved through the judicial redress, while representing an instrument for civil society to hold government accountable for ensuring access to sufficient, good-quality water for the citizens (Scanlon, Cassar&Nemes 2004).

CONCLUSION

The papers concludes empathetically highlighting the need for framing water in terms of rights and addressing water related issues througha right based approach in the Sri Lankan context as a methodology by which prevailing crisis in governance of the water sector can be withdrew, while founding the good governance therein. This legal mission not only ensures the water makes reality for every Sri Lankan, but also guarantees the legal support towards the widely held outpouring all over the world demanding that 'no one should be denied the life that water provides' (Davidson-Harden et al,p.5).

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Degradation of the Maha Oya vital ecosystems and its impactson the communities

Chamila Weerathunghe

ABSTRACT

Water resources in a country are of vital importance to the social, economic and environmental health of a country, thus rivers play a crucial role in providing freshwater to the myriad of needs of the communities living by, ecosystems dependent on and add intrinsic value to the nature. Rivers are associated with very important ecosystems including riverine, estuarine and coastal environs whose good health and sustenance are dependent on a number of factors including pressures and stresses exerted by anthropogenic activities.River sand mining is one of such stresses upon rivers in many countries; many of Sri Lankan rivers are adversely impacted due to the indiscriminate river sand mining. The Maha Oya is one of the perennial rivers in Sri Lanka, which is the 7th largest river in terms of the catchment size. The Maha Oya has been subject to excessive river sand mining since late 1980s, owing to the escalating demand of sand with the boom of construction industry catalyzed by the free economic policies adopted by the government of Sri Lanka in late 1970s.

The midstream and the downstream are severely degraded due to these detrimental activities; the impacts are twofold as impacts on the riverine environment and impacts on the coastal environment. Riverine impacts include river bank erosion, salinity intrusion to the river deteriorating the water quality and the loss of bio diversity of the aquatic ecosystems and associated riverine and estuarine wetlands, lowering of the river bed and consequent impacts on the lowering of water table and ultimate degradation of the river.

Impacts of the coastal environment are more deleterious to the coastal communities, not many people link the river sand mining to erosion of coastal stretches around the Island. But the Maha Oya context provides a classic example, the coastal stretch from Kochchikade to Chillaw which is being nourished by the sediment transported by the Maha Oya is severely eroded displacing thousands of people along the coastline creating a number of socio economic issues.

The existing devastation is enormous, it might take decades to regain the minimal originality back in to the system in the absence of any stresses. However, in the absence of systematic and integrated approach in addressing this problem by the responsible authorities, the root cause to all this havoc- sand mining is in persistence. A few non-governmental institutions try to address this issue by raising awareness among stakeholders and bringing the issue of sand mining in to forefront in decision making process of mandated authorities. However, their endeavours are short term and in the absence of a prolonged persisting machinery to act upon, piecemeal treatment is not sufficed since the issue is grown to a state that no simple solution does exist. An integrated approach which includes both top down and bottom up mechanisms is necessary. Policy changes from the government authorities should promote alternatives for sand and regulate the mining activities whilst grass root level work should account illegal mining activities and provide alternative livelihoods for people whose income earning activities are jeopardized due to regulation of mining. Stakeholder participation and action is the key for redress in reviving the damaged ecosystems associated with the Maha Oya.

INTRODUCTION

Water is a basic need for the survival and well being of both biota and abiota in the planet. It is one of the determinant factors in deciding the life on a particular locale. Water resources in a country are of vital importance to the social, economic and environmental health of a country, thus rivers play a crucial role in providing freshwater to the myriad of needs of the communities living by, ecosystems dependent on and add intrinsic value to the nature. Rivers start from a catchment inland and end up in ocean after traversing a distance that can vary from tens to thousands of kilometers. While traversing, rivers are subject to a number of stresses posed by humans, which cause detrimental impacts on the health of river associated ecosystems. These adverse impacts deprive valuable ecosystem services to the communities dependent on them.

Sand is one of the minerals extracted from rivers as a raw material, mainly for the construction industry. The significance of sand for construction industry lies where it is barely with any alternatives. Sand mining is one of the traditional livelihoods of the people lived along rivers; artisan mining did not disturb the harmonious existence of man and the river.

With the escalating population and,especially due to economic development and resultant growth in the construction industry, the demand for sand kept on increasing since early 1980s. The booming demand for sand paved the way for a very lucrative enterprise; a number of non-traditional sand mining groups entered into the industry and launched their businesses in commercial scale. Clay being another raw material which is found abundance along Sri Lankan rivers due to their geological associations with rivers, river sand mining and allied clay mining using machinery generated high profits to entrepreneurs. The climax of this enterprise was reached in late 1990s and as a result, not only sand deposits in river beds, banks of rivers and associated inlands have been subject to mechanized mining. Consequently, there have been a number of adverse impacts on the environment linked to the rivers, jeopardizing the services of riverine, estuarine and coastal ecosystems.The impacts of river sand mining are twofold as impacts on riverine environment and impacts on the coastal environment.

River sand mining has been identified as one of the principal reasons of coastal erosion by scientists (Western Sector River Basin Project; CCD; OUSL). Rivers transport sediment to nourish the beaches washed away by the natural wave action of the sea. Sand mining from rivers deprives the full load of sediment being transported to beaches, eventually consequent in loss of sand equilibrium in beaches and erosion of coastline. There are a number of implications associated with erosion of coastline; it's not only an environmental problem, but also gives rise to a number of socio-economic issues including loss of properties and houses, loss of livelihoods, loss of valuable lands among other things.

Impacts on the riverine environment are multifold; obvious ones include river bank erosion and loss of land, deepening of the river bed and consequent salinity intrusion to the river, lowering of the water table and changes in the river morphology which might trigger changes in hydrological parameters as well.

The Maha Oya

Maha oya is one of the largest rivers in Sri Lanka, with a catchment area of 1,528 km^2 and a stream length of 130km. It covers 4 provinces, 5 districts and 24 Divisions [Rathnayake, 2005]. It starts from Nawalapitiya and Aranayake area and falls in to the sea from Kochchikade, north of Negombo. The average run off of the river is 1.54 km^3 [Amarasinghe and Mutuwatte, 1999].

Nearly 1.1 million of population is living by the river, harnessing myriad of benefits from the river. The livelihood activities they engage in are diverse as agriculture, manufacturing, construction and other services. The land use of the river varies in upstream, midstream and downstream areas [Rathnayake, 2005]. The upstream is a hilly terrain with high rainfall, the land use being the tea and rubber plantations, forest gardens and home gardens. The midstream land use is again rubber and small scale coconut plantations and home gardens. In the downstream, there are more productive coconut plantations, rain fed paddy cultivation and brick and tile manufacturing. The river associated mineral extraction such as sand and clay mining is more prominent in the downstream especially in Kurunegala, Puttalam and Gampaha districts. There are 14 National Water Supply and Drainage Board water intakes along the Maha Oya, some of the important water users are Katunayake International Airport, Katunayake Export Processing Zone, Kegalle UC, Negombo MC, Mawanella PS and 04 other industrial parks (NWSDB). In addition, the riverine ecosystem harbours migrant birds in April and May season and rich biodiversity exists in the associated ecosystems of the river and estuarine.

DATA AND METHODOLOGY

The findings and information revealed and discussed in this paper has been generated during the Mangroves for the Future initiative funded project on the Maha Oya, which was implemented by Environmental Foundation from October 2009 to December 2011. For several scientific investigations, primary data has been generated at the field level as well as through literature reviews. Further data generated at field by other projects has also been used. Information garnered through stakeholder interviews as well as through direct observations has been used. Under each section of the discussion, the source of the data has been mentioned.

DEGRADATION OF THE RIVERINE ENVIRONMENT

The degradation associated with river sand mining on the riverine environment is multifaceted. Direct observations have been carried out under the MFF funded Maha Oya project for two and half years and some of the river related measurements have been taken under research work carried out thereof. The directs impacts of the river sand mining in the Maha Oya are river bank erosion, change in the river morphology and resultant changes in the flow patterns, water quality deterioration of the river due to salinity intrusion in to the river and contamination of the ground water with saline water and lowering of the water table. There are many implications of these impacts on environment and communities.

The exact mechanism of how river sand mining causes erosion of river banks is not established, it has been evident that erosion of river banks are exacerbated by indiscriminate sand mining in rivers (MFF funder Maha Oya project). River bank erosion has been quite an issue in the downstream and midstream of the Maha Oya since 1980s. The erosion has been

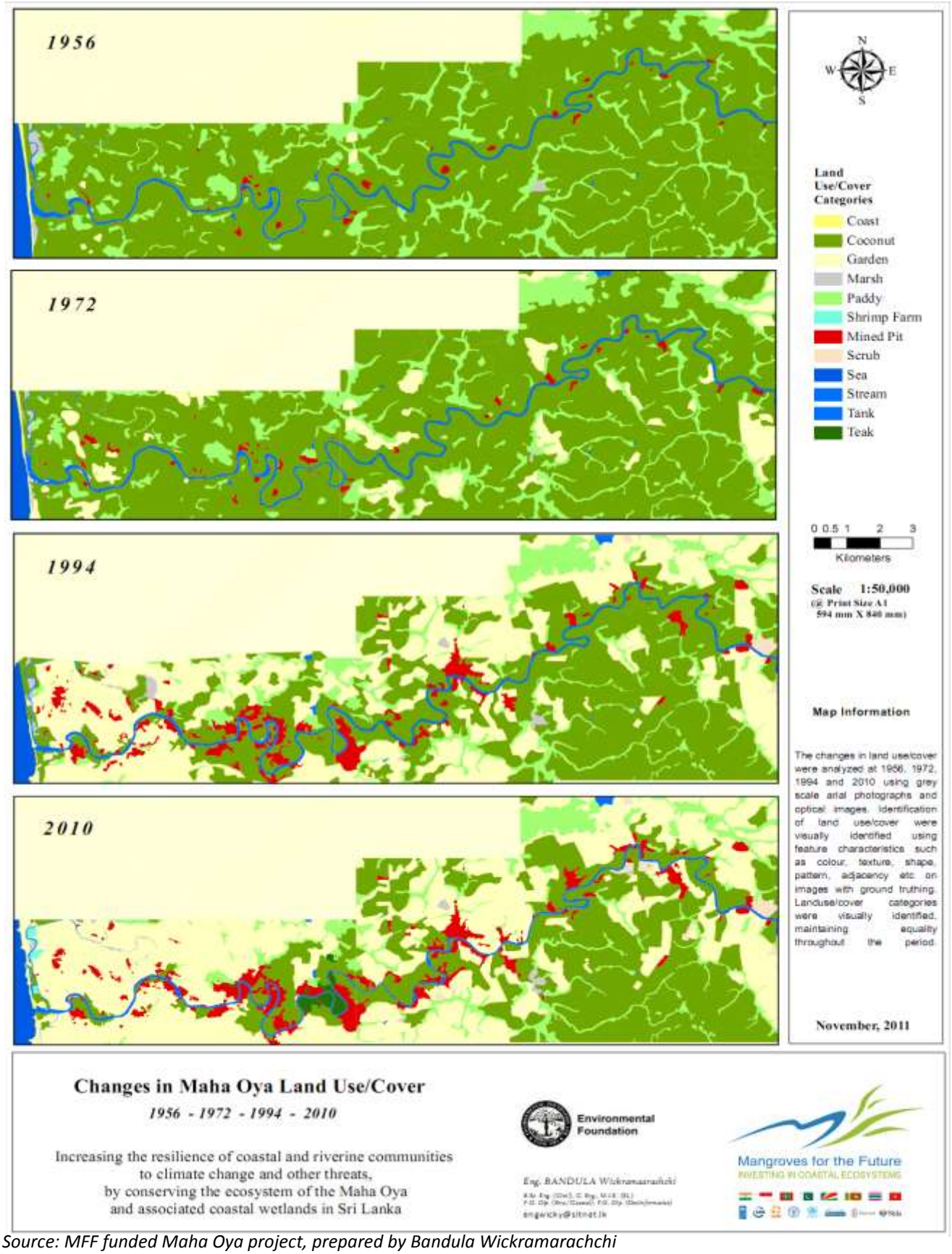
fairly obvious in both banks of the downstream of the river. In addition to erosion triggered by extraction of sand from the river,the river banks have been subject to mining activities due to their rich composition of both sand and clay.In the Maha Oya context, erosion of banks has caused widening of the river and loss of lands to the families who owned land adjacent to the river. Displacements have not been recorded; however, nearly 20 families within the first 10 km of the river from the downstream complained that they have lost portions of their lands.In comparison to the damage caused to river related infrastructure, loss of individual properties is negligible. The Badalgama bride is on the verge of washing away; during past 15 years, the bridge has to be repaired several times in order to mitigate the impacts of erosion on the bridge (RDA, Negombo). The bridge at Kochchikade has also faced an issue with stability, the scale is less severe than that the case of Badalgama bride. The road driven parallel to the Maha Oya from Kochchikade to Madampella has also faced the same danger; erosion of the left bank of the river has reached to the road itself. The Roads Development Authority had not estimated the damage to this infrastructure as per the data of 2011 November, but estimations would be much higher than the value of sand extracted over past two decades from this area. The other implication is that the government has to incur these expenses on repairs, which would otherwise be spent on other development activities benefitting the communities.

Change in the river morphology is associated with river bank erosion, at the same time mined pits contiguous to the river has caused changes in the river morphology.A comprehensive analysis work has been carried out by the MFF funded Maha Oya Project to analyse the changes in river morphology using Aerial images and Google Earth images and it was concluded that no considerable natural changes in river morphology has not been taken place during the period from 1956 to 2012 whereas most of the changes are attributed to anthropogenic interventions. The change in the river morphology has a number of implications on the ecosystems and the communities of the Maha Oya. Due to change of the river flow direction, the environmental conditions there are also in the process of changing. The nature of ecosystems gets changed adapting to the changing conditions of the river flow. The community responses to inquiries on floods in the downstream of the river provided evidence that flash floods after heavy rainfall have been more frequent in the recent years. There was an incident that a person drowned in a mined pit, filled with water to the brink and died.

As per Figure 1, the change in land use as a result of inland mined pits is quite visible over the years. This would have otherwise been the useful land for other productive purposes. Abundance of such mined pits in both sides of the riveris quite observable. These mind pits filled with water give rise to mosquito outbreaks and are not aesthetically appealing. They cause land degradation reducing the market value of such land. One of such inland mined pit has been the unofficial garbage dump of Negombo Municipal council since 1999, causing a number of environmental and health issues to the families living closer by.

Deepening of the river bed causes sea water intrusion in to the freshwater systems causing degradation of freshwater aquatic ecosystems. At the same time, community use of the river is hindered due to increased salinity of the river. The Bambukuliya water intake which supplies water to Bandaranayake International Airport, Katunayake Export Processing Zone and Negombo city is located about 4 km away from the mouth of the river. High salinity concentration increases cost of treatment of water to a considerable degree; in 1984 National Water Supply and Drainage Board (NWSDB) constructed a salinity barrier across the river spending about LKR 200 million, in order to prevent salinity intruding in to the upstream of the river (Data: NWSDB). Higher salinity concentrations have been recorded along the river from the river mouth up to the barrage at Bambukuliya (MFF funded Maha Oya project). Higher salinity levels in the river water causes salinity intrusion in to the ground water causing increased salinity levels in the wells closer by. It has been recorded by informal interviews with several community groups that a few wells have been abandoned due to high salinity levels.

In addition to the salinity intrusion, the only treated water storage tank of the Bambukuliya water intake was in the danger of losing its stability due to illegal mechanized mining in the adjacent land. Interventions of Environmental Foundation through the MFF funded project and legal case filed against illegal mining took actions to interrupt these mining activities and rehabilitated the area at the own cost of the person who carried out mining in the area. If the Water Storage tank of the Bambukuliya Water Intake had collapsed, there would not have been water supply to Bandaranayake International Airport and Katunayake Export Processing Zone consequent in huge economic losses. This is one single example to catalyse the thinking that indiscriminate mining activities can unintentionally resultant in huge losses in terms of financially, environmentally and/or socially.



Source: MFF funded Maha Oya project, prepared by Bandula Wickramarachchi

Figure 1 - Temporal variation of distribution of mined pits and changes in riverine land use

The bathymetric survey carried out by the MFF funded Maha Oya project has provided information that the existence of mined pits in the river with the depth of 60m. Salinity is accumulated in these deep mined pits deteriorating the quality of water in the river. There is another death of a person recorded in 2010, drowned in one of these river mined pits.

Widening of the river has other adverse implications including lowering of the water table. Water table in a riverine environment is a function of many parameters which includes rainfall, evaporation and width and the depth of the river (OUSL). When the river sand is mined out, it causes increasein river depth and width which consequent in lowering of the water table which has a number of adverse impacts on communities. Many families complained that they had to dig their wells time to time in order to reach the water table where as some people have abandoned their wells. This situation is more aggressive in the areas of 10-15 km away from the river mouth, specially in Godigamuwa area. In that area, nearly 100 families have either abandoned or dug their wells deep in order to reach the water table.

In the case of the Maha Oya, the degradation of the riverine environment is rather observable and it's the under-privileged communities who have been affected from the environmental degradation. The ecosystem services are retarded to a greater extent depriving communities the luxury of healthy environmental conditions; many people have been affected by river bank erosion, salinity intrusion to the river and lowering of the water table. The government has to incur additional expenses for repairing damaged infrastructure, constructing the salinity barrier and in other indirect ways such as increased health sector expenses.

DEGRADATION OF THE COASTAL ENVIRONMENT

Maha Oya transports sediments to nourish the beaches from its mouth in Kochchikade to Deduru Oya mouth in Chilaw which is located about 45 km Northwards from Kochchikade. Theadministrative area in this coastal stretch falls within the Puttalam district of the Northwestern Province, specifically in the Wennappuwa and Nattandiya DS divisions.

The lowlands in the downstream of the Maha Oya are wide floodplains. The sediments derived from upstream are rearranged in the downstream, generally depositing in the estuary and finer materials on flood plains after a flood. Annually, the huge quantities of sediments are discharged in to the sea particularly in monsoonal periods in the forms of suspended sediments and bed loads in order to replenish the beach subject to natural erosion. The sediments that are discharged at the river mouths are undergone to the coastal processes which are driven by forces of ocean waves and currents. Accordingly a portion of sediments distribute over beaches, and continued its motion along the shore or across the shore with the seasonal changes of ocean waves and currents.

Maha Oya is the fifth largest river in terms of sediment transport and the largest river to nourish the beaches of North Western Sri Lanka. However, National Sand Study (1992) guesstimate that the mining has been reduced the influx of sand to the coast by 55%. Transport capacity of Maha Oya is 200,000 m^3/year and only 90,000 m^3/year reaches to the coast. In addition to sand mining, further to defeat the salinity intrusion in to the water intake at Bambukuliya; a barrage has been constructed across the Maha Oya in 1986. With the cumulative effect of sand mining and obstructions by Bambukuliya Barrage, it was observed that the sediment supply has been reduced drastically (Research work of MFF funded Maha Oya Project).

In 2006, the Coastal Zone Management Plan identified that the coastal stretch from Negombo to Chillaw as the most degraded coastline in Sri Lanka (CZMP, 2006). A higher percentage of that erosion is attributed to the river sand mining of the Maha Oya (CZMP, 2005; Western sector river basin project, 1999). In the Lansiyagama area itself, erosion rate is higher as 12-13 m/year. That is, the coastline retreats by 12-13 m within a year, with this alarming rate, the country losesapproximately 1.25km^2 of valuable land per year per 1 km length. The Figure 2 illustrates the loss of land over 4 ½ years in the Katuneriya area.

There are a number of repercussions of coastal erosion in terms of social and economic aspects in addition to direct loss of land. The settlements in the coastal stretch were greatly affected, in the Wennappuwa DS division only, more than 300 families lost their houses over a span of 12 years from 1995 to 2007 (Data from Divisional Secretariat Office, Wennappuwa, 2010). As per data obtained in 2011, there are 40 families who have been living in temporary erected tents for over a two and half years period. The socio-economic implications of loss of houses and associated properties are vast and diverse. These people do not have a proper shelter above their heads; their livelihoods have been disabled due to the narrow beach which does not facilitate fishing by Ma-del. The extreme poverty they live in has deprived school education for their children and it has been a struggle to earn something for their next meal. Many of them are vulnerable to communicable diseases; skin related infections have been common among them owing to poor health and sanitation in the absence of proper infrastructure. The loss of social system is evident in these fishing villages, as coastal erosion washed away their houses and other properties.

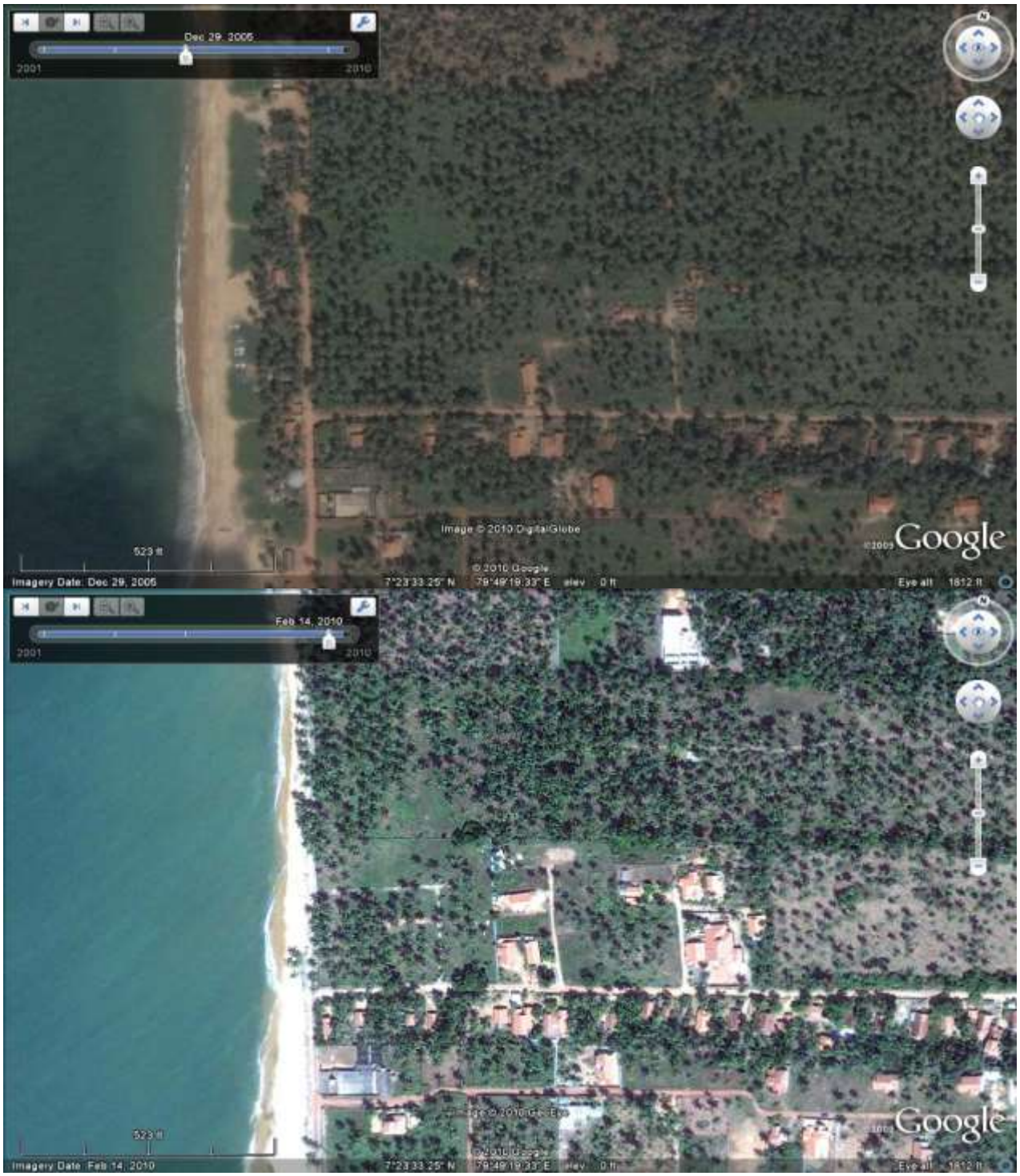


Figure 2 - Time series comparison of Google Earth images of Katuneriya area; the top image in December, 2005 and bottom image in February, 2010

In addition to the displacements of families settled along coastline, the fisheries industry, hotel industry and other beach associated tourism activities have been affected by the coastal erosion and, coastal erosion mitigation structures.

In order to address this issue, continuous measures have been taken by the Coast Conservation Department of Sri Lanka, with the objective of stabilizing the coastline. The expenses associated with mitigating coastal erosion is so huge, that it is worth investigating the benefits of river sand mining over expenses incurred in mitigating the impacts. The Coast Conservation Department of Sri Lanka has been protecting the coastline against erosion through a number of measures as discussed below. As coast protection and stabilization measures, two major projects have been implemented in the past.

1. DANIDA (Danish International Development Agency) 1986 - 1989,
2. CRMP (Coastal Resource Management Project, *funded by Asian Development Bank*) 2001-2006.

As per the information from CCD, apart from the two projects, few coast protection measures have been introduced by CCD. The expenditure for the coast protection in the past has been given in the Table 1.

Table 1 - Expenditure for coast protections

Project	Exepditure (Rs. million)	Years of implementation
DANIDA	121	1986 – 1989
CCD	150	1990 – 2002
CRMP	1,243	2002 – 2006
CCD	240	2006 – 2010

The total protected coastal length by any means is 23 km (as at Dec, 2010). For the protection, it has been introduced

- 31 nos of offshore breakwaters
- 23 nos of Groynes
- 10 km long revetments
- Approximately 2.5 million m^3 of sand nourishments.

Source: study carried out by Mr. Bandula Wickramarachchi under the project implemented by Evironmental Foundation, funded by the Mangroves for the Future Initiative

As per the records from CCD, the erosion moves northward for the last period. In each year 1 – 2 km coastal stretch has been subjected to erosion. That is each year, CCD has to extend their coastal protection programme further northwards along the coastline, either through permanent structures including offshore breakwaters, groyones and revetments or nourish the beaches with sand.

DISCUSSION AND RECOMMENDATIONS

The existing devastation is enormous, it might take decades to regain the minimal originality back in to the system in the absence of any stresses. However, in the absence of systematic and integrated approach in addressing this problem by the responsible authorities, the root cause to all this havoc- sand mining is in persistence. So far there is no mechanism to supply the market demand of sand; Maha Oya being one of the key fine sand producing rivers in Sri Lanka, it is not easy to control the mining activities in the river. The sand from the Maha Oya and Deduru Oya are considered high quality and with the banning of sand mining in the Deduru Oya, a huge demand has been in existence for the sand from the Maha Oya. In this light, it is crucial to come up with alternatives for sand in order to restrict the indiscriminate sand mining in Sri Lankan rivers including that for the Maha Oya. Sea sand has proved to be a good alternative for the river sand; however policies and effective marketing backed by accurate technical certification of the quality of sea sand are not in place to make it a viable alternative. Although Sri Lanka Land Reclamation Authority(SLRCA) dredges sea sand, no authority has taken over the responsibility of technical certification and marketing so that demand for river sand could have diminished. This is a key requirement in order to reduce the stresses on rivers upon mining activities.

The other important aspect is thestakeholder collaboration and integration for managing the river system. With the current mechanism in existence for river related decision making, there are a number of government and semi government authorities. The Department of Irrigation is the key responsible authority for managing the inland waters of Sri Lanka, although their priority is for irrigation schemes associated with rivers. The authority responsible for managing mining activities in rivers and inlands is Geological Survey and Mines Bureau established in early 1990s. They are the licensing and regulating authority for mining of geo materials including sand, clay and earth. For controlling the river related pollution activities Central Environmental Authority imposes legislation and carries out monitoring activities. Further, National Water Supply and Drainage Board (NWSDB) extracts water from the river; along the Maha Oya itself, there are 14 NWSDB intakes are located. In addition, Divisional Secretariats also participates in decision making on river related issues to a minor extent.

The issue here is the coordination among these institutions is minimal. These individual institutions draft their own management plans for the river and coordination among these institutions has not been observed and this in turn affects the proper management of the river. In addition, involvement of the Coast Conservation Department is also vital in the context of sand mining causes coastal erosion and degradation of coastal ecosystems. Participation of communities in riverine area planning and management is also bare minimum, although their involvement is very crucial in conserving the ecosystems of the river.An integrated approach which includes both top down and bottom up mechanisms is necessary. Policy changes from the government authorities should promote alternatives for sand and regulate the mining activities whilst grass root level work should account illegal mining activities and provide alternative livelihoods for people whose income earning activities are jeopardized due to regulation of mining.

In addition, generation of proper scientific data is also vital so that policies are backed by science and it lessensthe room for these policies to produce adverse effects on the river and associated ecosystems and communities. In the case of the Maha Oya, river flow data do not exist from late 1990s owing to the fact that sand mining hinders accurate readings. There are many such examples that fundamental scientific data is not available for deriving rational decisions.

A few non-governmental institutions try to address this issue by raising awareness among stakeholders and bringing the issue of sand mining in to forefront in decision making process of mandated authorities. However, their endeavours are short term and in the absence of a prolonged persisting machinery to act upon, piecemeal treatment is not sufficed since the issue is grown to a state that no simple solution does exist. Stakeholder participation and action is the key for redress in reviving the damaged ecosystems associated with the Maha Oya.

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- Staff of Geological Survey and Mines Bureau, Sri Lanka;
- Staff of Department of Irrigation, Sri Lanka;
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Local technologies for removal of hardness in groundwater

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ABSTRACT

Groundwater is the major natural resource in Jaffna peninsula and it is used for all purposes. Jaffna peninsula is underlain by a Miocene limestone aquifer which is the main source for hard water. Considering problems of water hardness its removal is essential to prevent from health hazards and to get soft tasty drinking water. Five treatments were selected during the preliminary test as 30 minutes boiling, four hours aeration, overnight aeration, two hours aeration plus ten minutes boiling and electrocogulation running time for 20 minutes. Different hardness content groundwater sources were selected. Raw water samples and treated water samples were analysed for pH, electrical conductivity, chloride, alkalinity and hardness. Aluminium residue also was checked to electrocoagulated water. Raw water hardness was varied from 244 mg/l to 883 mg/l but the SLS maximum desirable level is 250 mg/l which express the severity of the hardness problem . Very low average reduction of 36.7% was got in electrocogulation but it is mostly suitable for high degree of hardness area. The reduction range varied from 10.7 to 68.2% in four hours aeration. The reduction percentage was greater than 40 to 80% of the selected well in overnight aeration. Reduction pattern is nearly equal to boiling and two hours aeration plus ten minutes boiling. Highest average percentage reduction of 56.5 was achieved in boiling. Reduction level was higher than other treatment in boiling to 65% of the selected well water. In addition to hardness test chloride, alkalinity was not significantly changed to treated and fresh raw water. Treated water alkalinity and electrical conductivity were less than raw water. Boiling and boiling with aeration were selected as a suitable treatment to most of the area water and boiler was design without evaporation loss of water. The 50% of hardness was reduced by designed filter. Design filter can be used as domestic treatment to get soft water with low cost.

INTRODUCTION

The groundwater is dynamic, replenishable and dependable earth resource which acts as a viable substitute to the surface water supply in many countries (Sharma *et al*., 2007) which is expected to be one of the most critical natural resources in the twenty-first century.Groundwater is an important source of water for human consumption in many parts of the world and is occurring in large quantities in the rock formation in the earth crust (Cooray, 1984).Groundwater constitutes 97% of global fresh water and is an important source of drinking water in many regions of the world including Sri Lanka (Panabokke and Perera, 2005).A great deal of emphasis has been given to the study of hydrogeological systems in the dry zone areas of Sri Lanka, as the consumption of groundwater for domestic and agricultural purposes has increaseddramatically over the last few decades (Christensen and Dharmagunawardhane, 1986).Groundwater is the major natural water resource in the Jaffna peninsula and it is used for domestic, agricultural and industrial purpose. Jaffna peninsula has a source of groundwater store in the sub terrain layer of the limestone is the main aquifer. It is an excellent aquifer for storage because the aquifer has several isolated caves and caveins capable of storing groundwater without evaporation losses (Arumugam, 1970). However, the region experiences groundwater problems as the resource is limited and its quality has deteriorated over the years (Navaratnarajah, 1994)

The hardness of the water is much high in Jaffna peninsula becauseof miocene limestone aquifer.The groundwater contains dissolved salts and other constituents depending on the geochemistry.Therefore, groundwater must have an important bearing on the health of the population (Dissanayake, 2005). The presence of different chemical andphysicalconstituents in excess of their permissible limits for various uses can create health hazard and environmental problems (Al – zarah, 2007).

Among water quality parameters, hardness has always been investigated as an important factor (Saurina *et al*., 2002). Moreover, water hardness is an essential parameter in industrial water consumption in manufacturing of high quality products (Viero *et al*., 2002).Water hardness originates from existence of cations such as calcium, magnesium; and in lower traces; aluminium, iron and other bivalent and trivalent cations. Among them hardness causes ions, calcium and magnesium are identified as main factors of hardness (Padmasiri and Jayawardene, 2011). Probably high value of hardness indicates the richness in the calcium and magnesium. If hardness is greater than 150 mg/l, it called as hard water. High amounts of calcium and phosphate in the drinking water may accelerate stone formation in the bladder. Due to the hard water consumption, people in the area suffer from calculi in the urinary tract (Sivarajah, 2003).

Hard water causes many problems in domestic and industrial consumptions like scale formation in hot water pipes, kitchen devices, water supply facilities, boilers, cooling towers, membrane clogging, dealing efficiency of heat exchangers (Saurina*et al*., 2002).The water hardness are above 200 mg/l may cause scale deposition in the distribution system. According to the National Water Supply and Drainage Board records, most of the supplywells groundwater hardness is greater than SLS maximum desirable level.Public acceptance of hardness varies from community to community, which creates a lot of problems for life and industry (Mameri, 1998). Considering the problems of water hardness, its removal is essential (Kawamura, 2000).Hence removal of hardness for drinking is essential to prevent from the health hazards and to get tasty soft water for drinking. There are various techniques for removal of hardness each with its own special advantages and disadvantages (Malakootian*et al*., 2010). However, most are high cost technology. A large scale treatment for hardness is highly expensive and complicated. Hence the study was aimed to find suitable low cost technology to remove the hardness from the drinking groundwater and design of filter with local methods of hardness removal for drinking groundwater with sustainability and local economic stimulus.

MATERIALS AND METHOD

Selection of wells and collection of water sample

Altogether twenty wells were selected, in which twelve wells from National Water Supply scheme wells and other from randomly selected wells from Jaffna Peninsulla with different hardness value. Each water samples were poured into plastic bottles after rinsing several times with the sample water. Sample water EC, pH and temperature were measured on spot and the sample bottles was tightly closed and labelled. Then samples were taken to the National Water Supply and Drainage Board, Jaffna for chemical analysis. Samples were drawn from the selected wells at bottom level from 2011 December to 2012 February.

Preliminary study

Boiling, aeration, aeration after boiling, boiling after aeration, electrocoagulation and filtration were used in preliminary study to select the appropriate treatments.The processing time was changed in aeration and boiling to find the low cost and high efficient treatment time. Electrocoagulation unit which is 20 V and has six aluminium plates was used to treat the water sample for a period of 20 minutes.

Chemical Analysis

Water samples were analyzed for pH, electrical conductivity, chloride, total alkalinity, and total hardness, based on Sri Lanka standards 614: part 1 (1983) before and after the treatment process. Table 1 shows the methods of analysis and chemical used in each analysis of parameters. Residual aluminium in treated water was analysized and compared with SLS drinking water standard.

Table 1 - Drinking water quality parameters and method of analysis

Parameters	Method	Chemicals used
1. Chloride	Mohr's titration	0.02N AgNO3 solution
2. Total alkalinity	Acid-base titration	0.02N HCl
3. Total hardness	EDTA titration	0.01N EDTA
4. pH	pH meter	-
5. EC	EC meter	-
6. Residual aluminium	spectrophotometer	-

Design of filter

Designed filter has three component; as aeration unit, boiler and sand filter. The bubble aeration type was given to the aerator can which has the outlet tap near the bottom part. A boiler was designed with two vessels to ensure the loss of water due to evaporation. Small vessel was kept on the top of the other vessel. An inlet and outlet were given to both vessels. Valves were fitted to the inlet and taps were used in outlets. A pipe was connected between the outlet tap of top vessel to inlet of bottom vessel to pass the top water to bottom vessel. Inlet of the top vessel pipe was connected with aerator water can tap water tap to get the aerated water. An outlet tap was fitted on the middle of bottom vessel which was used to collect the boiled water.A sand filter was designed to remove the suspended particles and calcium scale of the boiled water. The pebbles were placed to six centimetre and then sand was placed to 20 cm height finally charcoal in the top to three centimetres.

Analysis

Hardness reduction percentage was calculated. Values of water hardness, EC, pH, alkalinity, and chloride were compared for raw and treated water to see the effect of treatment in the parameter. Statistical analysis was done to compare the mean hardness reduction percentage among the treatments.

RESULTS AND DISCUSSION

Distribution of hardness of selected wells

Figure 1 shows the total hardness of selected wells ea raw water. The value of hardness varied from 244 mg/l to 883 mg/l. Of the twenty wells measured, result showed that 95% of the wells were above the recommended SLS maximum desirable level of 250 mg/l, in which 5% of wells had above SLS maximum permissible level of 600 mg/l. Probably high value of hardness indicates the richness in calcium and magnesium. The highest value of hardness was observed as 883 mg/l at Karainagar. Only Velanai well water hardness was less than SLS maximum desirable level and all other well waters were hard which confirmed that there was a problem of hardness in Jaffna Peninsula and is a necessary to remove the hardness from the groundwater.

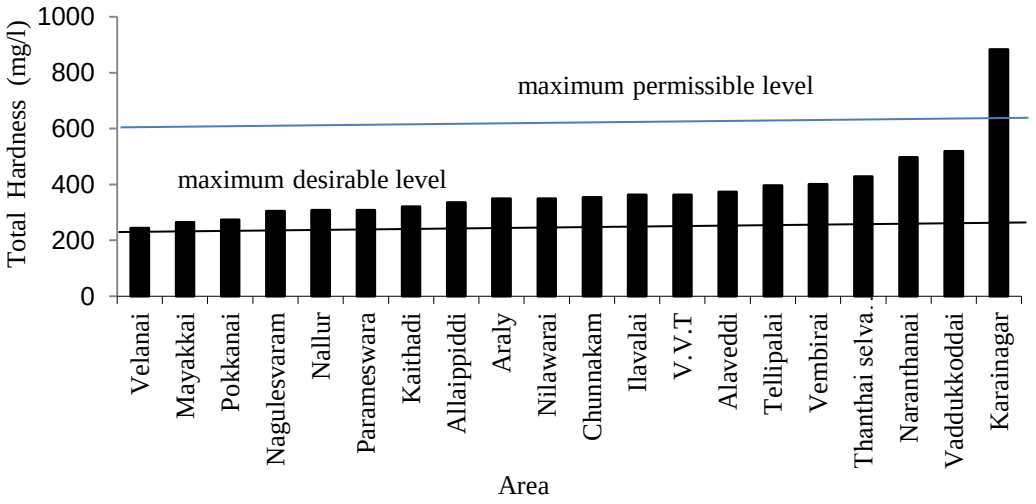

Figure 1 - Total hardness of the selected wells

Selection of treatment from preliminary test

From the preliminary study, five efficient and effective treatments were selected considering with running time and percentage reduction of hardness which were electrocoagulation (20 minutes running time), four hours aeration, overnight aeration, two hours aeration plus ten minutes boiling and thirty minutes boiling. Percentage reduction of total hardness was increasing in decreasing rate with boiling time, in addition to that water loss also increasing in increasing rate with time. Water loss in 5 minutes boiling was negligible however, the % reduction of hardness was very low but in one hour boiling 94% of hardness reduction was achieved with the water loss of 51%.Mean time it wasn't an economic one due to loss of water and cost of boiling. At the same time concentration of chloride was double of the raw water due to the saturation of water. Again this creates the problem of acceptance and suitability for drinking purposes so that 30 minutes boiling was selected as a treatment in which the quality of treated water wasn't changed with 80% reduction of hardness and 35% of water loss.

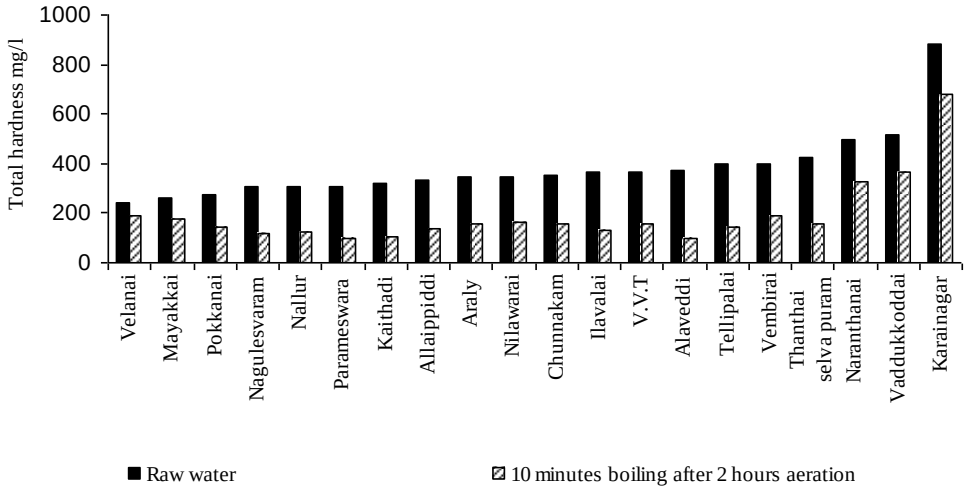

Figure 2 - Total hardness of raw and 10 minutes boiling after 2 hours aerated water

The figure 2 shows the raw and treated water hardness due to ten minutes boiling after two hours aeration as one example. Aeration is a common practice to aerate water to remove CO2, since CO2 is an acidic gas, its removal tends to decrease H+ and raise the pH.Malakootian*et al*., 2009 stated that with pH increase, the rate of hardness removal

increase. Even though the pH changes with aeration and it was less than the recommended SLS maximum permissible level (pH 6.5- 9). Figure 3 shows the percentage reduction of hardness through electrocoagulation and it varies from 15% from 60% for selected wells.

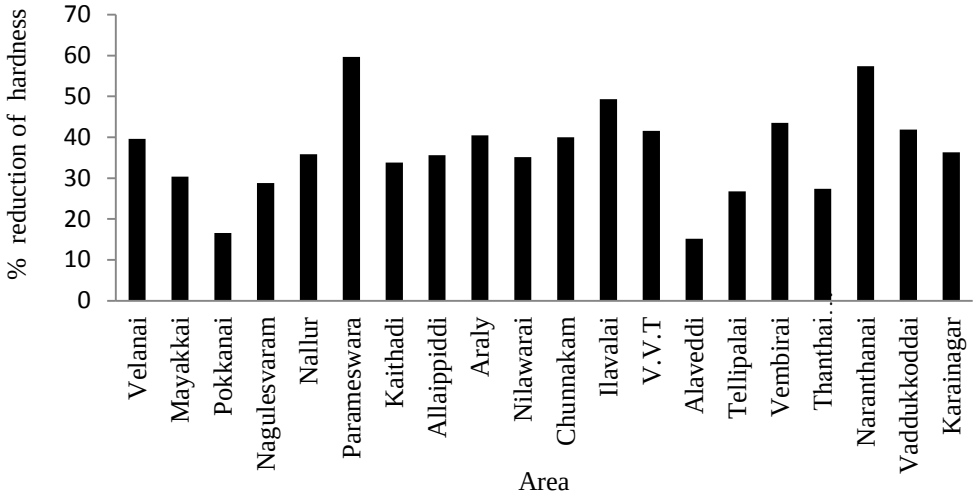

Figure 3 - Percentage reduction of total hardness through electrocoagulation

The hardness reduction range was varied from 10.7 to 68.2% in four hours aeration. The reduction percentage was greater than 40 to 80% of the selected well in overnight aeration. Higher reduction was achieved to Alaveddi water which was 73.4% and lower reduction was achieved to Velanai water as 22.6% for 10 minutes boiling after 2 hours aeration in selected area well water. Mean time higher reduction % was recorded to Alaveddi water which was 89.9% and lower reduction was recorded to Karainagar water (11.4%) in boiling.Reduction pattern was nearly equal to boiling and two hours aeration plus ten minutes boiling.

Significance of the selected treatments

Table 1 shows the mean reduction of the hardness with standard deviation. The percentage reduction of hardness were significantly ($p<0.05$) differed between different treatment. The boiling treatment has highly significant effect followed by 10 minutes boiling after two hours aeration but there was no any significant different between boiling, 10 minutes boiling after two hours aeration and overnight aeration. Usually the peoples are doing the boiling in domestic to remove the hardness but the problem was the duration of the boiling and temperature. Least effect was observed for electrocoagulation and four hours aeration but no any significant variation between electrocoagulation and four hours aeration. Electrocoagulation is the best suited method for hardness removal with cost involvement for high hardness water. But here the low average reduction percentage for electrocoagulation was due to selected water hardness which were medium and low.

Table 2 - Mean reduction of hardness to treatments

Treatments	Mean	SD
Electrocoagulation	36.77^{c}	11.28
Four hours aeration	35.70^{c}	15.47
Overnight aeration	$45.57^{a,b}$	11.15
2 hours aeration plus 10 minutes boiling	$52.12^{a,b}$	15.39
Boiling	56.54^{a}	18.97

Means with the same letters are not significantly different at alpha 0.05 in Duncan's separation.

Hardness reduction

The figures 4, 5 and 6 show the percentage reduction of hardness for different raw water hardness. The figure 4 shows the percentage reduction of hardness for less than 300 mg/l hardness water. The process of removal of hardness is not essential to low hardnesswater however boiling was suitable one.

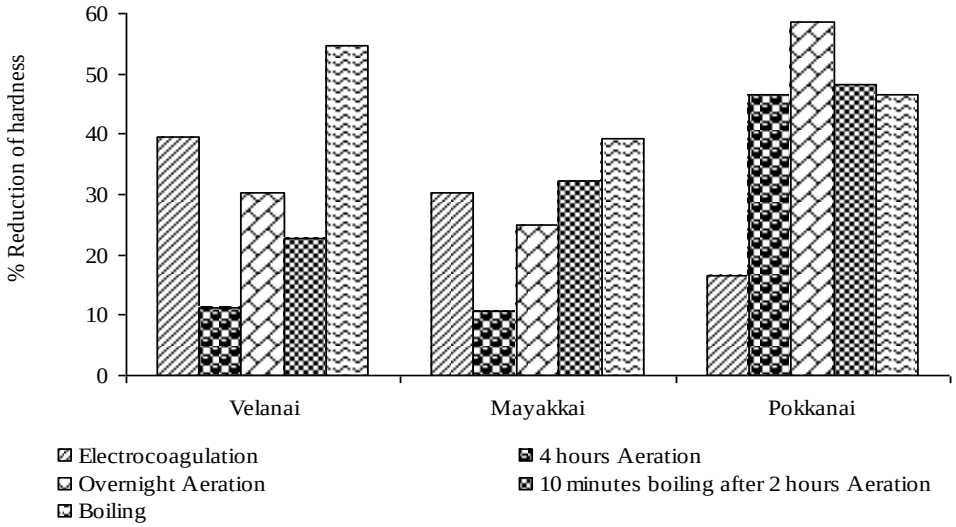

Figure 4 - Percentage reduction of hardness in low hardness area's water

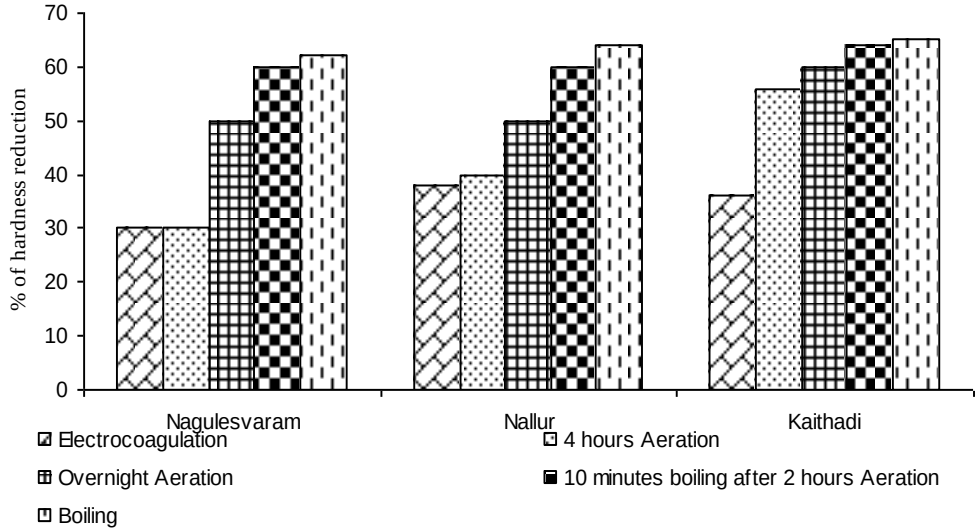

Figure 5 - Percentage reduction of hardness in medium hardness area's water

Overnight aeration, 10 minutes boiling after two hours aeration and 30 minutes boiling was suitable for medium level hard water (300 – 428 mg/l) and shown in figure 5. For high hard water (greater than 428 mg/l) electrocoagulation was suitable method which is a one of the advanced technology however low cost compare to other methods. Residual aluminium also was found in treated water through electrocoagulation but that it was less than SLS maximum permissible level.

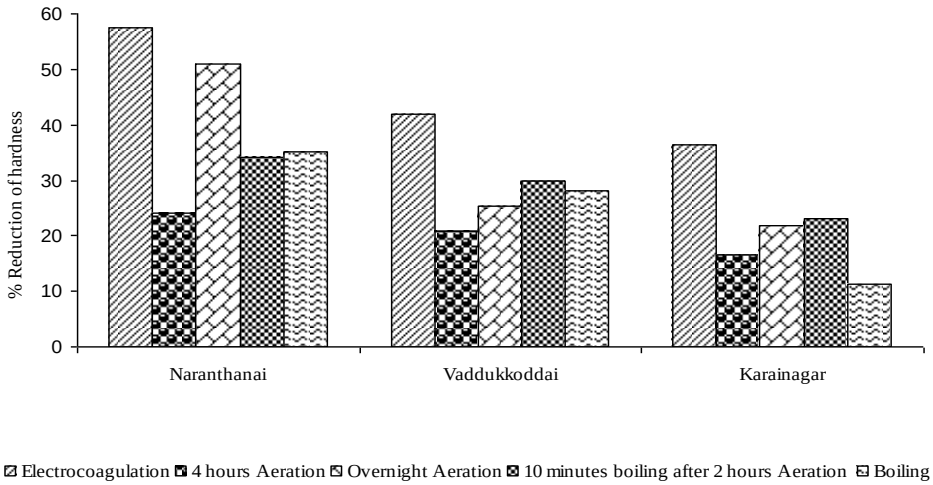

Figure 6 - Percentage reduction of hardness in high hardness area's water

Reduction level wasn't depending on the level of raw water hardness which changes with other chemical parameters. There was no any significant change in chemical parameters of chloride, and alkalinity.Electrical conductivity was reduced and also according to Padmasiri, 2011 in the bench scale model, electrocoagulation reduces the EC of water. But pH was slightly increased by the formation of calcium carbonate but it was less than SLS permissible level. Boiling and aeration were recorded as efficient method for more range of hardness water so this one was selected to design an appropriate filter for local community.

Design Filter

The figure 7 shows the outline of the designed filter with boiling and aeration. Traditional technology of boiling of water in pots was the disadvantage of evaporation loss and boiling duration and temperature. This designed filter will overcome the problem of loss of water. The designed filter could be used as efficient method to remove hardness without any evaporation loss.

CONCLUSION

Raw water hardness was varied from 244 mg/l to 883 mg/l which ensure the problem of hardness in Jaffna Peninsula. The maximum percentage reduction of 56.5% was recorded in boiling. Two hours aeration after 10 minutes boiling and Boiling were selected for suitable method for medium hard water. Removal of hardness not necessary for hardness less than 250 mg/l however boiling is suitable for this water. Electrocoagulation was selected as best treatment for high hardness water. Removal of hardness changes the electrical conductivity, alkalinity and pH, no any effects to the chloride. Also all tested chemical characters were reduced to all treatments except boiling of Karainagar water for electrical conductivity. But pH of all selected wells were increased slightly. Boiler was designed without loss of evaporation water. The designed technology could be used as domestic treatment to get soft water in low cost for households.

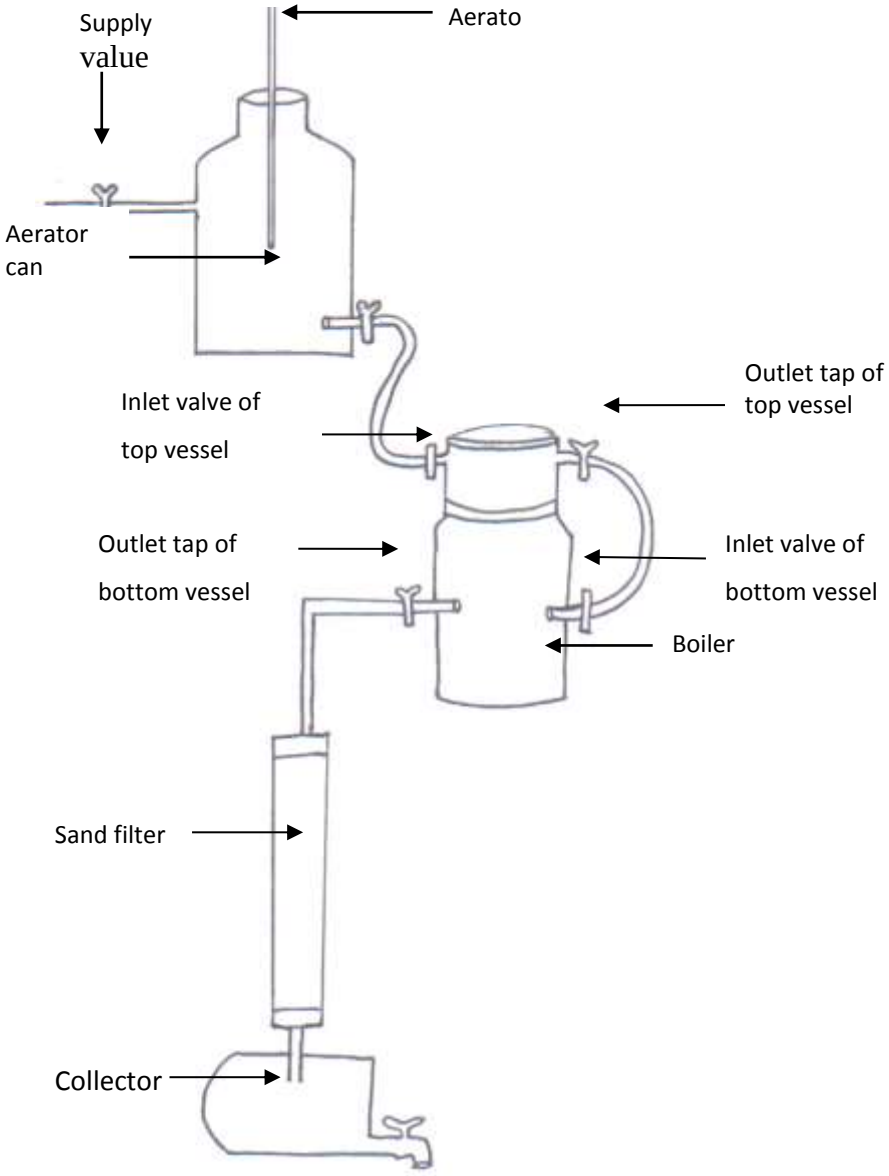

Figure 6 - Diagrammatic view of designed filter

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Pseudomonas aeruginosa in bottled dinking water in Sri Lanka

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INTRODUCTION

Bacteria belonging to the genus *Pseudomonas* are widely spread in the environment and are often opportunistic pathogens for many episodes of infections. *Pseudomonas aeruginosa* is associated with food and water-borne diseasesand is considered a primary infectious agent(Warburton, 1993; Romling *et al*., 1994). Outbreaks of infection caused by *P. aeruginosa* in water are widespreaded (Sirinivasan *et al*., 2003; Trautmann *et al*., 2005). In addition to being a primary infectious agent, *P. aeruginosa* is an indicator of other opportunistic pathogens (Clesceri *et al*., 1998).

This species can even grow in low-nutrient water (Moreira *et al*., 1994) and therefore, can colonize in bottled waters and also survive for long starvation periods (Legnani *et al*., 1999).*P. aeruginosa* has been found in some mineral waters in various countries such as Brazil, Canada, France, Germany, Spain, and United States among others (Schindler *et al*., 1995). During the period of storage, the growth of *P. aeruginosa*could lead to a risk for consumers especially the immunologically weak persons, as well as very young or elderly individuals (Legnani *et al*., 1999). Therefore, bottled mineral waters must be free from *P. aeruginosa* as its presence is a health risk to people. Examination of drinking water for *P. aeruginosa* is not recommended as a routine procedure, however, can be used as an indicator of the quality of drinking water (WHO, 2006; Gerba, 2000). According to drinking water criteria of the European Union, *P. aeruginosa* should be absent in 250 ml for bottled water (European Communities, 2007). However, in Sri Lanka, although *P. aeruginosa* is considered for natural mineral water standards, it is not included for bottled drinking water standards.

Currently, the Ultraviolet (UV) radiation is considered as one of the best alternatives to chemical disinfection of effluents and more specifically to chlorination (Meiting *et al*., 2009). UV radiation does not inactivate micro-organisms by chemical action but the released energy interacts with nucleic acids and other vital cellular components, damaging or killing exposed cells. The knowledge gained in this field confirms that ultraviolet radiation is acting fast, efficient, safe and offers a cheap environmentally friendly technology (USEPA, 2003).

Ultraviolet-C (UV-C) (100-280 nm) radiation has been suggested as one of the successful disinfection practices for water treatment. Currently, UV-C treatment has become a practical solution for safe disinfection of water. Ultraviolet sanitizing units are used in many water purification systems to control bacteria and have certain applications in animal drinking water systems (http:// www. dwc-water. com/ technologies/ uv-disinfection/ index. html).UV units can be effective water treatment tools, however, it is important to recognize its effectivity, limitations andmaintenance requirements. Although 100% destruction of microorganisms cannot be guaranteed, it is possible to achieve 99.9% reduction in certain applications and with proper maintenance. Required UV dosage for destruction of microorganisms depends on the type of bacteria, viruses, mold species etc. Accordingly, required UV dosage for destruction of *P. aeruginosa* is in the range of 10,500 $\mu W/cm^2$(Eccleston, 1998).

Objectives ofthisstudy were to detect *P. aeruginosa* from bottled water samples using Cetrimide agar as a selective culture media. Further, identification of*P.aeruginosa* isolated from bottled water samples, using basic tests recommended in ISO 16266:2006, API 20 NE identification systems and molecular identification. Finally, evaluate the efficacy of UV-C irradiation in eliminating of *P. aeruginosa* from bottled water.

MATERIALS AND METHODS

Sample collection

In order to determine the presence or absence of *P. aeruginosa* in bottled water available in Sri Lanka, thirty six (36) different brands of bottled water which were randomly selected were used for the study. Ten bottles (500 ml) from each brand were purchased from local markets from Kandy, Colombo, Nittambuwa, Badulla, Monaragala, Katharagama, Mahaillukppallama, Kurunegala, Anurdhapura, Rathnapura, Puttalam, Batticaloa and Jaffna, covering the entire island.

Microbiological analysis

Detection of Pseudomonas aeruginosa in bottled drinking water samples; Membrane filtration was used to detect *P. aeruginosa* in water samples as follows. One hundred ml volumes of each sample were passed through the membrane

filtration apparatus (Pyrex, Germany) using sterilized membrane filters (Sartorius, Germany) with 0.45 µm pore size. Filters were incubated on Cetrimide agar plates supplemented with 15 mg/l of nalidixic acid at 37 °C for 44±2 h. Colonies that showed a bluish/greenish pigmentation or that were fluorescent when examined under 364 nm ultraviolet radiation were selected as presumptive *P. aeruginosa* isolates. Pure cultures were isoated on nutrient agar plates at 37 °C for 22±2 h of incubation (Casanovas-Massana, 2010). *P. aeruginosa*(ATCC 27853) was used as a reference control in all the assays performed in the study. Three bottles from each brand were analysed in duplicate, resulting in six replicates per brand.Stock cultures of all isolates were maintained for further identification.

Confirmation of Pseudomonas aeruginosa (ISO 16266:2006 procedure);All isolates were streaked on nutrient agar plates and the plates were incubated at 37 °C for 22±2 h. Subsequently, well isolated colonies were subjected to confirmation initially by the Gram's test, oxidase test and the catalase test. Subsequently, assays performed and included in ISO 16266:2006 were used for identification of bacteria as described below (Casanovas-Massana, 2010).

Cetrimide agar; All isolates were cultured on Cetrimide agar plates (Oxoid, UK) supplemented with 15 mg/l of nalidixic acid and incubated at 37 °C for 44±2 h under humid conditions to prevent drying.After 24±2 hof incubation, isolates showing bluish/greenish pigmentation, caused by pyocyanin were further observed after 44±2 h of incubation. Isolates showing reddish brown pigmentation caused by pyorubin, were considered positive for this assay. In addition, the plates were examined under 364 nm ultraviolet radiation and all isolates showing fluorescence as a result of the production of pyoverdin were also considered positive for the assay.

Acetamide broth;All solates were inoculated to acetamide broth tubes (Hi-media, India) using a sterile inoculating loop. The tubes were incubated at 37 °C for 22±2 h. Subsequently, 1 or 2 drops ofNessler Reagent (BDH, England) was added. All the tubes showing a yellow to brick red color, caused by ammonium production, were considered positive for the assay.

King B agar;Isolates were subcultured on King B plates (Fluka, Switzerland) at 37 °C for five days in humid containers to prevent drying. The plates were examined daily under 364 nm ultraviolet radiation. The presence of fluorescence during the five days of observation was considered a positive reaction.

Growth at 4 °C and 42 °C;Two sets of all the isolates were subcultured on nutrient agar plates (Hi-media, India). One set was incubated at 42 °C and the other set at4 °C for 5 daysin humid containers to prevent drying.

Identification using API 20 NE and API 20 E identification strips;The API 20 NE and API 20E systems (Biomérieux, France) werecarried out following the manufacturer's instructions. The profiles obtained were identified with the APIWEB^{TM} database.

Molecular characterization

Isolation, PCR amplification and sequencing of genomic DNA of Pseudomonas aeruginosa;Genomic DNA of *P. aeruginosa* was extracted using the Promega Wizard® Genomic DNA purification kit according to the protocol.DNA samples extracted from bacterial cultures were subsequently amplified with universal bacterial primers for gram negative bacteria (16S rRNA primers). Diluted DNA samples (1:300) were used for PCR reaction. PCR primers used for identification included the primer pair rD1 and fD1 (forward: 3'AGAGTTTGATCCTGGCTCAG5'; reverse: 3'AAGGAGGTGATCCAGCC5').PCR product was sequenced by bidirectional direct sequencing at Asiri laboratory, Colombo, using 16S rRNA universal bacterial primers. The sequence was identified using NCBI nucleotide BLAST tool (http://www.ncbi.nlm.nih.gov/).

Elimination of Pseudomonas aeruginosaby UV radiation

UV germicidal lamp was used for irradiation (Hayes *et al.,*2008). A manually operated switch was employed to control the length and time of UV exposure. Two 15 W low-pressure UV lamps (VC-215.G, France) were the light source. The reactor was placed in a petri dish (90 mm). A radiometer (ST 512 Sentry Optronic Crop. Taiwan)was used to measure the irradiance in microwatts per square centimeter (µW cm^{-2}).

Exposures spanned a UV dose range of approx. 10,350– 24,500 µW cm^{-2}. The suspension (5 ml) of *P. aeruginosa* (ATCC 27853) in sterile distilled water was prepared by adjusting the optical density to 0.132 at 600 nm to bring the cell density similar to 0.5 Mcfarland standards. Suspensions of *P. aeruginosa* (1 x 10^4 cfu/ml) were separately irradiated with UV doses of 10350, 17,300 and 24,500 µW cm^{-2} for 5, 10, 20 and 60 seconds for each dose. Different UV doses were obtained by changing the distance between UV lamps and the bacterial suspension. The irradiated samples were serially diluted and plated on tryptic soy agar using Miles and Misra method (Hedges, 2002).Non-irradiated samples were plated as controls. Duplicate plate counts were made at each dilution in three replicate trials.

Subsequently, bottled water samples (confirmed as contaminated with *P. aeruginosa,* 128 cfu/100 ml) were exposed to UV doses as mentioned above.

RESULTS

Microbiological analysis

Detection of Pseudomonas aeruginosa;Among the brands tested, (previously confirmed as contaminated with *P. aeruginosa*)was detected in 18 (50 %) brands. Six brands showed high*P. aeruginosa* counts on Citramide agar, while the isolates were fluorescent when examined under 364 nm ultraviolet radiation. Seven brands were free of *P. aeruginosa* (Table 1).

Table 1 - Number of presumptive*Pseudomonas aeruginosa*isolates detected in bottled drinking water samples

No of *P. aeruginosa*colonies isolated per 100 ml	No of bottled water brands
0	7
1-2	7
2-10	7
10-100	12
>100	3

Conformation of Pseudomonas aeruginosa; One hundred and eighty six isolates on Citramide agar, were considered to be presumptive *P. aeruginosa.* Out of these isolates, 176 were Gram negative, catalase negative and oxidase positive. These 176 isolateswhen subjected to ISO 16266:2006 test,viz; production of pyocyanin, pyoverdin or pyorubin on cetrimide agar, production of ammonium from acetamide and production of pyoverdin on King B agar and in addition, growth on nutrient agar at 42 °C and absence of growth on nutrient agar at 4°C, 108 isolates were confirmed as *P. aeruginosa.*

The API 20 NE system identified 39 out of 47 isolates (previously confirmed by ISO 16266:2006 procedures) as *P. aeruginosa* with a percentage identification between 98 % and 99.9 %. In addition,*Pseudomonas florescence*, *Pseudomonas oryzihabitans,Aeromonas sobria*, *Aeromonas hydrophila* and*Burkholderia cepecia*were identified from bottled water samples.

Molecular characterization

PCR amplification for identification of P. aeruginosa;DNA samples extracted from bacterial cultures confirmed as *P. aeruginosa* were amplified with 16S rRNA universal bacterial primers to verify the presence of *P. aeruginosa.* Presence of *Pseudomonas*spp.was detected by a 1500bp fragment (Fig. 1).

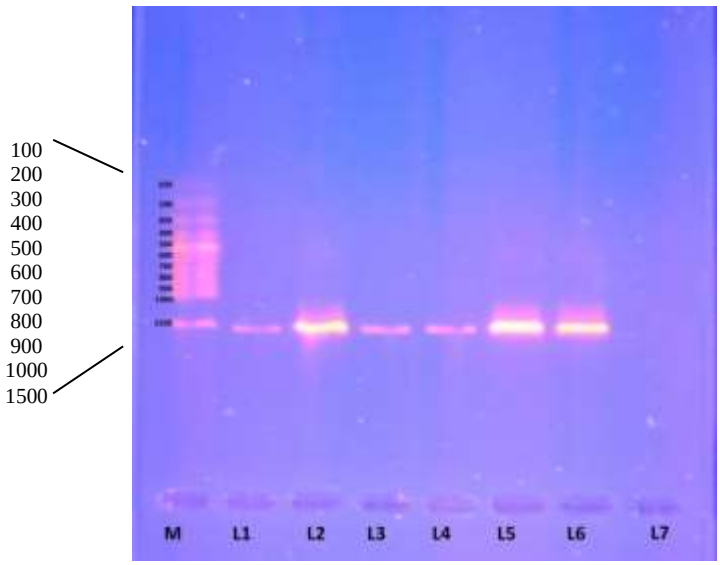

Figure1 - Gel showing PCR amplification of a 1500bp fragment of *Pseudomonas aeruginosa* using 16S rRNA universal bacterial primers. M- 100bp DNA ladder, L1, L2, L3, L4, L5, L6- DNA samples, L7- negative control (H_2O)

DNA Sequencing;According to bidirectional direct sequence data, the DNA sequence was confirmed as *Pseudomonas aeruginosa* using NCBI nucleotide BLAST tool http://www.ncbi.nlm.nih.gov/.

Elimination of P. aeruginosa in bottled drinking water samples

UV doses of 24,500 and 17,300 µW/cm^{2}were effective against *P. aeruginosa*(1x10^4 cfu/ml), eliminating all bacteria within 5 seconds of exposure time.Six log reductions of bacteria was obtained at lower UV dose (approx. 10,350 µW/cm^2) within 5 seconds of contact time. There was no reduction of bacterial growth in controls which were not exposed to UV light (Table 2).

Table 2 - Counts of *P. aeruginosa* following exposure to various doses of UV irradiation. All samples were duplicated with triplicate trials; the number of colony forming unites per milliliter (CFU/ml) indicates the average bacterial counts of replicates. Abbreviation is as follows: TNTC = too numerous to count

Time (sec.)	CFU/ml		
	UV dose (µW /cm^2)		
	24,500	17,300	10,350
5	0	0	0.25 x 10^2
10	0	0	0.625 x 10^2
20	0	0	0.25 x 10^2
60	0	0	0.25 x 10^2
Control	TNTC	TNTC	TNTC

Initial bacterial count (CFU/ml) = 1 × 10^4

UV doses of 24,500, 17,300 and 10,350 µW/cm^{2}were effective in eliminating *P. aeruginosa* in bottled water samples (bacteria count - 128 cfu/100 ml), within 5 seconds of exposure time (Table 3).

Table 3 - Counts of *P. aeruginosa* of bottled water samples following exposure to various doses of UV irradiation. All samples were duplicated with triplicate trials; the number of colony forming unites per milliliter (CFU/ml) indicates the average bacterial counts of replicates

Time (sec.)	CFU/ml		
	UV dose (µW /cm^2)		
	24,500	17,300	10,350
5	0	0	0
10	0	0	0
20	0	0	0
60	0	0	0
Control	0.25 x 10^2	0.25 x 10^2	0.25 x 10^2

Initial bacterial count (CFU/100 ml) = 128

DISCUSSION

Pseudomonas aeruginosa has been implicated in waterborne and food borne diseases, and is also considered as a primary infectious agent (Elaichouni *et al*., 1994).*P. aeruginosa*being an opportunistic pathogen, typically infects the pulmonary tract, urinary tract, burns, wounds, and also causes other blood infections in immunocompromised individuals.The organismexpresses virulence factors such as, exotoxins, a phagocytosis resistant slime layer, various enzymes and hemolysins that degrade host tissues (Vachee and Leclerc, 1995).

*Pseudomonas aeruginosa,*which is a common bacterium in tropical regions (Dowens and Ito, 2001) has the capacity to adapt to a multitude of host and environmental conditions. This ability to activate bacterially useful phenotypes under environmental stress has allowed the species to persist in adverse conditions, such as nutrient deprivation, pH, oxygen tension, osmolarity and etc. Therefore, *P. aeruginosa*can colonize bottled waters easily. The results of the current study, provides further evidence to this explanation. Contamination of bottled water with *P. aeruginosa* has been confirmed by many other studies in different countries (Obiri-Danso *et al*., 2003; Venieri *et al*., 2006;Da silva *et al*., 2007). Manaia *et al*. (1990)reported that 83% of carbonated bottled water samples tested were contaminated by *Pseudomonas* spp., while Hunter *et al*. (1990)found 29% of the *Pseudomonas* spp. frombottled water to be *P. aeruginosa*.Another interesting feature of *P. aeruginosa*is, in the absence of other bacteria the organism reaches higher numbers than the viable aerobic flora, with a low doubling time, while in the presence of the other bacteria, doubling time of *P. aeruginosa* is higher due to competition from the accompanying flora. This is due to the fact that *P. aeruginosa* has a smaller cellular mass than the majority of other bacteria in the water, resulting in a greater number of cells when growth reachesa plateau (Tamagnini and Gonzalez,1997).Literature revealed *P. florescence* as another frequently isolated organism from bottled

water (Arms and Sutherland, 1999; Venieri *et al*., 2006). Similarly, the current study revealed the presence of *P. florescence* along with other bacterial species.

Pseudomonas aeruginosa is used as an indicator organism in water contamination (Gerba, 2000) and ithas been suggested as a surrogate indicator for the presence of other opportunistic pathogens (Geldreich, 1992). In most countries,*P. aeruginosa* is also used as a parameter of bottled drinking water standards. According to the European Union bottled drinking water standards, *P. aeruginosa* should be absent in 250 ml for bottled water (European Communities, 2007). While in the United Kingdom (Barrell *et al*., 2000),Canada (Health Canada, 2001) and East African Standards (EAS, 2009)*P. aeruginosa* should be absent in 100 ml of bottled water.In Greece *P. aeruginosa*is included as one of the unacceptable microbiological criterion in bottled water and is used as a process management indicator during production. Its presence means contamination during the bottling process or that the source has become polluted by organic material (Rosenberg, 2003; Bartram *et al*., 2004). Moreover, it has been documented that if these microorganisms are not adequately removed during processing and bottling, bacterial multiplication may occur 1–3 weeks after bottling, and the bacterial count can reach 10^3–10^4 bacteria ml^{-1} at 37 ^oC (Hunter *et al*., 1990; Tamagnini and Gonzalez, 1997). The storage temperature of bottled water has also been demonstrated to affect the rate of multiplication and survival of microorganisms (Bischofberger *et al*., 1990; Warburton *et al*., 1992).However, in Sri Lankan Standards, although *P. aeruginosa* is a criterion for natural mineral water standards, it is not included for bottled drinking water standards.

Ultraviolet or UV energy is found in the electromagnetic spectrum between visible light and X-rays andcan best be described as invisible radiation. In order to kill microorganisms, the UV rays must actuallystrike the cell. UV energy penetrates the outer cell membrane, passes through the cell body and disruptsits DNA preventing reproduction. Hijnen *et al*. (2006) have noticed that vegetative cells of bacteria are significantly more susceptible to UV radiation than viruses and spores of *Bacillus subtilis* and *Clostridium perfringens*.

In the current study, UV irradiation was found to be an effective method of disinfection in the elimination of*P. aeruginosa.* It reduced the number of detectable *P. aeruginosa*to zero within 5 seconds of exposure time at UV doses 17,300 and 24,500 $\mu W/cm^2$. Eccleston (1998) reports that*P. aeruginosa* could be eliminated by 10,500 $\mu W/cm^2$. However, in the current study, only six log reductions of bacteria was obtained at a UV dose of 10,350 $\mu W/cm^2$ within 5 seconds of contact time.Under ideal conditions, a UV unit can provide greater than 99% reduction of all bacteria. Even with this performance, ultraviolet disinfection has some limitations: UV units only kill bacteria at one point in a watering system and do not provide any residual germicidal effect downstream. If just one bacterium passes through unharmed (100 % destruction of bacteria cannot be guaranteed), there is nothing to prevent it from attaching to downstream piping surfaces and proliferating. Further, bacteria cells are not removed in a UV unit but are converted into pyrogens. The killed microorganisms and any other contaminants in the water are a food source for any bacteria that do survive downstream of the UV unit. Due to these limitations, the piping in a watering system treated by UV disinfection in the bottling plants will need to be periodically sanitized with a chemical disinfectant, lamp replacement, monitoring performance and monitoring UV dosage. The high number of *P. aeruginosa* in botted water in the current study may be due to the improper UV treatments, faulty UV systems or cross contamination.

CONCLUSION AND RECOMMENDATIONS

According to the results of the current study,the presence of *P. aeruginosa*, an opportunistic pathogen in bottled water raises health concerns since *P. aeruginosa* is an indicator of vulnerability of water. *P. aeruginosa* can grow in low-nutrient water compared to other bacterial species, therefore, probably colonize in bottled water and survive for long starvation periods.Therefore, regular monitoring of bottling plants, specifically for its efficiency of the UV system is recommended in order to provide safe bottled drinking water to the Sri Lankan market.

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Sanitation and water pollution in small towns: A case study from Kadugannawa

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ABSTRACT

NanuOya is a medium sized perennial stream passing through Kadugannawa, Pilimathalawa and Peradeniya before joining the Mahaweli river. During the past two decades the water quality of NanuOya has been deteriorating due to many sources of pollutants caused by development of small unplanned townships along the stream bank. Previous studies have reported 500 - 2500 cfu of fecal coliform bacteria in NanuOya. Main objective of the study was to assess the existing situation related to water and sanitation of the riparian community along NanuOya and its impact on NanuOya. The findings will be useful to develop a collaborative conservation plan for the stream and the catchment. A comprehensive questionnaire survey with filed observation was carried out for sixty units of households and business premises along the stretch from Henawala Junction up to the NanuOya Junction in Pilimathalawa. Results revealed that the households and commercial units are highly congested.Majority of the surveyed units have access to pipe borne water and basic sanitation facilities. About 88% of the units have individually owned latrines, while 69% of them are water sealed pour flush type. Even though the majority of residential units have their own onsite treatment and disposal mechanisms, stream water get contaminated by effluent diversion or leaching. Cesspit was found to be the most common (47%) onsite sewage disposal method of the surveyed units whereas 13% of the units possess septic tank and a soakage pit. About 79% of the cesspits are located keeping less than 10 m from the stream which is in the potential contamination zone. The local authorities have a good mechanism of collecting solid waste, but people still dump wastes into the NanuOya. About 63% of the respondents divert grey water to the stream. No institutional interventions have been reported to delineate the riparian zone and to stop constructions in the stream bank. Collaborative action of all stakeholders of the issue would be highly important to minimize the water pollution of NanuOya. Therefore, comprehensive program including awareness to people, capacity building of related institutions, and technical supports is required to change the existing situation.

INTRODUCTION

Water and sanitation is a major topic in development arena and frequently discussed in many world forums. As declared by the United Nations, access to safe drinking-water and sanitation is a human right (WHO, 2011). More than one tenth of the global population still relyon unimproved drinking water sources even though the Millennium Development Goal (MDG) drinking water target has been met (UNICEF/WHO, 2012). Water scarcity is becoming a serious issue for agricultural development as well,challenging the food security fornine billion of world population expected in mid century. While water becoming 'gold' to the people in thirsty world, people in water rich areas in Sri Lanka has often ignored the environmental and economic value of water and havemake use the water courses as a waste receiver. Unplanned urbanization has posed serious threat on streams which flow through or closed to the main roads, because of the limited space and access to discharge their solid and liquid wastes. The paper will assess the water and sanitation infrastructure and practices of people in Pilimathalawa town and periphery and their impact on water pollution of Nanuoya.

NanuOya is a medium sized perennial stream feeding by three tributaries coming from Amunupura, Udawela and Pamunuwavillages. It passes through Kadugannawa, Pilimathalawa and Peradeniya before joining the Mahaweli river at the foothills of Hanthanamountain about 0.5km upstream from the Peradeniya junction (Bandara, 2007). Development of unplanned townships may have caused deterioration of the water quality of NanuOyawhich is reported as 500 - 2500 cfu of fecal coliform bacteria.Unplanned urbanization has found to be the main cause of the extreme levels of pollution in many of the water ways i.e. MedaEla, PingaOya, PussellaOya(Abeygunawardana et al.,2011; Mahees, 2011; Rajapakshe et al.,2008) of Sri Lanka. Although the impact of large cities and industries on water pollution has been investigated,less concern is given to pollution of water ways caused inperi-urban and small township areas.

The objective of this paper is to discuss the causal factors related to water pollution of Nanuoya by assessing the water, sanitation infrastructure and practices of riparian communities in NanuOya, from Kadugannawa to Pilimathalawa.

METHODOLOGY

The dwellers on the bank of NanuOya along the Kandy Colombo main road from Henawalajunction up to the NanuOyajunction was the target group for the study. The methodology was rapid survey with field observation,but it comprehensively gathered all required information from randomly selected 60 dwellings including both houses and business premises. Initial observation tour along the selected stretch of NanuOya, and structured interviews with the residents and business owners were carried out. The questionnaire was contained close ended questions for the convenience ofenumerators to select the relevant answer by asking the question or observing the place. However, open ended questions were also included to receive people's views and additional information from the respondents while validating the collected information. Thorough inspection of the sanitation and sewerage and waste water disposal methods were performed to identify the nature of the situation and also to confirm the information obtained verbally.

Questionnaire included 6 (A-F) major sections, namely:

A) details of households' or business premises,
B) water(availability, access, storage, quality, etc.),
C) sanitation(type of latrine, accessibility, issues, etc.),
D) observation(hygienic use of sanitation system, distances to water sources etc.),
E) waste disposal (type of wastes and disposal method), and
F) knowledge of households and willingness to invest or pay for improved sanitation.

Information collected was analyzed using Statistical Package for Social Sciences (SPSS) and presented in graphical and tabulated formats.

RESULTS AND DISCUSSION

Residences, Business Premises and Land Details

Surveyed group comprised of 24 houses, 25 business premises and 11 units with both houses and their business premises. A variety of businesses, i.e. hotels and restaurants - 17%, groceries and supermarkets - 14%, computer and print shops - 8%, and educational centers - 8% were observed among the 36 business units. Hotels and restaurants are the major type of business in the study area. These units generally produce large amount of grey water[1] and black water[2] potentially contributing to stream water pollutions upon lack of wastewater management facility. The majority (67%) of the houses are owned by the residents while 33% of the houses are rented from a person orPradeshiyaSabha (PS). Unlike the houses, 52% business premises wereself ownedwhile the other 48% were rented. A clear majority (45%) of the respondents is residents less than 10 years whereas 25% has been residing for a period of 10 – 25 years. Therefore, it indicates the urbanization and commercializationtrend of the area during the last decade (Table 1). The ownership of the premises is an important criterion determines the community participation for implementation and maintenance of an improved sanitation system in the area. During the survey it was observed that when the resident does not have the ownership of the land or the premises and they do not know about the sanitation system.

Table 1 - Land ownership and the period of residency of the respondents

Land ownership	No of units for residing period in years					Total
	Not stated	< 10	10 - 25	25 - 50	> 50	
Self owned	4	12	11	10	1	38
Encroached land	0	0	1	0	0	16
Rented from person	0	12	2	1	1	1
Rented from PS	1	2	1	0	0	4
Estate owned	0	1	0	0	0	1
Total	5	27	15	11	2	60

All the surveyed units were located on the narrow land strip between the stream and the main road. Some of the buildings have been constructed on a concrete platform on stream bank, and some were on columns running down to the stream bed. Out of the 60 surveyed units, 18% were located on flat land while the remaining 82% were located on slight to steep slope lands. Therefore, rapid runoff facilitated by the steep slopes brings more pollutants to the stream. frequency analysis of land extent indicated that 56.5% (n = 23) of the houses have less than 1 perch of free land available

[1]Greywater is the wastewater from kitchen and bathrooms.
[2]Blackwater is the wastewater from the latrines which is a mix of excreta, urine, washwater and toilet flushing water.

and 82% of the business premises in the sample do not have any free land available. These highly congested buildings will also enhance the risks on stream pollution.Buildings along the roadsides are purely business based, but there were few poor households and the majority is in medium wealth. The stated income of households found to vary between Rs. 5,000 – 90,000 the income of business premises ranges from Rs. 8,000 – 60,000.

Water Supply and Sanitation

Majority of the respondents have access to pipe borne water source inside or outside the house and only 8% use protected wells for drinking. It was observed that stream is used by 3% of the dwellings for washing kitchen utensils and bathing. Therefore, the stream pollution is directly affected on those who rely on the stream water and nearby well for domestic purposes.Water use for latrines varies from 2.5 to 40 L for households with an average of 20 L/day which is below than the normal water usage for latrines in Sri Lanka. According to the Sri Lanka Standard Institution (SLSI) average daily flow of blackwater varies from 40 to 60 L/person /day (SLSI, 2007). There is a huge variation in the water use for latrine per head in business premises and the units with house and business premises. Restaurants use more water whereas other shops used very less amount of water for latrines. Low water usage may lead to poor hygienic situation of the latrines causing bad smell and fly attraction as well. When consider the water sources for latrines; 76.5% of the dwellings which have individually owned latrineshave pipe borne water inside the latrine while few bring water from an outside tap. Another 12% and 4% obtain water from protected wells and unprotected wells respectively for their latrines. The remaining 6% of the respondents with individually owned latrines obtain water to the toilets from stream.

Majority (88%) of the respondents have latrines exclusively for their use whereas only 7% has no latrines. Open defecation is not a common issue in this peri-urban area,however one family in Henawalareported to use the stream for defecation. Poor wealth and income was found to be the reason behind poor sanitation and hygiene of the particular family. The comments from the community verify that the wealth, land availability and ownership issues has affectedin establishing a good sanitation system. Out of total surveyed units, eighteen places have more than one latrine in their buildings. The type of latrine and the water availability affect for the amount of water use, and then affect to the amount of wastewater generated in their premises. Majority (69%) of the latrinesare water sealed pour flush type, whereas 25% are commode type of flush latrine. Others have flush latrines with squatting pans. Nine percent of the surveyed units use both pour flush type with squatting pan and flush latrines with commode alternatively.

Many respondents do not experience any problems with their existing type of latrine, but very few commented on bad smell, fly attraction as issues mostly related to their pour flush latrine. Nine respondents have the problem with lack of access to water to maintain latrines hygienically.Worst hygienic conditions of latrine were found in the four line houses belong to tea factory of Pilimathalawa. Four extended families with children share a small room about 15*15 ft^2 space located closed to the stream and two latrines which are located in the stream bank. The hygienic conditions of the family members were very poor. The total monthly income for the family was about Rs.20000 per month and the mode of income generation is employment of both parents at the tea factory. These houses belong to the estate, and are in poor conditions even without a secured water supply. Hygiene condition of the latrines was also poor. It was observed that the people in these line houses have disposed their wastewater directly into the stream and burned solid wastes at the stream bank, and at the same time use stream water for washing purposes.

Observations verified that bad smell of the toilet - 26 % of the units, fly attraction - 8% of the units, andvisible faecal stains - 13.5% of the units. On overall, it was observed that 17.5% pits of the units are not maintained the properly (Table 2). This unhygienic condition of the latrines relates to low water usage by the households with pour flush latrines and lack of access to water at some dwellings. Unhygienic condition of latrines was mostly observed in the business premises than in the houses.

Sewage treatment and disposal system for most of the latrines werecesspits. Two self owned business premises were identified without cesspits/septic tanks, and could potentially bethe polluters of stream by diverting their raw sewage. Around 36% of latrines are connected to septic tanks, but only 17% have soakage pits whereas 19% discharge the septage[3] into the drain or stream (Figure 1).

[3]Septage is the effluent/ wastewater from a septic tank which is partially digested.

Table 2 - Hygienic condition of the latrines by observation

Type of premises	Cleanliness		Maintenance		
	Fly Attraction	Any bad smell	Fecal stains in squatting pans	Cracks in the system	Badly maintained pits
Houses	3	3	2	2	3
Business Premises	0	10	4	3	2
House with business premises	1	1	1	0	2

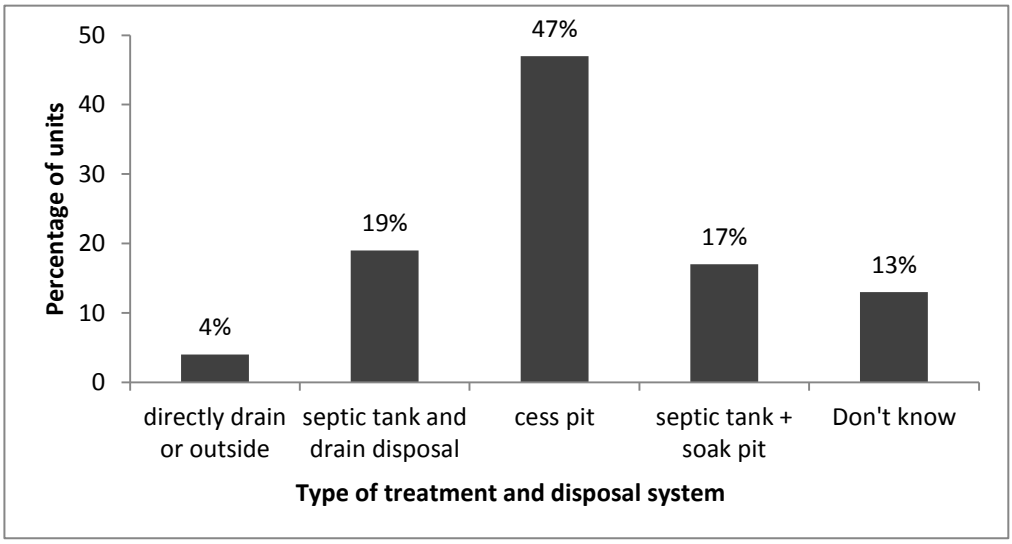

Figure 1 - Details of onsite treatment and disposal methods of sewage (n=53)

There are few places which is unknown about the disposal mechanism or place of pits where users are not the owners of the system (rented out). Some of those unknown methods could be the direct disposal to stream possibly through underground pipes, or secret diversions. It was observed that 45% of the units has pipe diverted to the stream from their buildings, but could not clearly demarcated whether those pipes are diversions for blackwater or greywater.

Majority of the system owners/users do not know about the pit details, but considerable amount of respondents (24%) have revealed that bottom of their pits have reached to similar depth to the ground water table. Though 32% of respondents said that their pits did not reached the water table, it is unconvinced to accept when consider the stream water level during the rainy season. Contamination from the pits which are closed to the stream is also possible during the rainy season. Few commented that they experience floods during the rainy season, and then there is a high risk of faecal contamination of stream water posing high risk of spreading diseases. According to the observations made during the survey, 79% of the pits are located at distance less than 10 m to the stream (Table3). Majority (92%) of the systems are in the potentially contamination zone when compared with SLS 745:2002 standard and PHI manual, where an 18 m (50 feet) distance has been recommended between streams and soak pits. Table 5 shows that the potential contamination by different disposal systems because of their location closed to stream.

About 42% of the wells are located less than 18 m distance to the septic tanks or pits. When consider the latrine density, the cesspits are not suitable for most of the places because they are located below than 10m distances from each other. Majority (75%, n=53) of the respondents have never experienced overfilling the latrine pits and has never been used the gully sucker to empty their pits. The pits located close to the stream in same level are suspicious to be contaminating the stream water through seeping of pollutants. There were some households who have constructed pits quite away from the river and maintaining the reservation area with a nice garden. Few respondents complained about sewage diversion into stream by nearby houses. Therefore, interviewing a neighbor household on each other would also be a good strategy for data collection surveys on sanitation.

Table 3 - Distances to stream from different types of sewage disposal systems

Disposal and treatment method	Distance pit to stream		
	<10 m	10-18 m	>18 m
Directly drain or outside	2	0	0
Septic tank and drain disposal	7	2	0
Cesspit	22	4	1
Septic tank + soak pit	6	1	2
Don't know	6	0	0
Total	43	7	3

Garbage and greywater disposal

Garbage in NanuOya is usual scenery to somebody who walks along the NanuOya. It is impossible to divert greywater to a pit or land other than the stream from the houses which has been constructed in 1-2 perch land space at the stream bank. Pilimathalawa Urban Council (UC) and YatinuwaraPradeshiyaSabha (PS) have a mechanism of collecting garbage regularly. People have been advised to separate their waste into two types as degradable and non-degradable, and to handover the tractor in separate days. Some people claimed that they are not aware on this collection pattern. Certain dwellers admit that they are disposing all the garbage into the stream mainly because of easy throwing outside the window or over the wall. The Figure 2 shows that the majority (80% and 72%) of the business premises give their wastes to the UC/PS tractor,but only 29% of household handover their kitchen waste to the UC/PS tractor.Another 25% households throw it to the stream, and another 25% use a pit to bury it. Kitchen wastes, polythene, plastics, and garden wastes are dumped into the stream by about 25% of the households with the clear negligence on the environment. People commented that the outsiders also throw bags of wastes into the stream while they walking or travelling by vehicles along the road.

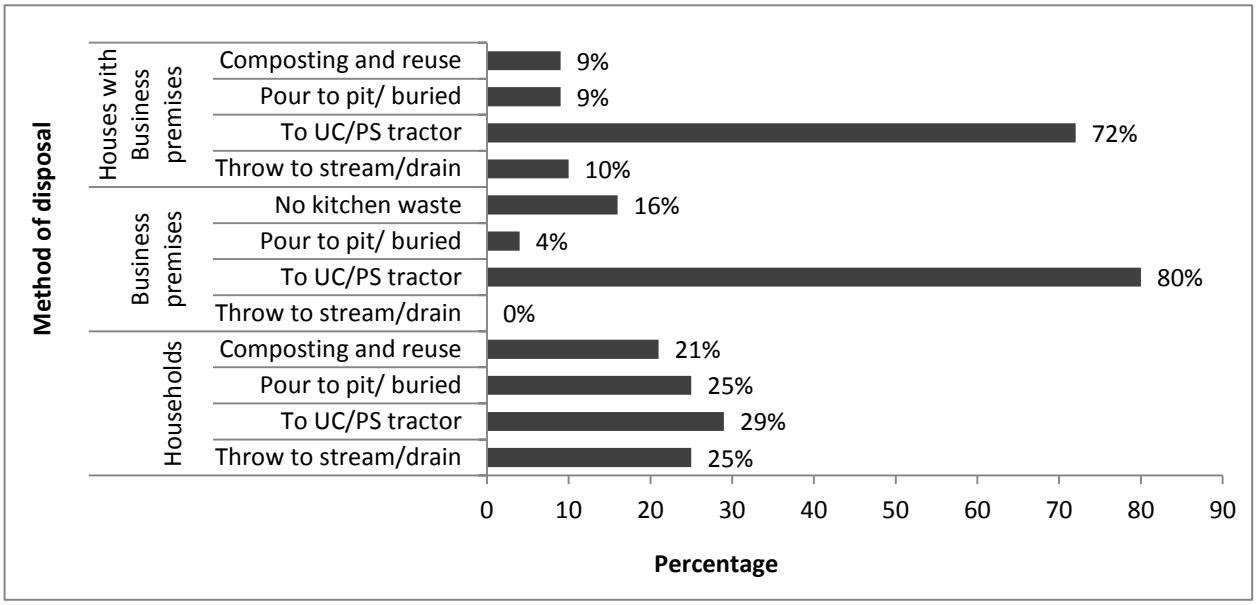

Figure 2 - Method of kitchen waste disposal

Regardless the type of premises it is well observed that majority 63% diverted their greywater from kitchen and bathrooms into the drain or directly to the stream (Figure 3). Even some of the well educated and well recognized people in the surveyed group carry out the same practice of diverting wastewater into stream. It shows the requirement of an environmental awareness program. Only 10% of the respondents use pits to dispose greywater and another 10% used to pour greywater into the garden or a plant. A common observation was that people often complain on how upstream or neighboring people dispose waste into the stream, but they rarely think on their own responsibility.

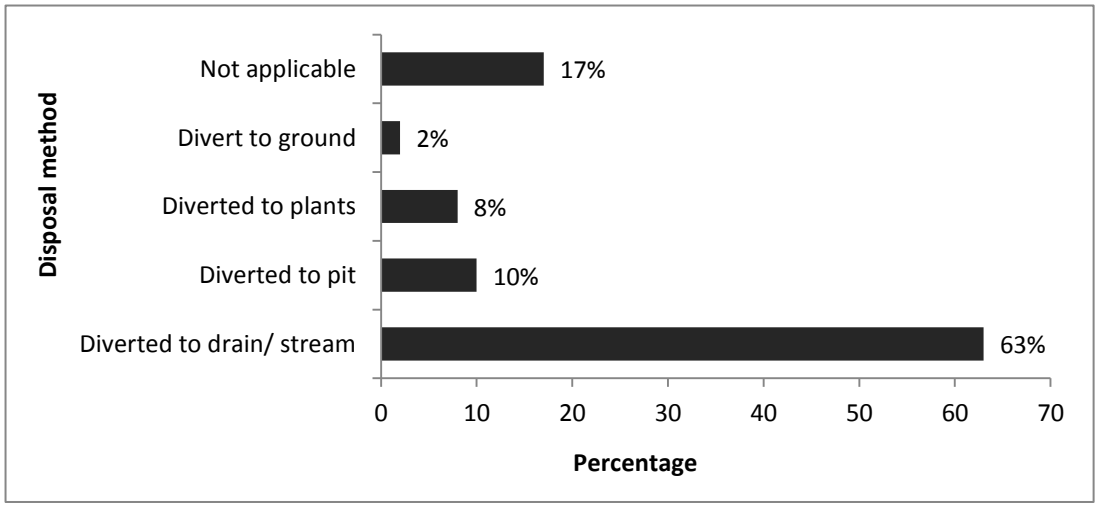

Figure 3 - Method of greywater disposal

There is a possibility to carry out an awareness campaign for the dwellers on environmental issues as 53% of the units have educated members up to A/L. Majority (78%) of people think that their existing sewage disposal system is sanitary enough. Therefore, it is difficult to decide on how much they can invest to upgrade the system to safeguard the environment. Many people agreed that they will financially contribute according to the solution and the technology that will be given and relative importance, but 20% think that they do not need any improvement. Willingness to pay for a centralized system varies from 50 rupees to 1000 rupees per month. Mean value of willingness to pay is 378 rupees per month for houses and 435 rupees per month for business premises. According to the comments of the people regarding the issues related to NanuOya and health of nearby communities, they do not receive any support from government institutions other than the collection of solid waste. Major reason for aggravated problems of NanuOya is giving permission/ deeds for the lands which should be allocated as reservation for the main road and the stream. Now some people have no other option other than discharging the effluents into NanuOya, because they have very limited space for construction.

CONCLUSIONS

Unimproved water and sanitation of the riparian communities of NanuOya pose immense pressure on health of the people and the stream. Poor wealth, insufficient land space, lack of awareness on the waste collection schedule, lack of conservation attitudes, and already polluted nature of the stream has led the people to dispose their solid and liquid waste into NanuOya. Sanitation and water are two human needs which are highly co-relate each other. NanuOya, by locating next to a heavily usedmain road of the country, provides an example for lack of interventions so far taken by the relevant government ministries and local authorities to conserve water and make its precious and sustainable use. Since the studied area is unplanned and highly congested, improved sanitation plan need the participation of all stakeholders.

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Envioronmental degradation and associated impacts by agricultural water pollution in upcountry of Sri Lanka

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ABSTRACT

Upcountry areas of Sri Lanka including Nuwara Eliya are famous for exotic vegetable cultivation and itsignificantly contributes tothe national agricultural production.However, the studies have identified that the upcountry areas are facing environmental and social problems such as water pollution, land degradation, health impacts etc. as a result of these intensive agricultural activities.The objective of this study was to assess the social and environmental impacts due to intensive agricultural activities in Nuwara Eliya area and to elaborate the usefulness of applying Integrated Water Resources Management (IWRM)concepts to overcome the existing environmental and socioeconomic problems. Assessment was done encompassing 15 Grama Niladari Divisions in Nuwara Eliya District Secretariatareawhich also includes the catchment area of Lake Gregory.Primary data were gathered through a questionnaire survey of50 household units and secondary data were collected from literature, statistics available with relevant institutions and key informant interviews with relevant officials. Multi temporal satellite images were analyzed to identify morphological changes of Lake Gregory and its' catchment.

The sample mainly consisted of farming families. Main drinking water sources are shallow wells located in highly vulnerable areas for contamination by agro-chemicals. Main irrigation water sources are streams and common wells. A considerable number of farmers practice agriculture in encroached lands and in inclined slopes enhancing soil erosion and water contamination. Water contamination is further enhanced by direct disposal of agricultural waste into the tributaries and washing pesticide sprayers and vegetables in water bodies. Irrespective of ownership of the land and level of education, majority of farmers does not apply soil conservation methods. According to the survey, main chemical fertilizer used by farmers is Muriate of Potash and main pesticide is Propineb. The average application rate of fertilizers and pesticides by farmers is many times higher than the recommended standard application rates by Department of Agriculture. The study revealed that net phosphorus accumulation in soil by cultivation of carrot in Nuwara Eliya is over 200 kg/hectare/ year. This can be identified as a considerable threat to the health of the water bodies. Assessment of secondary data in surface and ground water sources in Nuwara Eliya revealed the presence of agricultural water pollutants such as nitrate, nitrite, phosphorous etc. Existing evidences for environmental degradation are identified as water pollution, land degradation, soil erosion, sedimentation, effects on flora and fauna and aesthetic values. Satellite image analysis revealed the reduction of water surface area of Lake Gregory and increase of cultivated area of catchment of Lake Gregory since 1992 to 1998.

Main socioeconomic impacts due to agricultural water pollution are loss of family income/education/productive time, effect on family relationships, psychological effects etc. at household level and cost of dredging of water bodies and water treatment.

The study identified that there are number of organizations working on agriculture and environment in the area with poor coordination among them or with the farmers. In addition, the intension of the farmers is to earn a high income from their land ignoring the environmental consequences of some agricultural activities. If this situation continues to prevail, there will be serious social and environmental implications which would not be able to rectify easily. Hence, the study recommends development of strategic plan to reduce agricultural water pollution with the use of IWRM principals. This would be materialized through the participation of all stakeholders in the area, soil and water quality testing at regular intervals, preparation of legislation to control over application of agrochemicals and conducting strong continuous awareness programs to encourage farmers to practice environmental friendly agricultural practices.

INTRODUCTION

Environmental degradation is identified as the deterioration in environmental quality from ambient concentrations of pollutants and other activities and processes such as improper land use and natural disaster (OECD, 1997). Environmental degradation relates to the depreciation in the qualities and quantities of vegetation, soil, air and water

resources among others (Jimoh, 2012). Water quality deterioration, soil and land degradation, deforestation, atmospheric pollution and loss of bio diversity are some examples for the environmental degradation. Modern agriculture is one of the leading factors in environmental degradation due to heavy use of chemicals.

Upcountry of Sri Lanka is famous for exotic vegetable production. It is now a proven fact that the farmers of upcountry apply overdoses of fertilizers merely considering economical gains. These excess agro-chemicals remain in soil of vegetable fields and add into water bodies by runoff or recharge. Subsequently they deteriorate the quality of water resources. Lake Gregory is a man made water body located at the heart of Nuwara Eliya. Water of lake Gregory is used for the purposes of irrigation and rarely for consumption (UDA, 1996). Catchment of Lake Gregory is mainly located in semi – urban and agricultural zone. Half of the municipal council area of Nuwara Eliya is laid inside the hydrological catchment of Lake Gregory (UDA, 2004). The fertile sediments which resulted by the soil erosion and transporting from the tributaries of the Gregory Lake via agricultural fields encourage the aquatic plant growth in the Lake (UDA, 2004). The catchment of Gregory Lake has intensive vegetable cultivation and high population density and therefore high amount of urban wastewater and sediments come through runoff (Amarathunga *et al.,* 2010).

There are main socioeconomic impacts due to water pollution in the world, which creates economical and social problems in national, and village level. According to Mubarak (2000), an estimate of Rs. 2700 million in 1992 was made for the economic costs of water pollution in Sri Lanka especially for health impacts, loss of wages, treatment costs etc. In considering the socio economic impacts in estate sector in Nuwara Eliya, the polluted water has a greater impact on estate women and their daily activities (De Silva, 2009). According to Abeygunawardena *et al*. (2010), the identified impacts due to water pollution includes disease occurrences, mosquito breeding, bad odor and flash floods and the people live proximity to the canal suffer from bad odour especially during dry spells.
Since above environmental and socioeconomic impacts are creating irreversible harm to the environment including the natural resources, the scientists insist the importance of sustainable management of agriculture including water resources. Sustainable management of water in agriculture is critical to increase agricultural production, ensure water can be shared with other users and maintain the environmental and social benefits of water systems (OECD, 2012).The concept of IWRM or Integrated Water Resources Management is a strategic way of sustainable agricultural water management.

Agricultural water management covers irrigation and drainage and water management in rain-fed (WHO, 2012). Participatory approach from each stakeholder is important in implementation of agricultural water management plan. Some of the key areas of agricultural water management are onsite water reuse, measuring soil water and crop water requirement, irrigation scheduling, efficient application of irrigation water, efficient transport of irrigation water, use or runoff water, managing drainage water etc. (EPA, 2010).

Research Objectives
The main objective of this study was to assess the social and environmental impacts due to intensive agricultural activities in Nuwara Eliya area and to elaborate the usefulness of applying Integrated Water Resources Management (IWRM) concepts to overcome the existing environmental and socioeconomic problems.

MATERIALS AND METHODS
Study area is located in 15 Grama Niladhari divisions in Nuwara Eliya district secretariat division including catchment area of Lake Gregory. The sample of 50 household units was randomly and purposely selected considering the data obtained related to excising environmental condition revealed by the preliminary study. Distribution of the sample in 15 Grama Niladari divisions is illustrated in Table 1.

Table 1 - Distribution of the households (HH) of the sample in GN divisions

GN Division	No of HH
Senliyanate	2
Brook Side	3
Herath pura	1
Ruwan Eliya	6
Black pool	7
Sandathenna	8
Kalukele	1
Nuwara Eliya	8
Hawa Eliya	2
Kuda Oya	1

GN Division	No of HH
Magasthota	2
Boralanda	5
Buluwala	1
Kande Ela	1
Kuda Oya	2
Total	50

More number of households was selected from heavy agricultural areas such as Sandatenna, Ruwan Eliya and Blackpool compared to the other areas. Questionnaire survey was conducted among the selected 50 household units to collect primary data related to demographic characters, agricultural practices of farmers, status of water quality and existing water management practices. Field visits were conducted to gather data related to observable water quality characters of water sources, impacts of agricultural water pollution in area. Secondary data were obtained from the published data and from institutions and key informant interviews with relevant officials to assess the existing condition of water resources. Data were analyzed by SPSS and MS Excel software. Multi temporal satellite images were analyzed to identify morphological changes of Lake Gregory and its' catchment. Table 2 presents the data used in the study.

Table 2 - Data and Material

Data	Source/ method of collection
Primary data (Information on agricultural practices and water quality issues)	Questionnaire survey Field visits
Secondary data (i) Publications / Maps (water sources and water quality) (ii) Topographic maps (iii) Satellite Images: LISS III (1998, February) LISS II (1992, March) Landsat (1992, March)	Relevant government and non government institutions

RESULTS AND DISCUSSION

In considering the general characters of sample, the average family size of the sample is five. It is above the average family size of Sri Lanka of 4.1 according to Department of Census and Statistics (2007). The average age of the head of the family is about 49 Yrs. Majority of the sample (56%) has obtained secondary level education. Thirty percent of the sample involve in farming as their occupation. The average income of the sample is Rs. 20,327.00 and the average expenditure of the sample is Rs.23,770. About 46% of the sample receives monthly income above the national average monthly household income of Rs.20,048 (Department of Census and statistics, 2007).This shows that sample population is in fairly good economic condition.

Status of the water resources

There are many surface and ground water resources in the study area. Farmers use the water sources for domestic and irrigation purposes. Common water resources in Nuwara Eliya are own wells, common wells, tap water, natural springs and streams. Fifty percent (50%) of the sample uses their own well to fulfill drinking water requirements. This is a factor to be considered because most of these wells are located within or very close proximity to the agricultural fields and vulnerable to nitrate pollution. Main irrigation water sourcesare streams (39% of sample) and own wells (35% of sample).

Pollution of water sources occur due to theirclose location to agricultural lands, cultivation in encroached areas and waste disposal to the water bodies.Table 3 presents the vulnerability of water sources to pollution due to agricultural contaminants as a result of their location.

Table 3 - Distance from vegetable fields to the water source and their vulnerability to pollution

Distance from vegetable field	Vulnerability	% Drinking water source	% Irrigation water source
< 10 m	Highly Vulnerable	45	38
10 - 30 m	Vulnerable	23	14

Distance from vegetable field	Vulnerability	% Drinking water source	% Irrigation water source
30 - 100 m	Moderately Vulnerable	18	25
100 - 500 m	Less Vulnerable	11	14
> 500 m	Least Vulnerable	3	9

Fourty five percent (45%) of the drinking water sources in study area are located within the highly vulnerable distance from the agricultural fields. This is a serious health concern since there is a high possibility of contamination of drinking water with agrochemicals. Only 14 % of the drinking water sources are located in less vulnerable and least vulnerable distances. A considerable percentage (38%) of irrigation water sources isalso located in highly vulnerable distance facilitating contamination with agrochemicals.

Farmers have different perceptions regarding the general observable water quality of their drinking and irrigation water sources. As revealed by the survey, high percentage of respondents believe that their drinking (42%) and irrigation (77%) water sources are contaminated with agricultural pollutants. Figure 1 shows different comments of the households towards their drinking water sources in the area.

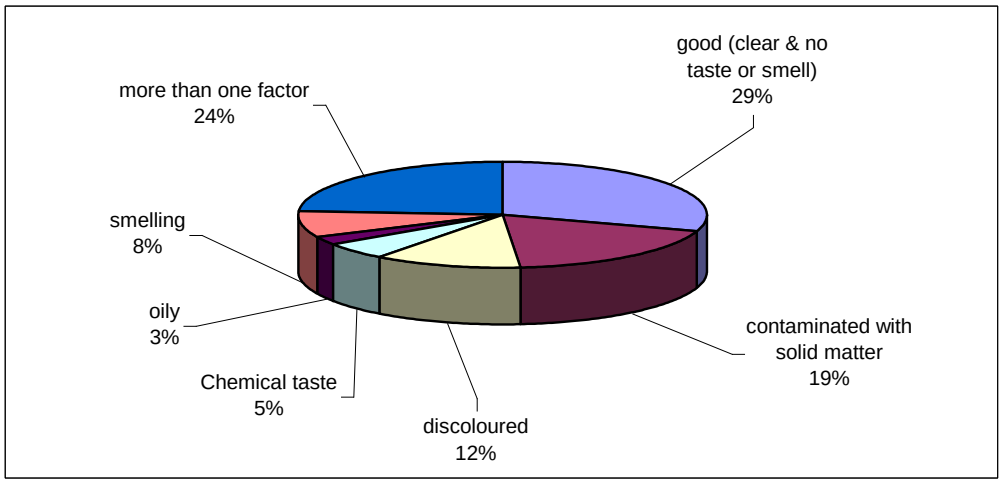

Figure 1 - Comments of the farmers regarding basic observable water quality of drinking water

As revealed by Rajakaruna *et al* (2005), higher values of NO_3-N concentrations(0.2 – 60.6 mg/L) are found in well water in Nuwara Eliya, which is about 2-3 times higher than WHO standards of 10mg/L and higher values of K+ concentrations (0.2 – 60.6 mg/L) are found in well water in Nuwara Eliya which is higher than acceptable range of K in irrigation water of 0-1.95mg/L (Ayres and Westcot,1985).As stated by Watawala *et al*. (2009) groundwater and surface water of upcountry have extremely high risk of contamination by fungicides according to Pesticides Impact Rating Index (PIRI). High Cr level (0.25-8.33 ug/L) was reported in Bomuruella reservoir. Maximum Cr level of 2ug/L is acceptable according to CEA standard for fish and aquatic life and most of the water samples had higher Chromium values as sted by Jayasinghe *et al.* (2011). Water quality of surface water bodies in Ragala area of upcountry showed Nitrate of 10 mg/L NO3] which is higher than WHO guideline of 10mg/L for Nitrate (National water Supply and Drainage Board, 2007/2008).

The above results obtained in past research have revealed the presence of agricultural pollutants in surface and ground water sources of upcountry. Intensive agricultural activities conducted in upcountry with improper agricultural practices and over application of fertilizers are identified as main reasons for these contaminations.These activities will ultimately lead to eutrophication, nutrient enrichment, in water resources enhancing environmental degradation.

Farming practices

A considerable number of farmers practice agriculture in encroached lands and in inclined slopes enhancing soil erosion and water contamination. The main crops grown include potato, beet, carrot, cabbage, lettuce, leeks and cut flower and total root crops cultivated are about 50% out of the total crops cultivated throughout the year. About 9 % of farmers in the study area have cultivated in encroached lands, enhancing the vulnerability of water sources for contamination by agrochemicals.Irrespective of ownership of land and level of education, majority of farmers does not apply soil conservation methods. Majority (61%) of the lands are with no soil conservation measures. There were enough statistical evidences to say that farmers tend to apply more soil conservation measures when the land size gets increased. This can be due to several reasons such as large lands are more vulnerable for soil erosion and economic reasons.

Water contamination is further enhanced by direct disposal of agricultural waste into the tributaries and washing pesticide sprayers and harvested vegetables in water bodies.It was observed that farmers wash vegetables and chemical utensils in streams and Nanu oya. As revealed by survey about 15% of the households stated that they are throwing their agricultural waste matters directly to nearby water bodies such as drains, and streams. Addition of poultry and livestock waste to the nearby water bodies is a major concern as it can pollute the water bodies very seriously. It is encouraging to see a considerable percentage (27%) of respondents use poultry and livestock excretaas organic manure.

According to the survey, main chemical fertilizer used by farmers is Muriate of Potash and main pesticide is Propineb. The average application rates of selected fertilizers were compared with the recommended fertilizer application rates (DOASL, 2006) of the Department of Agriculture (DOA). Accordingly, average application rates of MOP (Muriate of Potash) is 495%, 606% and 1588% higher than the standard application rate of MOP by Department of Agriculture for potato, carrot and beet respectively. The average application rate of TSP is 12% and 530% higher than the standard application rate of TSP by the Department of Agriculture for potato and carrot, respectively. Study revealed that the net phosphorus accumulation in soil by cultivation of carrot in Nuwara Eliya is over 200kg/hectare/ year. By cultivating carrot, input of 293 kg phosphorus per hectare (according to the study), managed to output 15 kg phosphorus per hectare (Potash Development Association, 2010). Therefore, there is a net phosphorus accumulation in soil over 200 kg/hectare/ year. This results in increasing phosphorus load to the surface and ground water sources and occurrence of eutrophication in water bodies. Further, the study investigated that average application rate of Propineb for cabbage has increasedby 21% more than the standard application rate of DOA (Department of Agriculture, 1997).

Environmental Degradation and Socioeconomic impacts

Existing evidences for environmental degradation are identified as water pollution, deterioration of riparian vegetation in the streams which can protect stream from inflow of sediments, sediment attached pollutants and other debries, and soil erosion. Encroachment of reservations and forest areas and the overgrowth of aquatic plants in water bodies are also evident.

Main socioeconomic impacts due to agricultural water pollution were identified in sample by survey as loss of family income (18%), loss of education (5%) and productive time, impacts on family relationships (49%), health impacts and psychological effects.About 55% of the sample population (Household units) spent equal or less than Rs. 500 per month for the treatment of drinking water and some extra cost for cleaning of drains. Secondary data revealed that the dredging of sediment in lake Gregory also create a huge cost to the government. For example Urban Development Authority/Nuwara Eliya had to bear a huge cost, approximately Rs. 90 million for dredging of lake Gregory in 1998 (UDA 2004). This can be prevented if there are stringent measures to protect the lake from inflow of sediments.

Morphological Changes in Lake Gregory and its catchment

Satellite image analysis revealed the reduction of water surface area and increase of cultivated area of catchment of Lake Gregory from 1992 to 1998. According to the analysis of land use maps prepared using Landsat TM image of 1992 and IRS LISS III (1998), about 66.49 hectare more has been cultivated in 1998 than 1992 and it is about 10 % increase. Catchment of Gregory Lake has intensive vegetable cultivation and high population density and so high amount of wastewater and sediment come through runoff (Amarathunga *et al.,* 2010) causing environmental degradation. The water surface area of Gregory Lake in 1998 has reduced by about 15.28hectare compared to the water surface area in 1992. The details of Urban Development Authority revealed that there was a huge occurrence of algal bloom on the water surface of Gregory Lake in 1998. This can be a major reason for the deduction of the water surface area. Land use statistics of Gregory lake catchment in 1992 and 2008 are given in Table 4.

Table 4 -Land use statistics of Gregory lake catchment in 1992 and 1998

Land use type	Area (Hectare) 1992	Area (Hectare) 1998
Cultivation area	660.59	727.08
Water surface area	45.62	30.34

Agricultural Water Management in the context of IWRM

There is a strong requirement for the land management plan in intensive agricultural areas of Nuwara Eliya ensuring protection of water resources. This study identified the government organizations (Eg: Department of Agriculture, Municipal Council, National Water Supply and Drainage Board, Central Environmental Authority, Urban Development Authority, Department of Agrarian Services, Disaster Management Center etc.), existed non government organizations (Palm Foundation, Sri Lanka Red Cross Society, Care International etc.) and farming community as the major stakeholders in land and water management in study area. However, lack of coordination among these organizations and farmers is one of the main reasons for poor land and water management in the area. Since the study area lies in the headwaters of

Mahaweli River, it is important to identify mechanism to conserve the watershed area through a participatory approach. In this approach, a coordinating body should be formulated with the representatives of all key stakeholders and the responsibilities should be shared between each of these organizations and individuals. Continuous awareness programmes should be conducted to farmers, tea growers, hoteliers and general public on protection of land and water as they were identified in very poor level. Lake management committee should be formed under the supervision of municipal council of Nuwara Eliya. The performance of these activities in the context of IWRM, should be continuously monitored and poor implementation of laws and regulations should be dealt with. A long term plan should be prepared by the coordinating body and the lake management committee to restore the riparian areas, control pesticide and fertilizer usage, promote organic fertilizer use and the progress should be monitored monthly basis. These activities should be considered as national priorities since the country is already facing a severe water crisis during long dry spells due to poor dry weather flow in major rivers.

CONCLUSIONS AND RECOMMENDATIONS

Nuwara Eliya and the surrounding area practice intensive agriculture where they cultivate two or more crops per year. Variety of water sources are used for domestic and irrigation use. However, own well in the most common water source for domestic use while natural streams are the main sources for irrigation. A considerable number of drinking water wells are located in close proximity at highly vulnerable areas to the agricultural fields posing a threat of contamination. Farmers have the perception that their water sources are polluted due to their poor physical appearance. Land encroachment and cultivation in steep slopes are seen as serious problems in the area. Majority of farmers do not apply land conservation measures however farmers with large lands more tend to apply land conservation measures to some extent.

Main chemical fertilizer used by farmers is Muriate of Potash and main pesticide is Propineb, a fungicide mainly used to maintain the crop in good condition. Highest average application rate of MOP (Muriate of Potash) is 1588% higher than the standard application rate of MOP by Department of Agriculture for beet. The highest average application rate of TSP is 530% higher than the standard application rate of TSP by the Department of Agriculture for carrot. Study revealed that the net phosphorus accumulation in soil by cultivation of carrot in Nuwara Eliya is over 200kg/hectare/ year.

It was revealed that there is no agricultural water management plan in the study area with IWRM concepts. Hence the study suggests formulating an apex body to identify the present environment issues and to prepare long term plan with IWRM concepts to manage land and water resources. Water quality testing at regular intervals, preparation of legislation to control over application of agrochemicals and conducting strong continuous awareness programs should be implemented to encourage farmers to practice environmental friendly agricultural activities. Further, a lake management committee also should be initiated to protect the catchment and lake Gregory. Strict monitoring and capacity building of relevant stakeholders will help to achieve the set goals within a relatively short period of time.

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Analysis of priorities in achieving environmentally safe sanitation: A note for policy reformation in sanitation and water nexus

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ABSTRACT

Sri Lanka has already on track to achieve the targeted sanitation coverage of 93% by 2015 in millennium development goals, but it is important to evaluate whether it is environmentally safe sanitation for all. This study reveals that the sanitation issues need to be addressed beyond the latrine infrastructure. A case study from the *Pussella Oya* catchment revealed that the due consideration for reducing faecal contamination of water should be recognized in addressing sanitation issues. Faecal contamination of surface and ground water is highly evident in *Pussella Oya* catchment though the majority of the households in three studied communities have their own latrines. This situation has been created by illegal discharges of sewage and groundwater contamination due to dense population in water rich areas. Mean knowledge scores on water and sanitation (town - 63%, village - 69%, estate - 67%), and hygienic practices scores (town - 70%, village -75%, estate 66%) are significantly different among communities which could play a major role in achieving environmentally safe sanitation. Knowledge on wastewater disposal and related regulations are insufficient among all the communities, thus leading to defecating and discharging wastewater into streams. Though plenty of legislative enactments are available to regulate the sanitation sector, contamination and related health issues are occurred because of poor enforcement and coordination among mandated institutions. In the present institutional set-up; final decision making, implementation, monitoring and regulation are finally vested with an institute or a person who has high political power which can reduce the capacity for good governance. Educating and empowering the community on sanitation, strengthening the institutional structure and improving the coordination among mandatory institutions are the important aspects to think in achieving environmental safe sanitation for all.

INTRODUCTION

Sanitation has been given a prime concern in the development programs because it is always related to health and dignity of people, and the environment. Inadequate sanitation could make water resources unsafe leading to widespread diseases via pathogenic contamination. Sri Lanka's position in terms of access to improved sanitation is 61% by 2005 and 85.7% by 2010 which is on track to achieve the sanitation target of millennium development goals (MDG) (NCED, 2005; NWSDB, 2011). However, it is evident that water related diseases are noticeable during the recent past in Sri Lanka, though we are on tract to achieve the MDG target. It is important to assess the case of hepatitis occurrence in Kotmale area in early 2007 which in the upstream (*Pussella Oya catchment*), and later rapidly spread to Gampola area in the downstream. There are three types of communities in the catchment; small town (peri-urban), villages, and estates. Though the preliminary measures were taken to control the outbreak by many institutions, faecal contamination of the water sources are still evident in the *Pussella Oya* catchment. Rajapakshe (2009), showed an increase of around 2000 CFU/ml mean faecal *Coliform* count of stream when it flows through the Pussellawa town. Provision of safe sanitation would improve people's health only if the sanitation facilities are well maintained and people have good personal hygiene. Even though a latrine is available, it would not be safe to use if the disposal system is contributing to the contamination of surface and/or ground water. Many rural people use groundwater as their potable water resource without knowing the potential faecal contaminations from surrounding latrines. This paper identifies the causal factors for poor sanitation, discusses the institutional and policy level issues related to water pollution management and proposes the solutions to address the perceived specific issues in national level.

METHODOLOGY

Several participatory research tools; *i.e.* transect walks, focus group discussions (FGD), social mapping, and questionnaire survey in three different communities (Pussellawa town, Black Forest village, and estate)were used to assess the prevailing water and sanitation situation of the *Pussella Oya* catchment. Questionnaire survey conducted using stratified random sample followed two steps namely; 1) water and sanitation survey for 300 households, and 2) Knowledge, attitudes, and practices (KAP) survey for 203 households. Data were analyzed using Statistical Package for Social Sciences (SPSS). Wealth scores and KAP values of households and their potential relationship to sanitation and water pollution were analyzed using Analyses of Variance (ANOVA) and non parametric tests appropriately. Institutional issues related to sanitation were noted during the FGDs, and officials of each institution related to water and sanitation

were also interviewed. Prevailing institutional set-up was studied and content analysis was done on the prevailing legislations, and their enforcement mechanisms.

RESULTS AND DISCUSSIONS

Sanitation and Water Pollution: A Case Study in Pussella Oya Catchment

Initial field investigation and stakeholder interviews recognized that sanitation issues in the *Pussella Oya* catchment are complex, and need an integrated approach for finding a sustainable solution considering technical, socio-economic and institutional aspects of prevailing issues. The access to basic sanitation facilities has been improved considerably from the time of occurrence of the hepatitis outbreak in 2007. Majority of residents in the town (90%), in the village (98%), and in the estate (68%) have access to latrines exclusively for themselves and 50 latrines were at construction stage in the estate. Open defecation is a common practice (13%) in the estate unlike other two communities and especially higher among the men. Few people interviews commented that "*No toilets in the field, we sit down under a tree or run to the jungle or the nearest stream when we need to defecate during field works*". According to their experiences, public toilets are not suitable for line rooms, owing to lack of maintenance plan by the estate or the community. The majority of the households who are in good or medium wealth categories, have considerably good access to and maintenance of sanitation facilities. ANOVA test shows that wealth scores are significantly different among the groups which have access to self-owned latrines and shared/no latrines (Tables 1 and 2).

Table 1 - Mean comparison for wealth and income among different sanitation groups

Comparison		Sum of squares	df	Mean square	F	Sig.
Wealth score	Between groups	32.383	2	16.192	29.270	.000
	Within groups	150.466	272	.553		
	Total	182.849	274			

Table 2 - Pair wise comparison of mean wealth score among different sanitation groups

Pair of comparison	Mean difference	Standard error	Sig.
Self-owned latrine Vs. Shared latrine	0.6819*	1.2169	.000
Self-owned latrine Vs. No latrine	0.8911*	0.2405	.005
Shared latrine Vs. No latrine	0.2092	2.6002	.422

* The mean difference is significant at 0.05 probability level.

The existing latrines of the *Pussella Oya* catchment contaminate surface and ground water due to high cesspit density, and illegal practices related to waste disposal by people. The majority (72%) of the latrines in the town are connected to cesspit whereas 14% are connected to septic tanks with soakpits, 11% discharge septage (partially digested sewage in septic tanks), and 3% directly divert sewage into drains. Almost all the latrines in the village and the estate are connected to cesspit, but fractures on pit cover and uncovered pipes were observed around 37% of the estate latrines. In addition, 3% of latrine were extremely dirty with filled faecal matter inside and backside of the estate latrines due to broken pits. Sometimes domestic poultry and dogs also feed on this dirt. Some of the line houses do not have upgraded latrine, but rely upon the old and dirty latrine without any repairs, cleaning or maintenance. In some instances, children (2-6 years) habitually defecate in the pavement of line houses and elders rarely control or teach them good practices. Elders also use the drain in front of the houses for washing their children after defecation. Some people throw the children's faecal matter to the waste dumping yard. All these dirt wash away with rain into the *Pussella Oya* and this unhygienic condition of line houses pose risk on health of the whole community.

Majority (81%) of cesspit are located without complying to the minimum recommended distance of 10 m among soakpits for the average daily flow of <2 m^3/day (SLSI, 2007) thus exceeding the potential soaking capacity of surrounding soil (Figure 1). Approximately 1/4 to 1/3 of cesspits in three communities were located adjacent to the water sources (Figure 2) and communities do not have a good knowledge about the ways of contamination. These results show that unplanned town settlements have aggravated the problems associated to sanitation and water pollution.

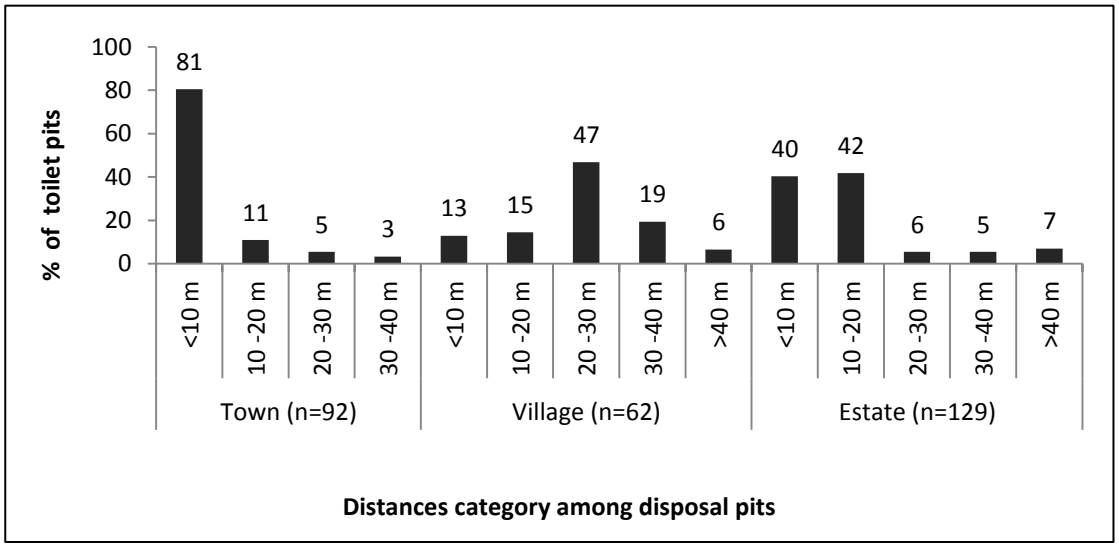

Figure 1 - Distances among disposal pits of latrine

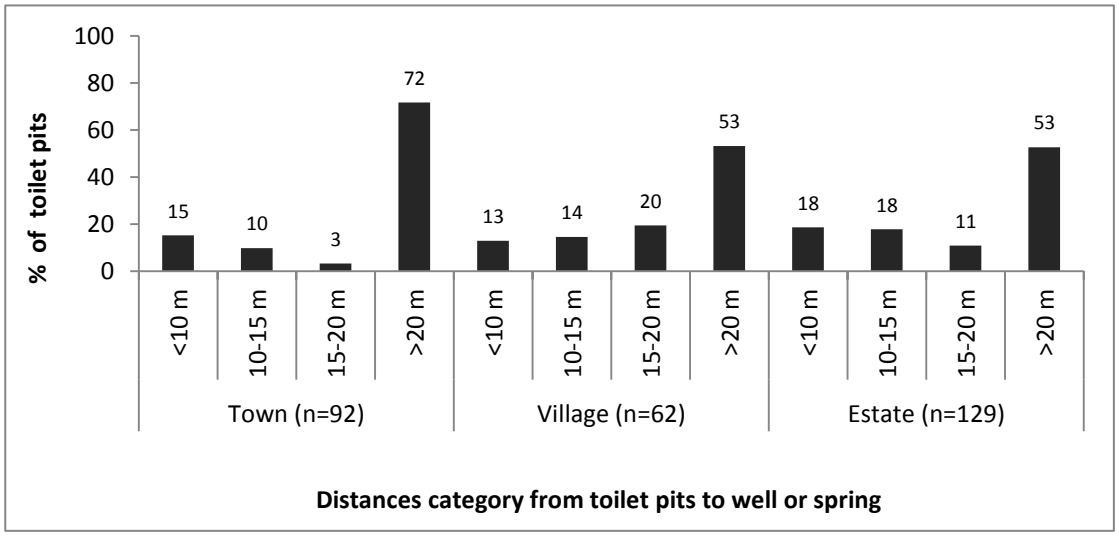

Figure 2 - Distances from latrine to drinking water sources

Above discussed issues are directly link with poor knowledge of people on both the regulations and technologies. Only part of the population has medium or good knowledge on each aspects related to water, sanitation, hygiene, and health, but only for very general questions. The average overall knowledge levels are 63%, 69%, and 67% for the town, village, and estate community, respectively which are significantly different among the communities (Chi square=16.296, p=0.000). Average overall practices scores are 70%, 75%, and 66% for the town, village, and estate, respectively and are significantly different among three communities (Chi square=23.103, p=0.000). Interestingly, answers to the attitude questions reveal that people strongly believe that pollution prevention is an institutional role rather than understanding their own responsibility. The estate community has a better knowledge than the town community, but their practices are poor because of lack of infrastructure, poor wealth, and negative attitudes for self involvement in their own sanitation and hygiene. Knowledge on some specific aspects like wastewater disposal, and related regulations are insufficient among all the communities, thus leading to direct discharging wastewater into water courses and defecating in streams. The results of KAP analyses imply that the poor hygiene practices leading to water pollution are closely linked with poor knowledge on wastewater disposal ways and regulations.

However, the education on safe disposal of wastewater and sewage, and regulations related to sanitation is necessary to prevent water pollution especially for the town community. The illegal wastewater disposal practices in the Pussellawa town are not entirely due to the knowledge gap, but also associated with lack of “transforming of technological solutions”. Providing latrine is not enough to upgrade the situation of the estate community, but strategies to improve the wealth, attitudinal change for self involvement, and education for behavioural changes are also required. Hygiene education is necessary for estate people to stop some habitual bad practices like open defecation. Attitudinal change through mobilizing estate people for proper maintenance of latrines would enhance the sustainability of the sanitation services provided by the management. Bad practices are not merely due to insufficient knowledge, but also due to

poverty, and poor access to basic water and sanitation facilities. Poor availability and quality of water is a critical issue in estate which affects the cleanliness of water sealed latrine and personal hygiene. Continuation of providing a house and a latrines and safe water for their exclusive use will be important to change their lifestyle and bad hygienic habits.

Institutional Set-up, Policies, and Legislations in Sanitation and Water Nexus

Sanitation and water nexus has a strong relationship of which lack of one component affects other and institutions responsible for water supply, prevent water pollution and ensure people's health are also included in sanitation and water nexus. The Medical Office of Health (MOH), National Water Supply and Drainage Board (NWSDB), Central Environmental Authority (CEA), Local government (LG) units and the Divisional Secretariats (Div. Sec.) are five main government institutions directly responsible in sanitation especially at the grassroots level. However, there is no separate single institution to regulate the sanitation sector in Sri Lanka. There are plenty of legislative enactments available to regulate the water pollution related to sanitation, but their implementation mechanism and coordination strategy among mandated institutions are not yet clearly recognized. It is clear that ad-hoc changes have been incorporated into the prevailing institutional structure time to time. This has been severely affected by the frequent changes being done during last 10-15 years in the central government with respective government ministries, and their mandates.

Sanitation is partly included in the water supply and sanitation policy, national water resources policy, and few other policy documents, but the content is not comprehensive enough to address prevailing issues of the sanitation sector in Sri Lanka. Understanding this issue, Sri Lanka is in the process of preparing the national sanitation policy, and the first policy document has been submitted for cabinet approval by the NWSDB. This policy has enormously focused on distributing the duties of the sanitation sector among relevant government and non-governmental organizations, but the coordination mechanism to the divisional/ village level is not clearly declared. It is obvious that the NWSDB is undertaking the national level coordination and the global networking, but activities will not promptly be coordinated at the ground level if such mechanism is not clearly identified and arranged.

Ground level institutional issues show that coordination is poor among the mandated institutions to take necessary actions. According to the views of Public Health Inspectors (PHI), they do not receive regular trainings and updates on areas such as new technologies and pollution control due to inappropriate sewage disposal. Identifying this problem, the PHI manual has recently been updated with contribution of the NWSDB including the environmental sanitation and required standards of the available technologies, but further capacity development is required. Many of the LGs do not have a proper mechanism for emptying gullies, unless dumping into a dug hole/pit. Since LGs are not equipped with human resources with required knowledge and experiences in waste management, the progress is still far behind. Though the draft policy declares that the NWSDB will provide technical assistance and design of treatment plants whenever requires upon the request of the LG, the process takes many years for designing and searching adequate funds. Divisional environmental officers of the CEA are responsible in monitoring and issuing Environment Protection License (EPL). Procedure of issuing EPL for small scale industries (in B and C bands) promotes the involvement of the CEA, LG, and MOH and decisions are taken by the technical and progress review committee. This procedure itself promotes the coordination among the responsible officials, but controversial situation is that the improper disposal of waste is still evident in some licensed slaughter units, and small industries in the research area. EPL monitoring procedure is strong enough to cancel the license of those who do these types of illegal discharges, but practical situation is that the discharges are still visible. Though PHIs have the power to act on public nuisances, they have limited capacity to recommend solutions because they are lacking the required specific technical knowledge for treatments. The inspecting officials of a business premises (for EPL) can propose technical options, but they do not recommend or support the business owner on the technology. Lack of institutional support for the technical guidance for sanitation at local level is a major reason for non-availability of appropriate wastewater treatment units in small scale industries. Another two major issues are that the political support for continuing offences and lack of commitment of the officials to find the offensive places. The major offence with respect to sanitation found in this study is the direct disposal of untreated sewage into a land by the LG units even though it is the main responsible institution to monitor the environmental health at local level. If the LGs are continuing offences, the CEA is the main government body who can take legal actions as required based on community complaints. Explorations revealed that the actions can only be taken on the approval of the minister because the National Environment Act has given the power of giving directions to the LG concurrence to the minister. It is clear that the political authority is the main governing body even in the sanitation sub-sector. The politicized institution, *i.e.* LGs have high power to act upon the illegal discharges, but giving directions to LGs is again authorized by a political person potentially leading to a slow progress of the LGs. The police also plays a role in inspecting the offences which is highly involved to the process recently. However, the role of environmental police is not included in the proposed sanitation policy.

The Summary of Issues related to Sanitation and Water Pollution

Sanitation is an essential need of a community and poses environment and health risks when the level of sanitation is low or insufficient. Sri Lanka has a comparatively good level of sanitation coverage, but it does not reflect the sustainability of sanitation services. Environmental, socio-economic, technological and institutional factors and their interactions have contributed to the complex nature of sanitation related issues in Sri Lanka. Diverse issues related to sanitation and water pollution identified in three different communities, perceived ground level and national level institutional and policy issues are incorporated in Figure 3. Knowledge dissemination on alternate technologies is needed where the soak pits are not appropriate.

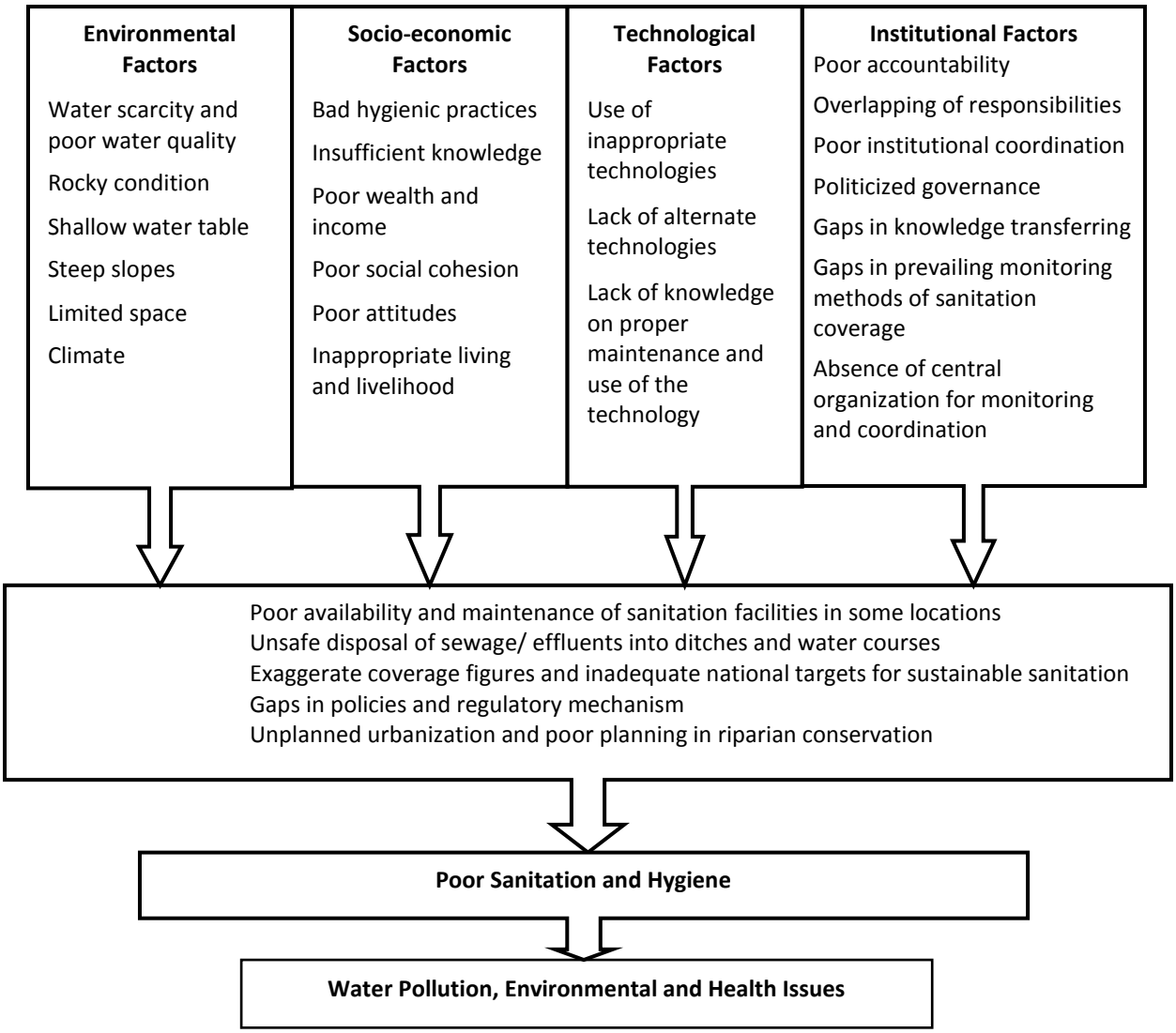

Figure 3 – Analysesof causal factors for poor sanitation and water polution

CONCLUSIONS

Poor sanitation highly affects on the pollution of surface and ground water resources and unplanned town settlements have aggravated the water pollution issues. Improved sanitation does not simply the access to a latrine, but it requires fulfilling of two major components; (a) secure access to hygienic latrine, (b) treatment and safe disposal. Despite the community category, environmental, socio-economic and institutional factors are highly related to and have an impact on the sanitation and health of a community. Therefore, provision of sanitation facilities should be a product of both hardware (technology) and software (knowledge, attitudes, institutional mechanism etc.) components. In the present institutional set-up, final decision making, implementation, and also monitoring and regulation are vested with an institute or a person who has high political power. As a result, it has reduced the capacity of good governance. A proactive strategic program is required instead of reactive programs to achieve environmentally safe/ total sanitation. Therefore, establishing an apex body to regulate, and coordinate the sanitation sector is recommended (similarly agreed this aspect in the Colombo declaration of SACOSAN IV). This apex body should be coming under a single ministry, should not be overlapped with mandates of other ministries and should be supported by a comprehensive and implementable national policy that will not allow for frequent changes. Monitoring and regulation should be given to an institute which is free from political interference, but with a strong governing power. Educating and empowering the community on

sanitation, strengthening the institutional structure and improving the coordination among mandatory institutions are the important aspects to be concerned in the national sanitation strategy. It seems that the perceived ground level problems are being addressed with the global movement of sanitation in past decade, but the above aspects discussed in this paper would contribute to streamline future programs.

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Performance of selected water treatment plants in the Central Province

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ABSTRACT

Water is an indispensable factor for all the living beings on earth. Safe and clean water has become scarce due to gradually increasing pollution. Therefore, surface water cannot directly be taken for consumption without treatment.

This study on selected three water treatment plants in the Central Province namely, University, Polgolla and Matale water treatment plants, aims to study the variation pattern of water quality parameters with time and investigate whether the variation of the parameters is within the desirable limits for drinking water. The probable reasons have also been found out whenever the variation is beyond the desirable limits.

A number of water quality parameters were considered for the statistical analysis. The variation of these quality parameters at four stages of the treatment, i.e. raw water, settled water, filtered water and treated water, was investigated. In view of achieving the objectives, these data was statistically analyzed using MINITAB 14 statistical package. Moving average curves were plotted for six month averaged data for each quality parameter and ANOVA was used. T- test was used to investigate whether there is any significant difference between raw water and treated water for these quality parameters and to investigate whether the parameters of treated water had been maintained below the desirable level or permissible level throughout the period for the test.

Analysis of the data revealed that all the water treatment plants have performed to the best of their existed capacity in order to remove 'colour' from raw water. Regarding 'turbidity', all the plants had performed satisfactorily as a whole, in the midst of various defects in the treatment processes, to remove excess turbidity from raw water. All the plants had maintained the required levels of pH, conductivity, alkalinity, hardness and iron amount in treated water.

Being considered the behavioral pattern of all the water quality parameters at these water treatment plants, it is found out that no major problems exist at the University and Polgolla Water Treatment Plants. The water treatment process can be further improved by addressing the minor defects existing. In case of Matale Water Treatment Plant, it can be recommended that the filters at the Water Treatment Plant should be attended and restored.

INTRODUCTION

Water is a key component in determining the quality of lives of the human beings. But, unfortunately, the liquid and solid wastes from communities have a considerable potential for water pollution. Therefore, water that looks drinkable can contain harmful elements, which could cause illness and death if ingested.

Raw water, especially surface water contains impurities in the form of suspended, dissolved and colloidal solids, bacteria, poisonous substances, colour, odour and mineral organic matter. Evidently, raw water is undesirable for drinking without being purified. This purification of water is called as water treatment.

Treatment of water is basically done at the Water Treatment Plants of NWS & DB. During various stages of the treatment, laboratory testing of water quality parameters is also done to find out whether the required standards have been achieved.

The treatment plants have been established a considerable period of time back, often with foreign aid. Due to financial limitations for operation & maintenance, various defects encountered at different stages of water treatment, may not have been addressed yet. Sometimes the water quality, even if not as good as earlier, may be still within the Sri Lankan Standards for Drinking Water (SLS 614) limits. All these defects may collectively act on lowering down the final product quality. Therefore it was proposed to analyze water quality data of three main water treatment plants i.e. University, Polgolla and Matale water treatment plants (WTPs), which are located in the Central Province with the following objectives.

(a) To study the variation pattern of water quality parameters with time
(b) To investigate whether the desirable limits for consumable water is achieved along the water treatment process from raw water to treated water.
(c) To find out possible reasons for deviations of water quality whenever the variation is beyond the desirable limits.

METHODOLOGY

Study Area

The study area which consists of University WTP, Polgolla WTP and Matale WTPare located in the Central Province. The first two water treatment plants are standing by the Mahaweli River while Matale WTP is standing by Sudu Ganga.

Data Collection

Monthly data regarding colour, turbidity, pH, conductivity, alkalinity, total hardness and total iron in water were collected from regional laboratory, NWS & DB, Peradeniya for the period of 1995 to 2006. At the regional laboratory, water samples are collected at four levels of the treatment,for testing. These are:

I. Water in the source : Raw water (RW)
II. Water mixed with alum : Settled Water (SW)
III. Water sent through sand filters : Filtered Water (FW)
IV. Water disinfected by chlorine gas or Bleaching powder : Treated Water (TW)

Statistical procedure

Firstly, water quality data were fed into the EXCEL spreadsheets. The outliers; extremely high and extremely low values were omitted from the data list using Box Plot method. Next, mean/average values for water quality data were derived. Rainfall has some effects on certain water quality parameters. Due to this reason, a period of six month was selected in deriving mean values so as it overlaps with the two main rainfall seasons in Sri Lanka, Yala and Maha, which are normally prevailing from March-August and September-February respectively. By deriving average values as described above, it eliminated the seasonal fluctuations within each Yala and Maha seasons.

For a single treatment plant, recorded quality parameter such as turbidity, colour, pH, conductivity, alkalinity, total hardness and total iron were taken for the analysis.Single quality parameter has values for four kinds of waters i.e. Raw Water (RW), Settled Water (SW), Filtered Water (FW) and Treated Water (TW).

To eliminate fluctuations between seasons, smoothing technique called as Moving Average method was used. In this study it was intended to select 2-point moving average due to the fact that 6- month average values have been derived for further analysis using this method. 2- point moving average values were obtained by feeding six-month average values to MINITAB (version: MINITAB 14).

Meanwhile, ANOVA (Analysis of Variance) was used to check for any differences between water types for different water quality parameters.

Paired t- test was also used for the monthly values to check for any differences between raw water and treated water regarding the quality parameters. Depending on this, it can be decided whether the plant has actually purified the incoming water with respect to each quality parameter, while it proceeds towards the production of treated water. Non-normal data were transformed to normal data using square root transformation method. One sample t- test was used for the original monthly data for treated water for all the quality parameters to find out whether the values for water quality parameters in treated water have been maintained within the desirable range.

RESULTS AND DISCUSSION

Turbidity

The summary of results obtained for the three water treatment plants is shown in table 01. As shown in the table, the mean values in turbidity for all the water treatment plants are following a decreasing trend from RW up to FW and the values are significant from each other ($P< 0.0001$). Therefore, it can be suggested that the turbidity in purifying water has been significantly removed from RW to FW.The difference of turbidity levels between FW and TW is not significant at University WTP and Polgolla WTP, and significant at Matale WTP.

The only treatment process after filtration is disinfection, where chlorine gas or bleaching powder is added. At this point removal or addition of turbidity cannot be expected. However, several reasons have caused the turbidity of TW at Matale WTP to be increased than FW.

Post-liming had been practiced at TW. Another reason may be that TW has got mixed with the trapped organic substances at the clear water sump. The washout valve of the clear water sump is positioned incorrectly and does not allow frequent and complete cleaning. Jar test apparatuswas out of function and therefore, alum strength had not been measured. Alum dosing pumps in the treatment plant were not working well and the quality of alum was varying. If the alum dosing rate is too low or too high the optimal sized floc is not formed and instead microflocs are formed. Generally, microflocs do not settle properly. There are two mixers to mix the raw water slowly in the sedimentation tank and to allow satisfactory flocculation. But these mixers were rotating in opposing directions. This also has led to the formation of non-optimum sized floc, which does not settle well and passes to the next step in the process. Turbidity in TW in Polgolla WTP has gone high, due to absence of a jar test apparatus, absence of dosing pumps and varying quality of alum.

It was also found that the values of turbidity in TW were significant against the DL (max) of turbidity in all the treatment plants ($P< 0.0001$). Turbidity of TW had been maintained below 2 (two) NTU at the University WTP and the turbidity of TW had been maintained above 2 (two) NTU at the Polgolla and Matale WTPs, throughout the period. Still, turbidity values in TW in these two treatment plants are below the maximum permissible level.

The difference between the turbidity values, between RW and TW was found significant reference to all the treatment plants ($P< 0.05$) which indicates satisfactory removal of turbidity by the treatment units.

Table 1 - Summary of the results obtained for turbidity at each treatment stage of water treatment plant

Statistical Test	Water Treatment Plant		
	University	**Polgolla**	**Matale**
ANOVA	RW = 8.943[a]	RW = 8.222[a]	RW = 6.917[a]
H_0, $\mu_1=\mu_2=\mu_3=\mu_4$	SW = 4.752[b]	SW = 6.459[b]	SW = 4.850[b]
H_1, At least one population mean differs	FW = 1.300[c]	FW = 3.595[c]	FW = 3.055[c]
	TW = 1.061[c]	TW = 4.628[c]	TW = 5.552[d]
One Sample	P< 0.0001	P< 0.0001	P< 0.0001
T-Test			
H_o, μ = DL (max)			
H_1, μ > or < DL (max)			
DL (max) =2 NTU			
Paired T-Test	P < 0.005	P< 0.0001	P < 0.001
H_o, $\mu_D = 0$			
H_1, $\mu_D \neq 0$			
Status	Satisfactory	To be improved	To be improved

$\mu_1, \mu_2, \mu_3, \mu_4$ = Mean value of the parameter in RW, SW, FW and TW respectively
DL (max) = Maximum Desirable Level of the parameter
NTU= Nephlomeric Turbidity Units
μ_D = Mean value of the difference between RW and TW

Colour

Table 02 reveals the statistical results for three water treatment plants, in terms of colour. As shown by the above table, the mean values of colour for RW, SW, FW and TW are significantly different from each other for Polgolla and Matale WTPs ($P< 0.0001$). In case of University WTP, a significant difference exists among RW, SW and FW and there is no difference in colour between FW and TW ($P< 0.0001$). The only treatment process after filtration is disinfection where chlorine gas or bleaching powder is added. At this point colour removal or addition cannot be expected other than a bleaching effect dependent on time of contact also. Therefore, the curves for FW and TW should theoretically be overlapped. The reasons explained in 'turbidity' for Polgolla WTP and Matale WTP have caused increased colour in TW, for these two treatment plants.

The majority in the Polgolla area has been supplied with ground water too, during the period from 1995 to 2006. This water were not subjected to any treatment except for chlorination. Ground water is normally rich in Fe^{2+} and Mn^{2+}. If the sampling for TW has been done by the laboratory personnel, for these disinfected ground water supplies, there is a possibility that the colour of the TW sample becomes high due to the presence of Fe^{2+} and Mn^{2+}. This might have been a cause for increased colour in TW in Polgolla WTP.

The values of colour in TW against the DL (max) were significant with related to all the treatment plants ($P< 0.05$). The mean values of colour of TW have been higher than the DL (max) for colour.

The details in table 02 further reveals that significant probability values for the difference between the mean values of colour in RW and TW have been resulted (P< 0.05)which denotes satisfactory removal of colour by the treatment plants throughout the period considered.

Table 2 - Summary of the results obtained for colour at each treatment stage of water treatment plant

Statistical Test	Water Treatment Plant		
	University	Polgolla	Matale
ANOVA	RW = 46.55[a]	RW = 47.99[a]	RW = 40.16[a]
H_0, $\mu_1=\mu_2=\mu_3=\mu_4$	SW = 26.07[b]	SW = 35.10[b]	SW = 28.87[b]
H_1, At least one population mean differs	FW = 8.95[c]	FW = 20.15[c]	FW = 20.01[c]
	TW = 8.95[c]	TW = 27.70[d]	TW = 33.53[d]
One Sample	P < 0.005	P< 0.0001	P< 0.0001
T-Test			
H_o, μ = DL (max)			
H_1, μ > DL (max)			
DL (max) = 5 Pt-CoUnits			
Paired T-Test	P< 0.0001	P< 0.0001	P < 0.008
H_o, $\mu_D = 0$			
H_1, $\mu_D \neq 0$			
Status	Satisfactory	To be improved	To be improved

Pt-CoUnits= Platinum Cobalt Units

pH

Secondary data analysis for pH related to the three water treatment plants has produced statistical results as given in table 03. As shown by the table, it is quite clear that at University WTP and Polgolla WTP, pH in each level of water is not significantly different from each other up to FW and there is a significant increase in pH from FW to TW(P< 0.05). At Matale WTP, there is a significant reduction in pH from RW to SW and afterwards no significant difference between SW/FW and FW/TW(P< 0.05).

In the WTPs, alum ($Al_2 (SO_4)_3 . 14H_2O$) has been the most frequently used coagulant. The reaction of alum with water is a complex process and this is frequently represented by the following simplified equation.

$Al_2(SO4)_3 + 6H_2O \longrightarrow 2Al(OH)_3 + 3H_2SO_4$
(McGhee, 1991).

Lime adds hydroxyl ions into the water.

Table3 - Summary of the results obtained for pH at each treatment stage of water treatment plant

Statistical Test	Water Treatment Plant		
	University	Polgolla	Matale
ANOVA	RW = 6.634[a]	RW = 6.573[a]	RW = 6.957[a]
H_0, $\mu_1=\mu_2=\mu_3=\mu_4$	SW = 6.531[a]	SW = 6.555[a]	SW = 6.811[b]
H_1, At least one population mean differs	FW = 6.514[a]	FW = 6.686[a]	FW = 6.832[b]
	TW = 6.710[b]	TW = 6.875[b]	TW = 6.775[b]
One Sample	P< 0.0001	P< 0.0001	P< 0.0001
T-Test			
H_o, μ = DL (max)			
H_1, μ > DL (max)			
DL (max) = 6.5 pHUnits			
Paired T-Test	P < 0.003	P< 0.0001	P< 0.0001
H_o, $\mu_D = 0$			
H_1, $\mu_D \neq 0$			
Status	Satisfactory	Satisfactory	Satisfactory

The University WTP practices post liming in addition to pre liming. Polgolla WTP is serving treated ground water also. Ground water is normally comprised of high levels of alkalinity, hardness and conductivity. Therefore, creating a high value for pH in TW is not questionable.

Pre liming is normally not practiced in the Matale WTP because RW is inherently basic due to the geological setting of the area. The Matale Plant receives Mahaweli water diverted from the Ukuwela Power Station. On and off, this flow of water is stopped and then the RW for the plant becomes the water from springs of the area and the water in the other streams. This water in streams and springs of the area that flows to the plant is highly basic. The plant operators do not know whether the receiving water comes from Mahaweli or not. Therefore, alum has been added in the usual way and this may not have resulted the effective pH for the coagulation. By the addition of lime, as post liming the acids caused by alum has been neutralized and pH of drinking water has brought up to a favourable basic region (Personal Communication, 2007[9]).

The values of pH for TW against the desirable pH level was also tested and found as significant (P< 0.0001). Therefore, it can be decided that the values for this water quality parameter have been higher than the DL (max). The best pH that should exist in drinking water is 6.5-8.0 (Monod, 1991). Since the values of pH in TW in all WTPs have been fluctuated within the desirable range, it can be concluded that they have maintained a desirable level of pH in TW.

A significant difference has been found between RW and TW in terms of their pH values (P< 0.05). Therefore, it is obvious that the treatment process has created difference in pH between RW and TW which cannot be considered as negligible.

Conductivity

Secondary data were collected with respect to conductivity and its analysis has derived following results as indicated in table 04.

Table 4 - Summary of the results obtained for conductivity at each treatment stage of water treatment plant

Statistical Test	Water Treatment Plant		
	University	**Polgolla**	**Matale**
ANOVA	RW = 54.24[a]	RW = 65.56[a]	RW = 80.24[a]
H_0, $\mu_1=\mu_2=\mu_3=\mu_4$	SW = 56.12[a]	SW = 73.18[b]	SW = 85.09[a]
H_1, At least one population mean differs	FW = 57.31[a]	FW = 75.16[b]	FW = 84.02[a]
	TW = 64.10[b]	TW = 85.50[c]	TW = 84.82[a]
One Sample T-Test	P< 0.0001	P< 0.0001	P< 0.0001
H_o, μ = DL (max)			
H_1, μ < DL (max)			
DL (max) = 750µS/cm			
Paired T-Test	P< 0.0001	P< 0.0001	P < 0.104
H_o, $\mu_D = 0$			
H_1, $\mu_D \neq 0$			
Status	Satisfactory	Satisfactory	Satisfactory

µS/cm= Micro Siemens/ centimeter

As shown by the above table, conductivity has gradually increased along the process. Concerning University WTP, a significant difference exists only between FW and TW (P< 0.0001)while no significant difference exists among each treatment stage at Matale WTP(P>0.05).Results for Polgolla WTP show that the difference in conductivity is not significant between SW and FW whereas it is significant between RW/SW and FW/TW(P< 0.0001).

Sulphates from alum, calcium, magnesium and carbonates in lime, hypochlorite ions at chlorination are the contributors to conductivity. At the university WTP, alum and lime are added to RW on its way to the sedimentation tanks. Therefore, the level of conductivity in SW has become higher than that of RW, though the difference in conductivity between RW and SW is not significant. There is no addition taking place at the filters and theoretically an increase in conductivity in FW cannot be expected unless immediately after backwashing. University WTP practices post liming and chlorination at the level of TW and due to this reason, the conductivity in TW has gone to higher levels owing to the addition of calcium, magnesium, carbonate ions in lime and hypochlorite ions in chlorine solution.

The Polgolla WTP has supplied groundwater as well, apart from treated river water and the majority of the supplies have comprised of groundwater. Therefore, the chances for the regional laboratory at Peradeniya, taking samples for TW of these treated groundwater supplies would have been high. Normally, groundwater contains a higher level of conductivity. The reasons behind the variation in conductivity from RW to FW can be further explained as done for the University WTP.

Geologically, the rock formation in Matale area is limestone. Therefore, the conductivity in RW is higher by nature and pre liming is not practiced. SW has higher values in conductivity owing to the usage of alum. On the other hand, TW is having the highest values of conductivity among all the types of water due to post liming and chlorination.

Being tested the conductivity in TW, against the DL(max), it was revealed that there is a significant difference($P< 0.0001$). This shows that conductivity of TW has been maintained below the DL(max).

The difference between the conductivity in RW and TW was also tested and resulted as not significant for Matale WTP($P>0.05$).The test has resulted significant values for University WTP and Polgolla WTP($P< 0.0001$). These results suggest that that the values of conductivity in TW have become promisingly different from the values for conductivity in RW as expected.

In the process of water purification the chemicals are not used in ample amounts. In this situation, the addition of chemicals has not caused significant changes in conductivity in real situation, even though TW has ended up with a higher level of conductivity compared to that in other types of water. In the light of all these information it can be stated that all the water treatment plants have performed well to produce drinking water within the specified conductivity range.

Alkalinity

The alkalinity of water is principally due to salts of weak acids and strong bases, and such substances act as buffers to resist a drop in pH resulting from acid addition. Alkalinity is thus a measure of the buffer capacity. The major portion of the alkalinity in natural waters is caused by three major classes of materials i.e. hydroxides, carbonates and bicarbonates. For most practical purposes, alkalinity due to other materials in natural waters is insignificant and may be ignored. Secondary data were collected with respect to alkalinity as well, and its analysis has derived following results as indicated in table 05.

The alkalinity in RW in relation to University WTP has slightly reduced at the next stage of water purification and gradually increased thereafter, along the water purification process. In spite of this slight variation in alkalinity in four types of water, there is no significant difference among each other in the context of alkalinity ($P>0.05$).

Alkalinity values at Polgolla WTP explain that, no marked differences are there, among RW, SW, and FW. Observation on the values further says that SW has possessed alkalinity values slightly higher than that of RW. However, FW has resulted more or less same values in alkalinity compared to RW. TW seems to have significantly higher values for alkalinity than all the other types of water ($P< 0.0001$).

As per the values in the table, alkalinity has increased from RW to SW at Matale WTP and gradually decreased up to TW. Even though changes have occurred in the levels of alkalinity, the changes have not become significant ($P>0.05$).

Theoretically, a big difference in alkalinity in water during its process is not expected because the effect of addition of OH^-, CO_3^{2-} and HCO_3^- ions by the addition of lime is cancelled off by the addition of H^+ ions through the reaction of alum with water (Tebbut, 1983). Alkalinity in SW may be slightly high or low from that of RW, depending on the usage of alum and lime at the initial stages of purification. The University Water Treatment Plant practices post liming in addition to pre liming. In the event of the post liming slightly high values in alkalinity in TW can also be expected.

As explained in the previous water treatment plant, high values for alkalinity in SW upon RW in Polgolla WTP and Matale WTP are solely due to the changes in alum and lime addition. Apart from that the Polgolla Plant has supplied ground water for a majority of areas. Therefore, the chances for the regional laboratory in Peradeniya taking samples of TW by these disinfected ground water supplies would have been high. Normally, the levels of alkalinity, hardness and conductivity are high in ground water than surface water (Mann *et al.*, 1982).

The higher values for alkalinity in RW Matale WTP, compared to RW for the University WTP and Polgolla WTP may be due to the discharge of municipal sewage, domestic sewage and urban wash off in to the fresh water bodies. Apart from that natural reasons also influence for alkalinity in RW. In Matale area limestone is abundant and these rocks are generally high in alkalinity. Hence, water flows through these regions contain high amounts on alkalinity. Changes in alkalinity at the level of SW may be due to changes in alum addition and changes at the level of FW can be explained with the use of theory of ionization applied in filters. Matale WTP has applied gaseous chlorine and bleaching powder for chlorination and hence it may have resulted a lesser value for alkalinity at the level of TW.

The difference between values of alkalinity in RW and TW showed no significant difference for University WTP and Matale WTP ($P>0.05$). Therefore, the two types of water had maintained their alkalinity at almost the same levels, while

on the processing. It was found that the difference between values of alkalinity in RW and TW was significant due to possible ground water sampling for TW (P< 0.0001).

Table 5 - Summary of the results obtained for alkalinity at each treatment stage of water treatment plant

Statistical Test	Water Treatment Plant		
	University	Polgolla	Matale
ANOVA	RW = 19.54[a]	RW = 24.62[a]	RW = 29.69[a]
H_0, $\mu_1=\mu_2=\mu_3=\mu_4$	SW = 18.25[a]	SW = 24.76[a]	SW = 31.22[a]
H_1, At least one population mean differs	FW = 18.77[a]	FW = 24.50[a]	FW = 30.41[a]
	TW = 19.89[a]	TW = 28.41[b]	TW = 29.46[a]
One Sample T-Test H_o, μ = DL (max) H_1, μ < DL (max) DL (max) = 200mg/l $CaCO_3$	P< 0.0001	P< 0.0001	P< 0.0001
Paired T-Test H_o, $\mu_D = 0$ H_1, $\mu_D \neq 0$	P < 0.362	P< 0.0001	P < 0.209
Status	Satisfactory	Satisfactory	Satisfactory

mg/l $CaCO_3$= Units of milligrams per liter (mg/l) of $CaCO_3$

Total Hardness

Hard water is generally considered to be those waters that require considerable amounts of soap to produce foam or lather and that also produce scale in hot water pipes, heaters, boilers and other units in which the temperature of water is increased materially. The hardness of water reflects the nature of the geological formations with which it has been in contact. Hardness is caused by multivalent metallic cations. The principal hardness-causing cations are the divalent calcium, magnesium, strontium, ferrous iron, and manganous ions. Aluminum and ferric ions are sometimes considered as contributing to the hardness of water. However, their solubility is so limited at the pH values of natural waters that ionic concentrations are negligible. Table 06 shows the results of hard water in different treatment plants.

Values for total hardness were subjected to statistical tests and following results were obtained as given in table 06.

Table 6 - Summary of the results obtained for total hardness at each treatment stage of water treatment plant

Statistical Test	Water Treatment Plant		
	University	Polgolla	Matale
ANOVA	RW = 25.35[a]	RW = 30.74[a]	RW = 37.17[a]
H_0, $\mu_1=\mu_2=\mu_3=\mu_4$	SW = 25.05[a]	SW = 32.03[a]	SW = 38.65[a]
H_1, At least one population mean differs	FW = 25.35[a]	FW = 31.53[a]	FW = 37.84[a]
	TW = 28.12[b]	TW = 36.71[b]	TW = 38.71[a]
One Sample T-Test H_o, μ = DL (max) H_1, μ < DL (max) DL (max) = 250mg/l CaCO3	P< 0.0001	P< 0.0001	P< 0.0001
Paired T-Test H_o, $\mu_D = 0$ H_1, $\mu_D \neq 0$	P< 0.0001	P< 0.0001	P < 0.189
Status	Satisfactory	Satisfactory	Satisfactory

It is evident that there is a significant increase in the values from FW to TW in relation to University WTP and Polgolla WTP (P< 0.0001)while no significant difference exists among each stage of water for Matale WTP(P>0.05).

The rock type in the area is charnockitic gneiss and the soil type in the upstream area of the University Plant is reddish brown latosolic soil where calcium and potassium ions are the main cations (Mapa, 2005). These ions can get added to river water via rainfall.A considerable difference in the levels of hardness among the four types of water cannot be taken place. This is because the contribution from the various chemicals i.e. alum, lime and chlorine, added to the purifying process is less. Although, the University Plant has practiced both pre liming and post liming, this addition has been done

with minimum dosages. In the University WTP, hardness in TW has risen to higher levels than the hardness levels for FW. The reason behind this condition may be post liming, which is practiced at TW level. Even though TW displays a significant increase in hardness, this amount is far below the DL (max) for hardness in Sri Lankan Standards for drinking water.

The upstream area of the Polgolla WTP comprises of the same rock type and the soil type as described in University WTP. Statistical analysis has resulted a significant increase in the level of hardness for TW. This is actually because the plant's major supply of water has been ground water, up to the recent time. Ground water normally contains hardness forming ions in ample amounts.

Observation on table 06 shows that the mean values for total hardness for the different types of water are higher than the levels for hardness in previously discussed water treatment plants. Matale area contains reddish brown latosolic soil. Calcium and magnesium act as basic cations there. The rock type is mainly chrystalline limestone deposits of Precambrian age. They occur inter banded with the other rock types such as quartzites, charnochites and gneisses as discontinuous but well defined bands, some of which can be traced for many miles along the strike (Mapa, 2005). These calcium and magnesium ions in soil and rocks in high amounts are washed away with rainfall and get accumulated in waterways. Because of this reason, all the types of water have resulted in comparatively higher mean values for hardness.

Total hardness values of TW were tested against the DL (max) for total hardness and significant probability values have been obtained($P< 0.0001$).That means the total hardness of TW has been maintained below the DL.

The level of significance for the difference between RW and TW, in their values for hardness was tested and found as significant regarding University WTP and Polgolla WTP confirming that the treatment processes have made TW significantly different from RW in terms of its total hardness($P< 0.0001$). The test was not significant for RW and TW in Matale WTP ($P>0.05$).

Total Iron

Iron is another important water quality parameter which is present in most surface and ground water and measured at the regional laboratories of the NWS & DB. The presence of iron in water in appreciable amounts imparts an unpleasant taste and objectionable colour in water which may be unacceptable by the public. Therefore, studying the removal pattern of this element along the process in different treatment stages with time, has become important. Table 07 summarizes the results obtained after statistical analyses with regard to this water quality parameter.

Examining the values in the table, it is evident that the four types of curves are fluctuating well below the DL (max). A significant reduction in the contents of iron has taken place in all WTPs when water proceeded from RW to FW. The difference in the contents of iron between FW and TW has not been significant at the University WTP while this difference has become significant at Polgolla WTP and Matale WTP ($P< 0.0001$). Accordingly, aeration, lime addition, filtration processes in the treatment plants have proceeded satisfactorily in the removal of iron. The addition of iron to purifying water at the clear water sump has been minimal at the University WTP which can be expected in a well functioning purification plant. At polgolla WTP, the content of iron in TW is somewhat higher than FW due to possible groundwater sampling in TW and the difference between FW and TW had not been significant as well. High contents of iron in TW at Matale WTP, may be due to the erratic position of the wash out valve in the clear water sump. Because of the above reason, TW has got mixed with accumulated iron in the sump resulting high iron content.

The values for total iron in TW being tested against the DL (max) for iron were resulted as significant ($P< 0.0001$). This shows that the total iron of TW has been maintained below the DL (max) throughout the study period at the three water treatment plants.

The difference between values for total iron, in RW and TW were also tested and it was proved to be significant ($P< 0.0001$). Hence, it can be concluded that the treatment processes in all the WTPs have created a considerable reduction in TW in its content of iron.

Table 7 - Summary of the results obtained for total iron at each treatment stage of water treatment plant

Statistical Test	Water Treatment Plant		
	University	Polgolla	Matale
ANOVA	RW = 0.2077[a]	RW = 0.2855[a]	RW = 0.2208[a]
H_0, $\mu_1=\mu_2=\mu_3=\mu_4$	SW = 0.1355[b]	SW = 0.1702[b]	SW = 0.1477[b]
H_1, At least one population mean differs	FW = 0.0409[c]	FW = 0.0885[c]	FW = 0.0927[c]
	TW = 0.0466[c]	TW = 0.1308[d]	TW = 0.1671[d]
One Sample T-Test	P< 0.0001	P< 0.0001	P< 0.0001
H_o, μ = DL (max)			
H_1, μ < DL (max)			
DL (max) = 0.3 mg/l			
Paired T-Test	P< 0.0001	P< 0.0001	P< 0.0001
H_o, $\mu_D = 0$			
H_1, $\mu_D \neq 0$			
Status	Satisfactory	Satisfactory	Satisfactory

CONCLUSION

The findings as described in the previous section leads to conclude that University WTP has performed satisfactorily for maintaining the quality in treated water. Polgolla WTP and Matale WTP has functioned properly with regard to all the water quality parameters except for 'colour' and 'turbidity' and water treatment process need to be further attended and improved in maintaining optimum 'colour' and 'turbidity' in treated water.

University WTP and Polgolla WTP did not encounter with major problems in the treatment processes. The water treatment processes can be further improved by addressing the minor defects existing. In case of Matale Water Treatment Plant, the rapid sand filters should be attended and restored entirely.

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Impact on groundwater quality in Puttalam area due to over extraction and improper agricultural practices

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ABSTRACT

Recently the water quality of Puttalam Limestone aquifer and surrounding area is affected by increasing Salinity, while some part of the Puttalam area are also affected by Nitrate & Phosphate contamination in groundwater. The study area covers three secretariat divisions (Puttalam, Vanathavillu & Kalpitiya) which are identified as most affected to the groundwater. Puttalam and Vanathavillu areas are adversely affected due to high salinity in groundwater and over abstraction aggravated the condition resulting sea water encroachment at the coastal stretches & upcorning effect in certain places. The groundwater in Kalpitiya area is contaminated due to high improper pesticides and fertilizer applications for agriculture. Therefore this study is focused to assess the impact on groundwater due to agrochemicals & pesticides and over extraction. Another aspect of this study was to identify the levels of possible sea water intrusion due to said effects.

The monitoring points were selected considering the issues identified and representing both shallow and deep aquifers. The sampling process was carried out for wet & dry period of the year. 52 water samples were collected during dry period (September-October 2011). Based on the results of chemical analysis performed for dry period, additional 50 samples were also collected during rainy season (February- March2012). These samples were analyzed for pH, EC, TH, TA, TDS, Ca, Na, K, Mg, Iron, Cl, Sulphate, F, Salinity, Nitrate and Phosphate. During the process, 144 Samples were analyzed for EC, pH, TDS, Phosphate and Nitrate as in-situ tests to identify the geochemistry of groundwater for the initial assessment at the site itself.

According to the chemical analysis, shallow aquifer in some areas indicates high contamination with Nitrate, Phosphate and there is a tendency to increase the salinity. Eththale, Alankuda, Norachchoelai, Minniya, Nirmalapura are mainly affected with Nitrate contamination of shallow groundwater. The Nitrate contamination pattern in groundwater of these areas (Nitrate concentration >10mg/l) show in form of localized pockets. However, there is a gradual tendency of increasing Nitrate contamination throughout the Kalpitiya area (NO3 level exceeds 5mg/l in many villages of Kalpitiya area). In Puttalam urban area is also affected with Nitrate contamination due to improper sanitation facilities. Shallow aquifer of the surrounding area of Mee oya shows high Electrical conductivity values. But in deep aquifer, there is no indication of increasing EC & Salinity. Some sampling points in the lagoonal areas as well as inland areas are shown site specific characteristics of increased EC & Salinity levels. The phosphate contamination in deeper groundwater aquifers could also be identified in the Vanathavillu upper part (Eluwankulama, Rahalmadu & Serakkuliya) indicating more than 2mg/l.

The geophysical applications of 1-D, 2-D resistivity imaging surveys, test well drilling, water level elevation contouring & aquifer tests result indicated that the hydrogeological flow regime of the Puttalam Limestone region is highly complex due to regional geological and structural settings. Therefore assessment is required in focusing on the different aquifers separately without considering as singly aquifer formation existed. Based on the results on these areas, the groundwater is mainly contaminated due to improper agricultural practices in high sensitive aquifer formations as well as lack of groundwater management plan.

INTRODUCTION

Groundwater actsa vital role in Puttalam area for drinking, agricultural and other domestic purposes. The surfacewater sources in the area is limited and not adequate for these high water demanding activities such as Paddy cultivation and other cash crops where extensively been cultivated by the farmers specially potatoes, onions, chilies & Tobacco. In addition the use of surface water for drinking and other requirement is hindered due to poor water quality which requires expensive pretreatment thus not at feasible level. This aggravated the risk on the groundwater sustainability and quality deterioration as well due to alarmingly high abstraction levels in the area.

The study area is covered the Puttalam, Vanathavillu & Kalpitiya Secretarial Divisions which were identified as most affected areas on groundwaterquality as well as in quantity wise in Puttalam District. Puttalam and Vanathavillu DS Divisions are within the Kala Oya and Mee Oya drainage basins. Annual rainfall of the area is in the range of 1000mm-

1250mm and average daily temperature exceeds 28^0C in general. Geologically, the coastal belt of the study area is underlain by the unconsolidated Miocene sedimentary sequence while rest of the part underlain by Precambrian Western Vijayan Complex. The spatiotemporal water chemistry of groundwater and flow behavior changes drastically over the different facies which originated due to structural block faulting specially within the limestone formation. Additionally, the landuse pattern, geology, hydrogeological flow regime are the majorgoverning factors in the variation of groundwater chemistry. It is observed two distinguished temporal variations of water quality in groundwater during wet and dry period of the year. There is depth-wise change of groundwater quality in Limestone aquifer which is not observed largely in hard rock formations of the area.

The occurrence of groundwater in this Miocene limestone formation which is confined to the entrance North and Northwest of the island is characteristically different with respect to the other part of the country. Limestone formation is the prominent source forgroundwater storagedue to its extensively cavernous (or Karstic) nature and the presence of innumerable joints, fissures, solution cannels and chambers in it. Most of these openings are being constantly enlarged by solution, the slightly acid water which circulates in as an underground drainage system using the fissures and joints as nine courses and the chambers and caverns as reservoirs of fresh water (Cooray,P.G., 1984).
Recently the water quality of Puttalam Limestone aquifer and surrounding area is affected by increasedsalinity while some part of the Puttalam area are also affected by Nitrate & Phosphate contamination in groundwater. Puttalam and Vanathavillu areas are adversely affected due to high salinity in groundwater and over abstraction aggravated the condition resulting sea water encroachment at the coastal stretches & upcorning effect in certain places. The groundwater in Kalpitiya area is contaminated due to high improper pesticides and fertilizer applications for agriculture. Therefore this study is focused to assess the impact on groundwater due to agrochemicals & pesticides and over extraction. Another aspect of this study was to identify the levels of possible sea water intrusion due to said effects.

METHODOLOGY

Literature Review

The literature review was basically focused on the following:

- The international guidelines of BS and ASTM for methods of sample collection, analysis and selection of monitoring points according to the issues identified.

- Information available on various issues related to Groundwater contamination as a result of extensive agriculture, sea water intrusion due to over abstraction and health affected scenarios in the previously done studies and programs.

- Acquisition of required Hydrological, hydrogeological, landuse, climatic, geological and previous water quality data and information of the region.

Preliminary Survey

A complete reconnaissance survey on all existing relevant data has been carried out to understand the influence on regional and sites specific hydrogeological flow regime of the area with considering the issues identified from the literature survey as well as from the previous studies carried out by the Water Resources Board in the area.

Selection of monitoring point for chemical analysis

At the initial phase of the program, preliminary field inspections were carried out to identify the possible impacts on the groundwater due to various processes at the site specific level in the target area such as waste disposal sites, possible industrial point source pollutions, heavy agricultural area and available information on water quality as well as abstraction levels etc. During the process, altogether 144 Samples were analyzed for EC, pH, TDS, Phosphate and Nitrate as in-situ tests to identify the geochemistry of groundwater for the initial assessment at the site itself.

The monitoring points were selected considering the issues identified and representing both shallow and deep aquifers. The sampling process was carried out for wet & dry period of the year considering the variation of water chemistry during these seasons. 52 water samples were collected during dry period (September-October 2011). Based on the results of chemical analysis performed for dry period, additional 50 samples were also collected during rainy season (February- March2012). These all samples were analyzed for chemical parameters (pH, EC, TH, TA, TDS, Ca, Na, K, Mg, Iron, Cl, Sulphate, F, Salinity, Nitrate and Phosphate), heavy metals (Mn, Cu, Pb, Cd) and bacteriological testing at identified vulnerable locations.

Assessment of flow regime

The groundwater level was monitored at identified locations to determine the flow pattern of the area. The elevation of the monitoring point was assessed by Differential GPS and obtained with respect to the mean sea level (msl). The flow

pattern was monitored at quarterly basis to identify the spatiotemporal variation as well as groundwater level fluctuation.

Hydrogeological assessment through 2D Geophysics

In addition to water quality and head monitoring surveys, the 2D imaging geophysical surveys were carried out to interpret the subsurface hydrogeological, geological and structural conditions in limestone aquifer including structurally weak zones, thickness of soil overburden, weathered rock and to observe possible changes in the groundwater quality with depth. This 2-D imaging resistivity survey method was applied which is one of the most prominent technique in groundwater prospecting. The *AGISuperSting R8/IP* is 8-channel memory earth resistivity meter with higher accuracy and lowest noise levels. The system includes *SuperSting R8/IP* equipment, switching unit which is capable to handle 112 electrodes and the passive cable system of spacing 5m to connect the 112 electrodes. Therefore, one survey line is expanded to 560 m on the ground surface and the probing depth is approximately 100 -130 m below the ground level depending on the resistivity array chosen.

RESULTS AND DISCUSSION

The chemical analysis, heavy metal analysis and bacteriological analysis were carried out on the samples selected at the identified locations during the field activities of this study.

The analysis result indicated high Nitrate & Phosphate contamination of groundwater as well as increased salinity levels in the shallower aquifer especially in Kalpitiya and Puttalam areas. Eththale, Alankuda, Norachchoelai, Minniya and Nirmalapura villages(more than 70% of the monitoring locations of these villages) are in Kalpitiya Secretariat division which are mostly affected with Nitrate contamination of shallow groundwater. The Nitrate contamination pattern in groundwater of these areas (Nitrate concentration >10mg/l as N) show in form of localized pockets. However, there is a gradual tendency of increasing Nitrate contamination throughout the Kalpitiya area (NO3 level exceeds 5mg/l in many villages of Kalpitiya area). This high elevated NO3 level in groundwater is possibly due to the extensive application of agrochemicals in Kalpitiya area. It is observed that the Puttalam urban area is also affected with high Nitrate contamination (Nitrate concentration >10mg/l) in groundwater. This may due to improper sanitation facilities and microbiological testing.

Phosphate contamination in deeper groundwater aquifers could also be identified in the Vanathavillu upper part (Eluwankulama, Rahalmadu & Serakkuliya) indicating more than 2mg/l. However it is not indicated in the shallow aquifer of the same area. This reveals that the phosphate contaminated groundwater may flow towards this deeper aquifer from a different area in the region. However, detail investigations are required to confirm this process. Phosphate distribution of shallow groundwater is also indicated high values (more than 2mg/l) in Puttalam town area.

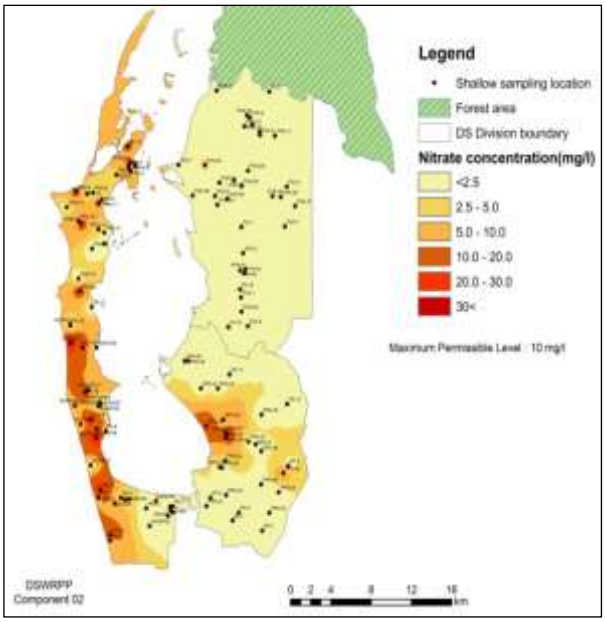

Figure 1 - Nitrate distribution of the shallow aquifer in the study area

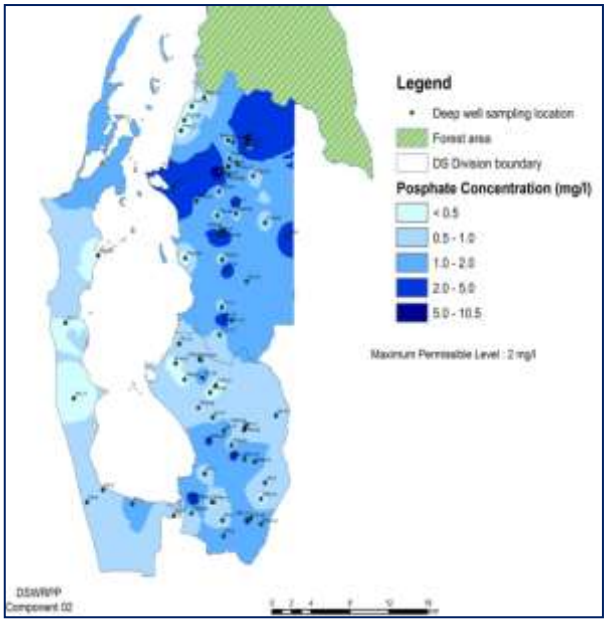

Figure 2 - Phosphate distribution of the deep aquifer in the study area

Shallow aquifer of the surrounding area of Mee oya shows high Electrical conductivity values. But in deep aquifer, there is no indication of increasing EC & Salinity. Some sampling points in the lagoonal areas as well as inland areas are shown site specific characteristics of increased EC & Salinity levels.

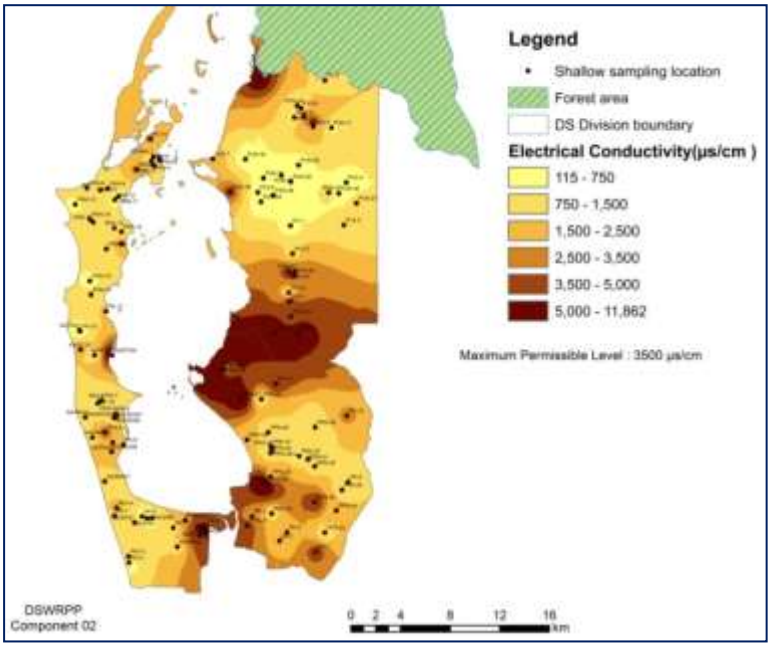

Figure 3 - Electrical conductivity distribution in the shallow aquifer of the study area

In Kalpitiya area, most of the land is covered with agrarian lands. The overburden of the area completely comprised with sand beds. The thickness of these sand beds is varying place to place and high agriculture activities are in progress on these sand beds. In addition,the farmers extract high amount of groundwater for their activities. In general, farmers add water to their plants in two or three times per day because of high temperate semi-arid climate and high permeability of the top soil layer (sand). Further, the application of fertilizers and pesticides are reported six times than the recommended levels according to the sources of Irrigation Department. Therefore, the possibility of agrochemicals infiltrating to the groundwater of these areas is on high risk level due to these specified reasons. During the dry season, the concentration of Nitrate in groundwater is increasedby approximately 1 to 5 mg/l range. The shallow groundwater bearing zones in the Kalpitiya area is existed in forms of water lenses (pockets)which are associated with sand dune structures.

Electrical Conductivity (EC) distribution in deep aquifer of the study area is not showncomparatively high values. However, the range of EC is expected at 400 to 2000 uS/cm except the localized peaks where it could be up to 4000 uS/cm.These occasional increased EC values are identified in the area which is controlled by the inherited nature of the soil or aquifer medium. This spatiotemporal behavior of EC in the region is getting more complex due to high heterogeneity of the subsurface layer within the same groundwater bearing facies or formations.

The Piper Tri-linear diagram is indicated that many shallow wells as well as deep wells fall into a zone of where if sea water was plotted in the diagram. The groundwater quality of deep aquifer at Puttalam, Vanathavillu and Kalpitiya shows predominantly Na-K-Cl type with some mixing towards Ca-Mg-HCO3type during both wet and dry period in the year.The similarity of groundwater quality shows the coastal regions property which most notably the mixing with sea water.

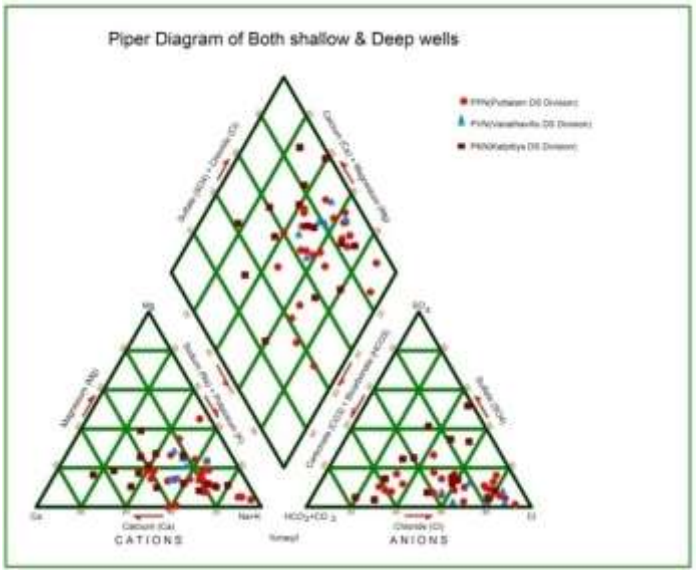

Figure 4 - Piper diagram showing the water quality type

There are several limestone aquifers consist in the unconsolidated sedimentary formation. Some of these formations are existed in large thicknesses and some are miner thin layers. These layers have different properties and complex behavior in respect to water quality, hydrogeology, aquifer properties etc. For instance, the groundwater water quality of a source well largely depends on how far the each layer has been penetrated. In this aspect, it is vital to determine the subsurface conditions through 2-D imaging Resistivity surveys which were carried out at the identified zones. The below cross section is shown the variation of subsurface near to the coastal line of Vanathavillu area (~2 kms towards landside)

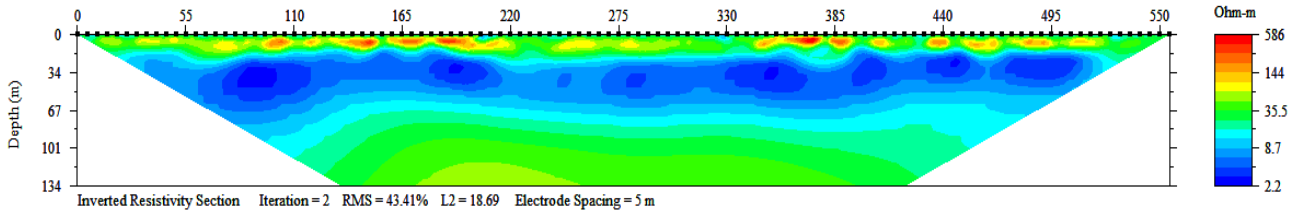

Figure5 - 2-D resistivity image carried out at Vanathavillu area

The top most part of the cross section indicates clayey Soil layer with representing comparatively high resistivity values. The subsurface low resistivity layer (in blue color)shows clay layer. The bottom layer is higher resistivity indicating the fracture/ caverns filled saturated limestone layer. This layer has more complex structure and formations such as fault zone, cavities, clay fill cavities etc. In the Puttalam area,it is reported that the total usage water volume is more than 70% of groundwater and the rest is fulfilled by surface water. At present, thecultivation is ever increasing and the domestic requirement is also increased with the population thus resulting high groundwater extraction at alarming level. This present setup demands for the necessity of implementing a definitive groundwater management mechanism or else the impact would not be reversible in the future.

Following graph indicates the over extraction of groundwater in some of the sampling locations in Puttalam and Vanathavillu area. From these locations only it is about 7,250m^{3}abstraction per day.

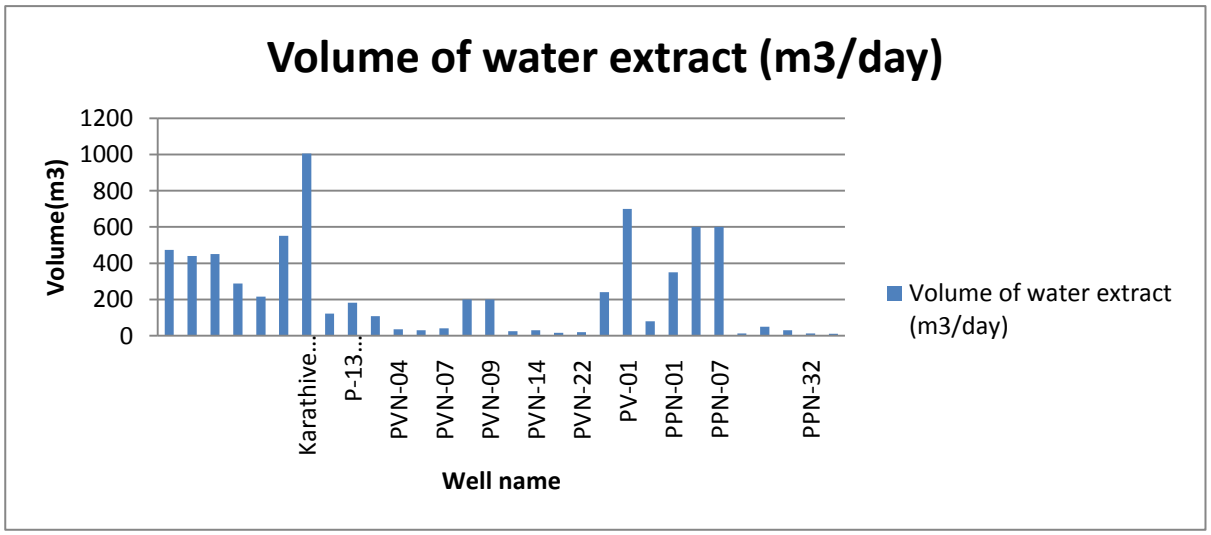

Figure 6 - Groundwater extraction of some sampling points in the study area

CONCLUSIONS AND RECOMMENDATIONS

Shallow aquifer in some areas indicates high contamination with Nitrate, Phosphate and there is a tendency to increase the salinity level. Eththale, Alankuda, Norachchoelai, Minniya, Nirmalapura are mainly affected with Nitrate contamination of shallow groundwater. The Nitrate contamination pattern in groundwater of these areas (Nitrate concentration >10mg/l) show in form of localized pockets. However, there is a gradual tendency of increasing Nitrate contamination throughout the Kalpitiya area (NO3 level exceeds 5mg/l in many villages of Kalpitiya area). In Puttalam urban area is also affected with Nitrate contamination due to improper sanitation facilities. Shallow aquifer of the surrounding area of Mee oya shows high Electrical conductivity values. But in deep aquifer, there is no indication of increasing EC & Salinity. Some sampling points in the lagoonal areas as well as inland areas are shown site specific characteristics of increased EC & Salinity levels. The phosphate contamination in deeper groundwater aquifers could also be identified in the Vanathavillu upper part (Eluwankulama, Rahalmadu & Serakkuliya) indicating more than 2mg/l.

In Kalpitiya area, it is necessary to identify whether there is any possibility to spread the Nitrate contamination for other surrounding well field which located nearby affected wells. Similarly the Nitrate concentration variation in groundwater of the affected area should study with the cultivation type, fertilizer type and the seasonal variation to find out the most affected reasons for the Nitrate contamination in the area.

The geophysical applications of 1-D, 2-D resistivity imaging surveys, test well drilling, water level elevation contouring & aquifer tests result indicated that the hydrogeological flow regime of the Puttalam Limestone region is highly complex due to regional geological and structural settings. Therefore assessment is required in focusing on the different aquifers separately without considering as singly aquifer formation existed. Based on the results on these areas, the groundwater is mainly contaminated due to improper agricultural practices in high sensitive aquifer formations as well as due to lack of groundwater management plan.

ACKNOWLEDGMENTS

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Heavy metal pollution and burden of aquatic animal health: A pilot study from an urban wetland in Sri Lanka

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ABSTRACT

Contamination of aquatic environments due to anthropogenic activities is increasingly evident globally. Heavy metals which are exposed to the environment through industrial and domestic wastes and effluents are serious pollutants of the aquatic environment, most of which are highly toxic. Heavy metal contamination of aquatic ecosystems pose threats to aquatic organisms by two means; high persistence in water and ability to accumulate in organisms via food chains. Heavy metals are reported to influence species by affecting health, altering behavior, physiology and anatomy which ultimately pose adverse impacts on biodiversity. Associations between aquatic pollution and health impacts on species are, however, complex and often poorly characterized.

The present study investigated impacts of Copper (Cu), Zinc (Zn), Lead (Pb), Cadmium (Cd) in water and aquatic biota in Bellanwila Attidiya Sanctuary (test site), an urban wetland situated close to Colombo, subjected to industrial waste release. We selected *Euphlyctis hexadactylus* (Indian Green frog) as the test species since amphibians are highly sensitive to aquatic pollution and act as environmental indicators. Health of the test animals were investigated by studying immunological parameters. Bolgoda South wetland was selected as the reference site with negligible amounts of heavy metals.

The Bellanwila Attidiya site was found to bepolluted with significantly highlevels of heavy metal ions, of Cu, Zn, Pb and Cd compared with the reference site in Bolgoda. Accumulation of all four heavy metals in the liver and muscles of *E. hexadactylus* was significantly higher in the test site compared with the reference site.

Some basic immunological parameters such as total and differential white blood cell counts, neutrophil/lymphocyte ratio, spleen weight/body weight ratio, spleenocyte count, basal immunoglobulin level were determined using standard methodology. All these tests confirmed significantly reduced immune capacity of frogs in the polluted site compared with those in the reference site. Reduced immunocompetency of frogs may result in increased susceptibility to other environmental stresses including diseases, parasitic infections and growth impairments.

In conclusion, this preliminarystudy for the first time in Sri Lanka, demonstrated that heavy metal pollution impair the immune system of frogs, which could in turn affect their overall health. Thus, if unavoidable, steps should be taken to minimize heavy metal pollution in wetlands to conserve aquatic biodiversity.

INTRODUCTION

There is an ever increasing trend in pollution of aquatic ecosystems and equally increasing evidence of consequent impacts. There has been widespread decline in biological health in aquatic ecosystems which ultimately affect biota in different ways. Globally, 24 percent of mammals and 12 percent of birds associated with inland waters are considered threatened (UN WWAP 2003). In some regions, more than 50% of native freshwater fish species and nearly one third of the world's amphibians, are at risk of extinction (Vié *etal*. 2009). Freshwater species in general face an estimated extinction rate five times greater than that of terrestrial species (Ricciardi and Rasmussen 1999) as there is an increased sensitivity to pollution exhibited by aquatic animals.

Heavy metals which are exposed to the environment through industrial, commercial and domestic wastes and effluents are serious pollutants of the aquatic environment (Harkumar *etal*, 2009; Chen et al., 2012). Heavy metals entering aquatic ecosystems pose threats to organisms in two ways: persistence of these in water is very high and these may accumulate in organisms *via* food chains (Chen et al, 2000). Heavy metals are reported to influence species by affecting health, altering behavior, physiology and anatomy which ultimately pose adverse impacts on biodiversity (Farombi et al., 2007). It has been reported that water borne metals may alter the physiological and biochemical parameters in fish blood and tissues (Vinodhini and Narayanan, 2008).

There are reports on heavy metal pollution that have caused irregularities and changes in the balance of such processes as predation, competition and cycling of material. Due to the complexity of pollution, the effects of take-up in aquatic life also dependon the characteristic features of pollutants. If several toxic substances are present together in polluted water they may exert synergistic effects. Among many metals, a considerable number of records exist on Cu, Zn, Pb and Cd as serious water pollutants (Demirak *etal*, 2005).

The broad aim of this study was to study the impacts of pollution of Copper, Zinc, Lead and Cadmium on frogs in an urban wetland. The specific objectives were to investigate these heavy metal concentrations in *Euphlyctis hexadactylus* (Indian Green frog), and to investigate related immunological impacts, in order to assess animal health.

METHODOLOGY

Sampling sites

The study was conducted ina highly polluted test site i.e. the Bellanwila Attidiya wetland (Figure 1) (longitudes E. 79.55' - 79.58'and latitudes N. 6.40' – 6.48'). While the control (reference) site was selected from the Bolgoda South lake with negligible human disturbances and pollution (Figure 2).

Figure 1

Figure 2

Water quality parameters pH, temperature, Dissolved Oxygen (DO) and Biological Oxygen Demand (BOD) were measured on each visit (four times per site) and analyzed using one sample t test. For heavy metal analysis, six water samples were collected in to thick plastic bottles from each site,preserved at the site of collection by adding concentrated HNO_3 (10 ml per liter of water), and transported to the laboratory.

Test animals

Adult Indian green frogs (N=6 per site) were randomly captured from water ways using baits. Body weights were recorded using a digital weighing balance up to 0.01 g accuracy. External morphometric parameters were measured using an electronic digital caliper (Grade 03, Control Company, United States of America). Animals were then transported in aerated plastic bags half filled with water, to the laboratory for further analysis.

Laboratory Analyses

Captured animals were kept in tanks half filled with water and with aeration for two days prior to further analysis. They were fed only once with chopped meat (~ 10% of their body weight).

i. Analysis of heavy metals

a. In Water

Heavy metal (Cu, Zn, Pb, Cd) concentrations of waters were measured by using atomic absorption spectrophotometry according to standard methods.

b. In tissues

Gastronemius muscle and liver isolated from *E. hexadactylus*were anlysed for heavymetals Cu, Zn, Pb and Cd according to the methods described in ASTM Standards 2000.

ii. Analyses of immunological parameters

We investigated several standard immunological parameters as described below from a-f to establish heavy metal induced impacts in frogs.

a. Total WBC counts

The perisac of the heart was removed and blood was obtained by heart puncture using a fine tipped pasture pipette. Blood was quickly collected into a tube containing EDTA to avoid blood clotting (Turgeon, 2004). The anticoagulated blood was used to obtain the total WBC count. Based on the method described by Arserim & Mermer (2008) Turck's solution was used as the diluting fluid for obtaining WBC counts using the haemocytometer. Data was analyzed using one sample t test.

b. Neutrophil / Lymphocyte ratio

The preparation and staining of thin blood smears were carried out according to the method recommended by the World Health Organization. Oil immersion microscopy (x100) was used to obtain differential WBC counts. The Neutrophil / Lymphocyte ratio was obtained using differential WBC counts. Data was analyzed using one sample t test.

c. Spleen weight to Body weight Ratio

The spleen was placed in a clean watch glass and the weight was recorded using an electronic balance (EB-3200H-A, Shimadzu cooperation, Japan). The spleen weight/ body weight ratio was obtained by dividing the weight of the spleen from the initial body weight.

d. Spleenocyte count

The method described by Hudson &Hay (1989) for mammals was modified and optimized for frogs. The whole spleen was teased out in to 7 ml of PBS and the cell suspension was transferred into a 15 ml tube, and the cell debris was allowed to settle. Neubauer hemocytometer was filled with the cell suspension and the nucleated cells in the center 25 squares were counted. Data was compared using Mann-whitney U test.

e. Bone marrow cell count

The method described by Garssen et al. (1995) was simplified using PBS to count the total number of bone marrow cells. The femur obtained from the dissected frog was used.Cells in the bone marrow were collected by flushing 4 ml of PBS solution through the femur using a 21-gauge needle. The number of nucleated cells was determined in the middle 25 squares of a Neubauer hemocytometer. A standard calculation was used to obtain the total count. Data was analyzedby using Mann-Whitney U test.

f. Immunoglobulin level

Serum was separated from blood dispensed in to anticoagulant free eppendorf tube, according to the method described by Hudson and Hay, (1989). The separated serum was stored at -20 ^{0}C until further use.

Ammonium sulphate precipitation method was used to partially purify immunoglobulins from serum. The absorbance of each dialysed sample was measured at 280 nm (Acton *etal*, 1972) using a UV/VIS/NIR spectrophotometer (V 560, Jasco cooperation, Japan). Absorbance values were converted into concentrations (Garcia *etal*, 2010). Data was analyzed by using Mann-Whitney U test. Significance level was set at $P<0.05$.

RESULTS

The results of this study indicated that the selected heavy metal concentrations of the impacted test site, Bellanwila Attitidya wetland, were significantly higher ($P<0.05$) than of the reference site. Similarly, specific immune parameters of the frogs collected from the test site were significantly lower when compared with those of the reference site.

Water quality parameters (Mean ± SD) of the two study sites are summarized in Table 1. Parameters such as temperature, pH, BOD did not show significant differences between the two study sites, except for higher DO values(*$P < 0.05$) in water of the polluted test site compared with that of the reference site.

Table 1- Water quality parameters of the two study sites

Study site / parameter	Test site	Reference site
Temperature (^{0}C)	30.475 ±0.532	30.275 ±0.64
pH	6.8975 ±0.0971	6.723 ±0.245
DO (mg/l)	2.985 ±0.1994*	3.695 ±0.126*
BOD (mg/l)	1.998 ±0.217	1.793±0.235

(*$P<0.05$)

Laboratory Analysis

i.Analysis of heavy metals

a. In Water

Heavy metal concentrations of water are presented in Table 2. The concentrations of metal ions in the two sites could not be statistically compared as the data obtained was not sufficient to do so. The concentrations of Lead and Zinc ions were detected in water of the Bellanwila-Attidiya site in significant levels, while the other two metal ions *i.e.* Copper and Cadmium were present in minute levels.

b. In tissues

Concentrations of heavy metals of liver and gastronemius muscle of frogs are illustrated in Figure 1. The accumulation of metals in tissues of the frogs from the test site was significantly higher compared with those of the reference site ($P<0.05$).

Table 2 - Concentrations of the metal ions in water of the two study sites

Study site / Metal ion (ppm)	Test site	Reference site
Zinc	2.71 ± 0.354	0.0590 ± 0.0580
Lead	0.955 ± 0.247	0.0
Copper	0.04 ± 0.0141	0.0
Cadmium	0.019 ± 0.001	0.0

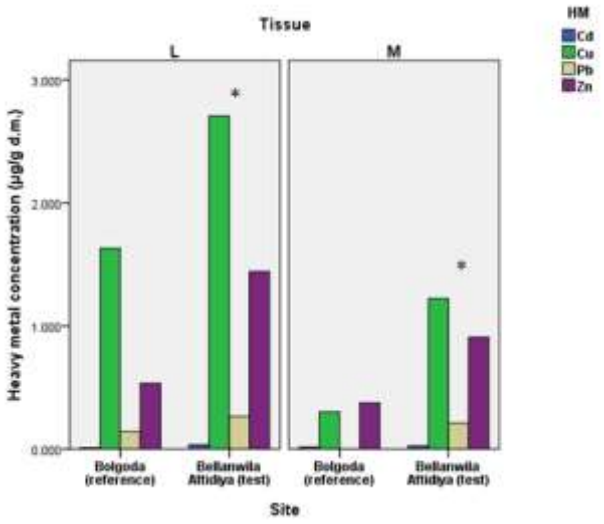

Figure 1 - Accumulation of selected heavy metals in test animals with respect to the two study sites; The muscle and liver accumulation of heavy metals in the polluted test site was significantly (*$P<0.05$) higher compared with the reference site. In both sites accumulation in liver was significantly higher than muscle accumulation.
L – Liver tissue M – Muscle tissue

ii.Analyses of immunological parameters

All the immunological parameters of Indian green frog recorded from the test sitewere significantly lower compared that of the reference site.

a. *Total WBC counts*

The comparison of total WBC counts in the two study sites are illustrated in Figure 2.a. The total white blood cell counts of 6 frogs from each site were calculated. The minimum and the maximum values of WBCs were in the normal value range. The average number of WBCs of the frogs in the Bellanwila site was significantly lower ($P<0.05$) than that of the frogs in the reference Bolgoda site.

b. Neutrophil / Lymphocyte ratio

The ratio of neutrophil to lymphocyte counts of the test site was significantly lower ($P<0.05$) compared to that of the reference site (Figure 2.b).

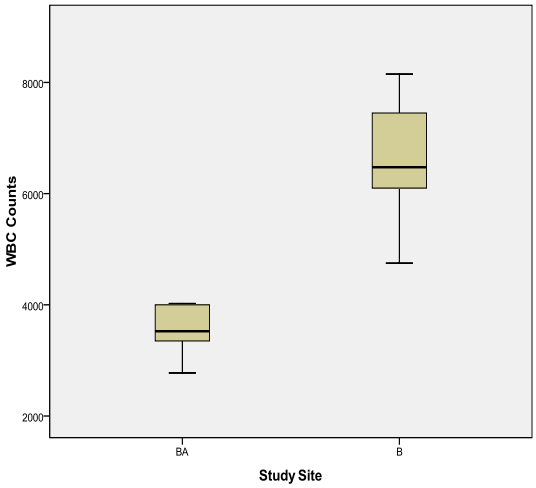

Figure 2a - Total WBC counts of frogs of the two study sites. Total WBC counts were significantly lower in test site compared with reference site. BA – test site; B – reference site

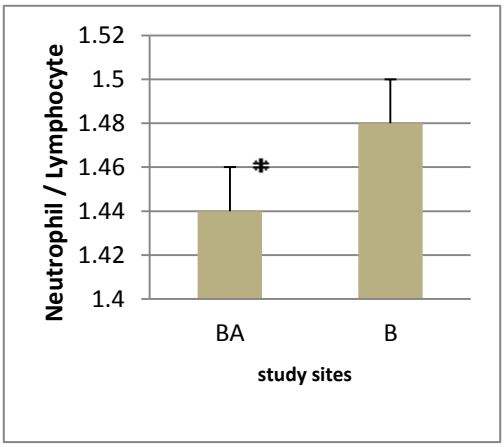

Figure 2b - Comparison of the Neutrophil / Lymphocyte ratio of the frogs of the test site compared to reference site. BA – test site; B – reference site

a. Spleen weight to Body weight Ratio

The spleen weight/ body weight ratio of frogs in the test site was significantly lower than that of the frogs in the reference site (Figure 3).

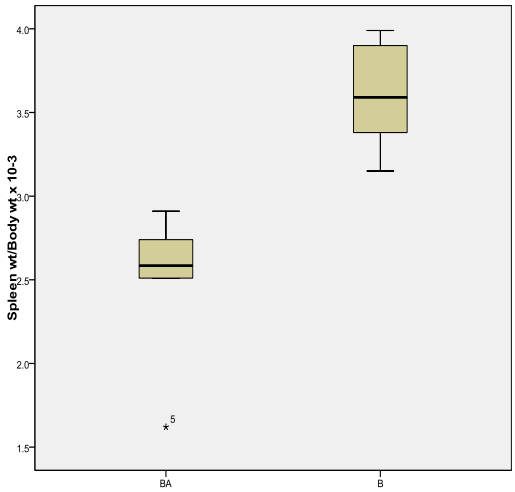

Figure 3- Comparison of spleen weight/body weight ratios of frogs of the study sites; spleen weight/body weight ratios of the test site was significantly lower (*P<0.05) compared to reference site. BA – test site; B – reference site

a. Spleenocyte count

Total spleenocyte counts of frogs of the test site were significantly (P<0.05) lower than that of the frogs in the reference site (Figure 4).

b. Bone marrow cell counts

Comparison of total bone marrow cell counts of the two study sites (Figure 4), indicated that cell counts of frogs in the test site were lower compared with those of the reference site. But the difference was not statistically significant (*P>0.05).

c. Immunoglobulin levels

Immunoglobulin levels of frogs of the test site was significantly (*P<0.05) lower than those of the reference site (Table 3).

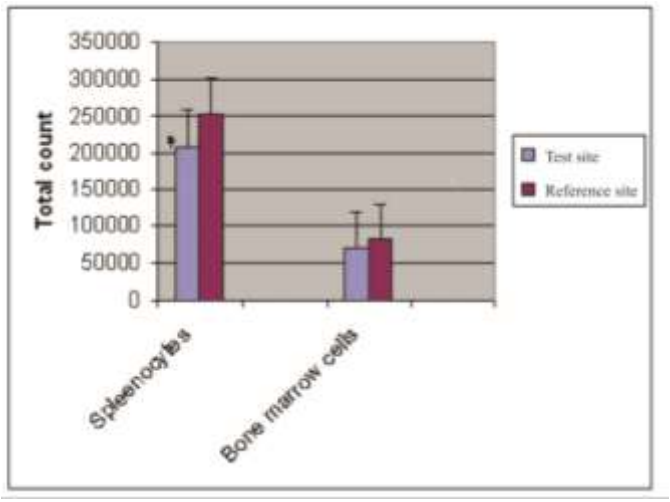

Figure 4 - Comparison of spleenocyte and bone marrow cell counts of frogs of the two study sites. Spleenocyte counts of frogs in test site showed significant (*p<0.05) reduction compared with reference site.

Table 3 - Absorbance and concentration values of Immunoglobulin levels. The Ig levels was significantly higher (*P<0.05) in reference site compared with test site.

	Absorbance (280 nm)	Immunoglobulin concentration (mg/l)
Test site	0.4678 ± 0.09830	0.5397± 0.2053
Reference site	0.5737 ± 0.0632*	0.7740 ± 0.0898*

DISCUSSION

The results of the present study emphatically show that heavy metal pollution could induce impairments in the immune system of the frog species, *Euphlyctis hexadactylus*. Since frogs posses sensitive and permeable skin and have a water dependent life style, these animals could be more prone to water borne pollutants (Burlibasa and Gavrila, 2011). Accumulation of heavy metals in organs of frogs may be considered as an important warning signal for their general health.

This study revealed several vital facts related to heavy metal contamination of water as well as tissues of frogs. All four heavy metals investigated existedathigher concentrations in the polluted test site. While accumulation of all four heavy metals investigated was recorded in both liver and muscle of frogs in both study sites, this build up was significantly higher in the test site (P<0.05). The ascending sequence of the accumulation of heavy metals was found to be Cu> Zn> Pb> Cd. It was also apparent that lower concentrations of these heavy metals were recorded in muscle rather than in the frog liver.

In this study we focused only on immunosuppression. Innate as well as adaptive immune responses of organisms are very important components of defense against infection. Parameters such as total WBC counts, neutrophil / lymphocyte ratio, spleen weight to body weight ratio, spleenocyte count, bone marrow cell count and Immunoglobulin levels embody both innate and adaptive immune responses which act against pathogens and protect organisms from infection and disease (Richmond *et al*, 2009). The current study established that all the tested immunological parameters except for the total bone marrow cell counts of the frogs at the test site were significantly (p<0.05) lower compared to those of the reference site. This is a clear indication of the level of impairment of immunity and hence the health of frogs inhabiting the polluted test site. In other words, a reduction in immunocompetence could cause a reduction in fitness (Gervasi&Foufopoulos, 2008; Whitehouse and Duffus, 2009; Blaustein *et al*, 2012). Frogs with impaired immunity are at high risk of infection and disease. Changes in immune systems impinge directly on wildlife health and survival and, consequently, affect the viability of their populations (Blaustein *et al*, 2012).

Absorbed heavy metals can be distributed quickly to tissues and organs (e.g. bone, gills, kidneys,) rather than accumulating in the liver (Yilmaz, 2005). Therefore, though this study focused on the liver and muscle accumulation of heavy metals, other tissues and organs should be targeted in future studies. Accumulation of heavy metals in tissues could generate various impacts (Ikechukwu *et al*, 2011). For instance, Solomon (2009) reports the effects of high amounts of Copper in aquatic organisms can be directly or indirectly lethal. Heavy metals including Zinc, Lead and Cadmium induce a broad range of essential physiological, biochemical and behavioral dysfunctions (Vinodhini and Narayanan 2008; Ololade&Ogini 2009; Rosenberg, 2003).

There is so far no reported study of the possible adverse effects of heavy metal pollution of waters on immunological systems of aquatic animals in Sri Lanka. This study clearly point towards immunosuppression of frogs in an impacted site polluted with heavy metals in a wetland in Sri Lanka.

This situation warrants immediate attention of all stakeholders i.e. conservation workers, governments and researchers as this shows looming signs of an impending crisis. Firstly, amphibians are reported to be declining globally and there are programmes to conserve them worldwide (Collins & Storfer, 2003;Gascon*et al*, 2007). Secondly, not only them but other aquatic organisms too, to various degrees, could be at stake due to heavy metal pollution (Lokhande *et al*, 2011). Thus, it is pertinent to assume that such contaminations could adversely impact the health of aquatic animals which in turn may disrupt the delicate balance of wetlands. Despite the fact that Bellanwila attidiya wetland was declared a sanctuary, due to accelerated industrialization of the surrounding area in the recent decades this fragile ecosystem receives pollutants including heavy metals (Anon, 2009).

In conclusion, this preliminarystudy for the first time in Sri Lanka, demonstrated that heavy metal pollution impair the immune system of frogs, which may in turn affect their overall health. Thus, if unavoidable, steps should be taken to at least minimize heavy metal pollution in wetlands in order to conserve local aquatic biodiversity.

ACKNOWLEDGEMENT

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Quantification of potential impacts of urban and peri urban agriculture and forestry, Sri Lanka, on climate change

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ABSTRACT

Around the globe climate change (CC) and global warming are recognized at present as top prioritized environmental challenges as it has severe threats on human lifestyle, health and food security.Agriculture-based livelihood systems are vulnerable to risk of increased crop failure, loss of livestock and fish stocks and increasing water scarcities. Changes in food patterns and extreme weather events are posing a great threat on human health. Rapid growth of urban population intensifies the impacts of climate change due to land fragmentations and deforestation. Ironically agriculture and forestry which is said to be the most affected by climate change are the best way to adapt to it as well. This paper suggests urban and peri-urban agriculture and forestry (UPAF) measures that have the potential to make an impact on Climate Change and are feasible in the context of urban areas in Sri Lanka. The impacts can be put in to different categories such as food production, changes in micro climates and frequency of extreme weather events like floods and droughts and reduction of food and fertilizer miles. Reduction of food and fertilizer miles has an impact on Climate Change by reducing generation of Greenhouse gas (GHG) due to the reduction of transport of food and fertilizer. Also the impacts UPAF on solid waste management is discussed as improper solid waste management leads to increased Greenhouse gas production intensifying climate change. The paper further suggests indicators that can be used to measure such impacts. Though GHG emissions are identified, by the intergovernmental panel on climate change (IPCC), as a major cause of climate change, and acts as a good indicator of climate change, there are limitations and constraints in estimating GHG levels for developing countries such as Sri Lanka due to lack of finances and relevant equipment. Hence feasible and simple indicators were identified through this study to measure the potential impacts of UPAF activities on CC. Measures that can be taken in order to strengthen the institution set up for monitoring were also identified in the study. The feasibility of the indicators was then confirmed through interviews with relevant authorities.

INTRODUCTION

Climate change has turned out to be one of the major global environmental challenges at present and is a mounting crisis with dimensions such as economy, health and safety, food production and food security, therefore needs immediate attention (IPCC,2000). According to the IPCC climate change is mainly caused due to absorption of infrared radiation by "greenhouse gases" such as water vapor, CO_2, O_3 and CH_4, which slows its escape from the atmosphere. Anthropological activities that accelerate the natural process by creating more greenhouse gases in the atmosphere can be categorized as burning natural gas, coal and oil, some farming practices and land-use changes, production of industrial gases and deforestation. The main characteristics of climate change are increases in average global temperature (global warming); changes in cloud cover and precipitation; melting of ice caps and glaciers and reduced snow cover.Increase in ocean temperatures and ocean acidity due to seawater absorbing heat and CO_2 from the atmosphere too are global impacts of climate change. All nations are affected by the impacts of climate change. However, developing countries are particularly vulnerable, as they lack the necessary adaptive capacity. Being a developing island nation subject to tropical climate patterns, Sri Lanka is highly vulnerable to climate change impacts. Extreme weather events such as high intensity rainfall followed by flash floods and landslides, and extended dry periods resulting in water scarcity are now becoming common occurrences in Sri Lanka. Climate is the primary determinant of agricultural productivity and Sri Lanka with its agricultural based economy faces a challenge of mitigating potential threats on agricultural productivity due to climate change. Climate change is expected to influence crop and livestock production, hydrologic balances, input supplies and other components of agricultural systems. . The change in temperature, as well as the accompanying change in precipitation, has the potential to profoundly affect agricultural production and prices.

The Urban cities are more vulnerable towards climate change due increasing population densities which leads to deforestation and land fragmentation and results in altered hydrological processes and incidences of flooding. In addition development of the phenomenon of Urban Heat Islands, described as a metropolitan area to be considerably warmer than it's surrounding rural areas, has become an intimidation to the urban dwellers. With the increase of urban population, it is required to convert agricultural land in urban settlements posing great threats to food requirement of the dwellers. Most of the urban population do not produce their own food and to meet the demand, it is required that food is imported or transported from elsewhere. Transport accounts for a significant share of the global fossil fuel combustion-related CO_2 emissions.

This paper recommends the practice of Urban and Peri urban Agriculture and forestry (UPAF) as a mitigation measure for negative implication of climate change on urban setups. It also is a mean of producing food closer to the urban cities and thereby reduce the amount of food imported and transported from elsewhere.Hence this is a mechanism to reduce food miles. Food miles is a term which refers to the distance food is transported from the producer till it reaches the consumer. Food miles are one factor used when assessing the environmental impact of food, including the impact on global warming. Likewise producing required fertilizer close to the agricultural plots reduces fertilizer miles. Fertilizer miles are, similarlyto food miles, refers to the total distance to transport fertilizer from the manufacturer till it reaches the end user.

The reduction of food and fertilizer miles is a mechanism to adapt to and mitigate climate change because emission of GHG reduces with the reduction of number of vehicles used for transporting. Vehicle transport imposes various environmental, social and health costs, and can cause climate change by emitting greenhouse gases. (Pretty et al., 2005)
If appropriately planned and integrated into urban design, urban agriculture can contribute to the comfort of citizens. Green spaces around apartment blocks and houses, as well as neglected spaces in the city, help to improve the physical climate because vegetation can: help increase humidity, lower temperatures and introduce more pleasant odours to the city; capture dust and gases from polluted air through deposition and capture by the foliage of plants and trees, and soils; and help break wind and intercept solar radiation, creating shadow and protected places , also contribute to the aesthetic value of the environment .

Suggested UPAF measures can be categorized according to their impacts such as food production, fertilizer production, water for irrigation, and aesthetic value. The success of these measures depends on a good basis of a scientific monitoring process which gives a sound demonstration of results achieved by UPAF. Monitoring impacts has to be done in two folds, one is to monitor the success of the project and the second to monitor it's impacts on climate change. A monitoring procedure from the beginning of the project till the end will help minimize errors and learn valuable lessons to replicate it elsewhere. It also allows validating any decisions made in regard to implementing changes. And the information) willbe usefulfor the people who are interestedin the potential outcome of the project

MONITORING MECHANISM

1. **Impacts on climate change**
   The main impacts of climate change to Sri Lankan urban cities are drastic increase of temperature, changes in rainfall patterns, land fragmentation and high housing densities which lead to the occurrence of floods, and also prolonged periods of Droughts. It is expected that the above suggested UPAF measures would bring about a change in the change of climate. To monitor such impacts it is necessary to collect and plot time series data from the beginning of the project to at least 10 years giving a sufficient time period to realize impacts from implemented activities. Daily monitoring of temperature and rainfall in the area that practices UPAF suggested measures are being practiced, and frequencies of flood and droughts can be taken into consideration.

2. **The progress of the project**

- **Food**

Home gardening is already a common practice in Sri Lankan households. The measures proposed encourages the expansion of such home gardens and also introducing it to those who do not yet practice it. Different innovative approaches can be practiced to minimize the problems arising due to lack of urban and peri-urban land area for cultivation. Domestic gardens can be created using limited land, hedges, and even by using non bio degradable disposable materials such as plastic bottles and bags as cultivation vessels. Vertical gardens, introduction of new crops and cropping patterns and planting flowering and fruiting trees to increase the agro forestry tree cover can be identified as achievable measures to improve home gardens. Another measure of UPAF is to breed fish in possible water stagnating areas. The outcomes of the above measures are production of food and the prices of food.

Quantity of food

Increase of production of food closer to the urban cities will bring about a reduction in the quantities of food being imported and transported to the city. The weights of UPAF food production is to be measured and recorded throughout the project time period. The imported food reduction can be measured by the reduction of quantity of food being transported to the city and for this the number and the sizes of vehicles used for this purpose could be monitored and recorded.

Prices of food

The prices of food are likely to reduce with the increase of urban food production and hence it can be used as a good indicator to monitor the impacts of UPAF on climate change and be compared with food prices of a market elsewhere which can act as a point of reference, for the study.

- **Fertilizer**

Composting is proven to be a simple process of enhancing the effectiveness of fertilizer application and also Municipality Solid Waste (MSW) management method which has positive impacts such as reduced soil erosion, water contamination, avoided costs for handling solid waste and also climate change (Hoornweg et al. 1999).

-Cost of fertilizing

Another indicator of fertilizer miles is the cost that should be borne in order to fertilize. Cost of fertilizer application is inclusive of the cost incurred to manufacture, transport, store etc. If fertilizer is produced by the UPAF farmers themselvesin the local area this cost can be reduced to a certain extent. A monitoring mechanism will be carried out to monitor the cost borne by the farmers for fertilizing per season.

- **Energy**

The bio- degradable waste generated by UPAF can be used to produce bio gas. Using of bio gas reduces the amount of municipal solid waste generation, and acts as a substitute to domestic energy sources. It can be used as an alternative energy source for lighting and heating requirements in the households.Reduction of cost borne for energy can be a good indicator to measure the benefits of producing bio gas. It will depend on what purpose biogas is used for in individual households as an alternative energy source for different purposes like lighting, heating and cooking.

- **Water resources**

The technique of rainwater harvesting can be a successful intervention in a country like Sri Lanka with the mean annual rainfall varying from 900mm-5000mm. Irrigation with raw or diluted wastewater will continue to increase in many areas of developing countries in order to keep pace with urban growth and to supply the urban food demand (Qadir et al., 2010).). These techniques will free treated water from irrigation for other domestic purposes. Reduction of the monthly domestic water bill act as an indicator to measure the reduction of use of treated water. The national water supply and drainage board data on the total water demand of the area can be used to triangulate the household data.

- **Aesthetic value**

Planting of flowering and ornamental trees in available and suitable land areas in order to increase the aesthetic value of the city can be an important component in town planning. This can be done as eco forests and wind or shelter belts.There can be an increase of tourist attraction to the area and the land value. An opinion survey of the residents in the area can give information regarding the tourist attraction. With the increasing tree cover attraction of birds, insects and animals will enhance the bio diversity of the area. An inventory of birds and animals will indicate such impacts on bio diversity.

3. Other Indicators

- **Solid waste**

Solid waste management is one of the greatest challenges facing Municipal, Provincial and Urban councils in Sri Lanka. The most common practice is to dump solid waste on to open grounds causing a lot of pollution and health hazards. Reusing disposable materials in UPAF activities can reduce the amount of total solid waste. It can be quantified by the number and the total area of open solid waste dumping grounds and the cost incurred by the urban councils to handle (collect and dispose) solid waste.

- **Institutional changes**

Changes in the institutional set up is an essential component in climate change adaptation as institutions play key roles in planning, implementing and sustaining development interventions. The institutions are the arms used by development managers to convert technologies and other interventions to practice. The matrix proposed includes the criteria, indicators, and data needs and data sources/methods for monitoring the institutional changes in the UPAF project.The institutional changes need to be measured in terms of capacity and commitment of institutions in managing climate change implications in local areas. (Annexure 2)

SUMMARY

Climate change is recognized as one of the top prioritized environmental challenges in this millennium. Ironically agriculture and forestry which is most affected by climate change are the best way to mitigate it as well. Urban and peri-urban agriculture and forestry (UPAF) hence is appropriate strategywith the rapid trends of urbanization around the globe. Through the suggested measures of UPAF food miles and fertilizer miles can be reduced and it can be quantified in terms of the reduction of both energy and cost incurred for food and fertilizer. Planting of large trees to create agro forestry are proven to be one of the main climate change and mitigation measure while providing means of producing food. The project should be carried out with integrating efforts of all individuals and relevant organizations. Hence mechanisms should be formed to create platforms for discussion and decision making of the project.

Monitoring the impacts of UPAF on climate change needs to be done during a substantial time period as there might not be immediate and drastic impacts and might require longer periods of time. Also continuous monitoring of complex indicators such as greenhouse gas emissions may not be feasible to a developing country like Sri Lanka due to lack of financial resources, hence simple monitoring tools were developed to measure direct and indirect impacts on environment and human livelihoods and to monitor the changes taking place in the bureaucratic set up in the organization involved in the project.

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Annexure1 -Quantification of potential impacts of UPAF on Climate Change (For Sri Lanka)

Development interventions	**Contribution of UPAF to CC Mitigation and Adaptation**	**Contribution of UPAF to Reduce Food/ Fertilizer/Fuel miles**	**Indicator to Measure**
Food			
Development of Home Gardens	Temperature, GHG emmissions,Urban heat island effect, Heat waves, Rainfall,C sequestration, minimize storm water runoff	Increase of UPAF food production and income	Household income and savings
			Monthly expenditure on food
Vertical gardens			Transporting, storing, refrigerating(cost/ volumes)
Introduction of new Cropping patterns			Food prices
Increase agro forestry cover			Food waste
Reuse non-biodegradable solid waste as cultivate vessels (bottles, plastic bags, etc.)		Collection/transport of SW	Number/extent of dumpsites/ cost of collection and disposal of SW
			Sun light intensity meter
Fresh water fish production (Inland ponds)		Increase in UPAF fish	Monthly expenditure on fish
			Transporting, storing, refrigerating fish(cost/ volumes)

Fertilizer			
Composting	GHG emissions, Reuse of waste	Fertilizer replaced by compost	Fertilizer(Quantity, cost)
		Transport of fertilizer	Cost incurred for fertilizer transporting
		Collection of SW	Labour and other related costs to collect SW
		Transport of solid waste	Fuel needs for transporting SW
		soil quality	C-N ratio, soil water retention capacity
		Cost of rehabilitating dump sites	Number/ extent of dump sites/ Area freed for UPAF
Erosion control & soil improvement measures	Minimize degradation of soil, minimize storm water run off	Soil quality	C-N ratio, soil water retention capacity
Energy			
Bio Gas production	GHG emissions, Reuse of waste	Reduction of domestic fuel needs(LP gas/wood)	Household energy cost/ Dependability on CEB electricity supply
Promotion of use of fire wood			
Use of energy saving Stoves(saw dust and other waste as fuel)		Collection/transport of SW	Cost of collection and disposal of SW
Water Resources			
Wastewater/Grey water irrigation	Mitigate floods, water scarcity, Droughts, Erosion	More water resilient cities	Area of water retention
Ground water development			Monthly water bill
Rainwater harvesting			Water treatment cost
			Labour days
Management of storm water drainage			Storm water O&M cost reduction
			Disaster relief cost
Aesthetic value			
Eco forestry	Temperature, GHG emmissions,Urban heat island effect, Heat waves, wind erosion	Reduction of energy to cool(A/C,Fans)	Land use maps(forestry)
Wind/ shelter belts			Attraction of tourists/ new citizens
Institutional changes			
Institutional audit and capacity building	Empowering institutes to adapt and mitigate CC impacts	Institutional changes to reduce food/fertilizer/fuel miles	
Gender			
Greater involvement of women in UPAF(individuals, groups etc.)	Empower women to adapt to CC	Self-reliance on local food	Involvement of women in UPAF(number of individuals, groups etc.)

Annexures2 - Matrix to Monitoring Institutional Changes

Criteria	Indicators	Data needs	Data sources/methods
Availability of necessary Organizations in Kesbewa MC area (GOs, NGOs,	No of organizations required Vs. Number available in the MC area	List of all the required organizations and the list of organizations available at	Interviews with UPAF project executing agency (Ministry of agriculture in

CBOs)		present	Western province), Kesbewa MC and conduct field recurrent surveys
Presence of required institutional elements within the organizations identified	Required rules, regulations, policies and procedures Vs. availability of such elements in the current organizations	List of rules, regulations, policies and procedures required for better success and actual number of them available	-do-
Behavioral changes of the institutional actors and project beneficiaries/institutional support receivers	Attitudes, norms and other behaviors of Institutional actors required for better implementation of the project vs. the current conditions of these behavioral elements	Develop list of these required behavioral elements and identify the availability of them within institutional actors and the communities	Qualitative surveys to measure the behavioral elements (institutions and communities)
Institutional performance	List of functions to be implemented by the institutions vs. current functions in terms of UPAF activities	Prepare list of functions required and identify the current functions of all relevant institutions in the Kesbewa MC area (in terms of UPAF and climate change adaptation)	Interviews with key actors of institutions present in Kesbewa MC area
-do-	Strategies/methods required for multi-institutional coordination vs. availability of such strategies and methods in coordination	Develop comprehensive List of coordination mechanisms required and identify the available mechanisms within Kesbewa MC area	Interviews with key actors of available institutions in Kesbewa MC
Institutional sustainability in managing RUAF project introduced changes	Capacity building programs required vs. available programs	Identify the number of capacity building programs and list the available ones in Kesbewa MC and with other relevant institutions such as WP agriculture Ministry/ department on UPAF activities	Secondary data in institutions and interviews
-do-	Funds required for institutional functions vs. available funds	Calculate the funds required for successful implementation of institutional functions in the UPAF project and funds actually allocated by the Kesbewa MC and other relevant institutions at present	Secondary data and interviews
-do-	Human resources required for successful implementation of UPAF activities vs. currently available human resources	Calculate no of trained persons required for the institutions (all types of institutions including CBOs) and also list the number presently available	Secondary data in all relevant institutions and interviews
-do-	Commitment of the institutions required for managing the changes introduced by RUAF project	List types of institutional commitments required and identify the available commitment	Surveys with project beneficiaries and also with institutions

The role of environmental factors on the pathogenesis of renal failure

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ABSTRACT

Chronic Kidney Disease (CKD) is an emerging global health problem. Although Major causes of CKD are Diabetes mellitus, Hypertension and aging population in most parts of the world,epidemic of CKD in the North central region of Sri Lanka seems to be environmentally induced. In the current study, relationship of environmental factors such as temperature, rain fall, water capacity of the reservoirs water issue patterns and the seasonality of farming to the morbidity patterns of chronic kidney disease of unknown aetiology (CKDu) over the last 10 years was investigated.The monthly mortality rates for CKDu showed higher rates in the period between November-January and it was consistent in each year. CKDu monthly mortality was significantly associated with rainfall ($P < 0.0025$) and minimum temperature (< 0.0001) of that month. Rainfall and minimum temperature interaction effect also indicated a significant association with renal failure deaths which was consistent in each year. Although rainfall & low temperature are related to high mortality rate these factors cannot directly cause CKDu. Increased mortality might be due to the increased exposure to the aetiological factor during this period possibly due to the excessive work and increased water intake.

INTRODUCTION

At present, human health is challenged in much different way than it was in the past. Less than a century ago communicable diseases (CD) were the main cause of human morbidity and mortality. Dynamic expansion of the scientific knowledge on human health has kept us unbeaten in the battle with these diseases throughout the history. Butnow non communicable diseases (NCD) have escalated leaving behind communicable diseases, to alarming levels and they are on the rise.While cardiovascular diseases, cancer, chronic lung disease and diabetes are the main causes responsible for these high rates of NCD, Chronic kidney disease (CKD) seems to be in epidemic proportions as well(Codreanu et al., 2006, Eknoyan et al., 2004).

CKD is defined as either kidney damage or decreased kidney function (decreased GFR) for three of more months(Levey et al., 2003).When it is established it almost always develops to end stage renal failure which would necessitate renal replacement therapy either with dialysis or transplantation for survival.Not only in the later stages even in the early phase of the disease, there could be adverse outcomes such as cardiovascular disease, sudden renal failure and premature death(Eknoyan et al., 2004).

Global burden of CKD is acquired to elevating prevalence of diabetes mellitus, hypertension,obesity and aging population (Levey et al., 2003, Ayodele and Alebiosu, 2010, Soderland et al., 2010). Although these conditions are responsible for CKD in most parts of Sri Lanka,the epidemic of CKD in the North central region is not associated with any of the above risk factors(Chandrajith et al., 2011b) and it seems to be environmentally induced(Chandrajith et al., 2011b, Wanigasuriya et al., 2007).Most of these patients are male farmers(Levey et al., 2003) in their middle ages and the disease typically has an insidious onset and a progression with late presentation when renal replacement therapy is needed(Nanayakkara et al., 2012). The quality of life of the patients become very poor at the last stages of the disease and the mortality rate is almost 100%, if they are unable to afford renal replacement therapy. Up to now four geographical clusters have identified and all of them are in the dry zone of the Island(Chandrajith et al., 2011b). Further, histopathological studies have revealed a tubulo interstitial nephritis which is commonly observed in toxic nephropathies (Chandrajith et al., 2011b).

Researchers who investigated the disease have proposed number of aetiological factors including high level of fluoride in ground water(Ileperuma, 2009), high fluoride level and the effect of Ca^{2+} and Na^{+} on the fluoride metabolism(Chandrajith et al., 2011a), exposure to inorganic pesticides(Peiris-John et al., 2006), cyanobacterial toxins, consumption of herbal ayurvedic medicine and effects of fluoride with the usage of aluminium containers for cooking(Ileperuma, 2009) etc. Earlier it was shown that ochratoxin does not cause CKDu in Sri Lankan patients(Wanigasuriya et al., 2008) but a recent study shows the possibility of this toxin as an aetiological agent of

CKDu(Desalegn et al., 2011). Heavy metals being the aetiological agent of CKDu have also been a very controversial topic in recent years. Some researchers believe that there is a correlation between heavy metals (especially Cd(Bandara et al., 2008) and As) with CKDu, however others research have found contradictory results(Chandrajith et al., 2011b).

CKD with regional clustering has been observed in former Yugoslavian countries which known as Balkan endemic nephropathy (BEN) and to a certain extent in Central American countries.BEN which was identified in late 1950s is the most investigated disease of this nature.Studies have revealed that the geographical clusters of BEN are scattered along the tributaries of Danube River indicating the environmental nature of its aetiology(Bamias and Boletis, 2008, Stefanovic, 1998).In Central America,the disease distribution shows that the hotspots are located in the low lands of the Pacific coastal areas(Ramirez-Rubio et al., 2012, Brooks, 2009). Although association with urinary tract tumours(Stefanovic, 1998) and female preponderance (Ceovic et al., 1992) differentiate BEN from other two endemic nephropathies,CKD in Central America seems to share many common characteristics with the disease in Sri Lanka. As in Sri Lanka most of the affected patients men engaged in agricultural work(Brooks, 2009, O'Donnell et al., 2011, Gracia-Trabanino et al., 2005, Orantes et al., 2011). Appearance of the similar disease in more than one focus (Sri Lanka & Central America) on the same climatic zone in the same period with inability to identify a likely agent in toxic concentrations indicates the possibility of the effect of climate & environmental factors in the pathogenesis. Hencethe importance of investigating the effect of environmental factors at the course of CKD is indispensable.

Significant variations in the renal markers with seasonality was observed in a study performed in BEN affected areas to investigate the effect of environmental factors on the kidney damage (Stefanovic, 1998).As suggested by many researchers if the aetiological factor of CKDu in Sri Lanka is environmentally induced, disease prevalence would be changed with the environmental changes. Aim of this study was to investigate the relationship between environmental factors such as temperature, rainfall and water capacity of the reservoirs with the morbidity patterns of CKDu over the last 10 years.

METHOD AND MATERIAL

The information on morbidity and mortality due to CKDu was traced back to 10 years, (1999-2008) using monthly MMR statistics of General hospital Anuradhapura. Data on rainfall, water levels of the large reservoirs, water issue pattern of the right and left canals of the reservoir, and the farming seasons of the year in the affected area (command area) was collected from the database of the Irrigation Department. Note that most of the patients were from the Padawiya and Medawachchiya area and as reservoir relevant data, Padawiya reservoir data was used. The assumption here is that management of all the reservoirs around Medawachchiya area is same as that of Padawiya reservoir. Data on the daily temperature was collected from the database of International Centre for Environmental Studies (ICES).

The association between renal failure deaths and the environmental variables was investigated using Spearmen correlation coefficients and Spearmen partial correlation coefficients. Subsequently Spearmen correlation coefficients were studied to analyze the association of the renal failure deaths to time lags of the environmental variables. Similarly time series plots were used to identify the seasonal patterns among the study variables.

Initially all environmental variables were screened by testing association of each variable with the disease. The selected variable were then used for linear logistic and log linear model fitting. In log linear logistic model fitting, renal failure deaths were considered as the dependent variable and all the environmental variables were used as explanatory variables/factors. Model fitting were done with PROC GENMOD of SAS and deviance (G^2) was used to assess the goodness of the fitted models. The change in the Deviance (ΔG^2) was used to assess the overall effect of the individual variables and interaction terms. Consistency of the renal failure death patterns in relation to the environmental variables were studied for period of 10 years.

Analysis was by the SAS System version 9.00 and Minitab version 14.1.

RESULTS

The monthly mortality rates for CKDu against time series plot of 10 years (120 months) are shown in Fig. 1. From the graph, a cyclic pattern can clearly be identified. Around the month December peak occurs while around June minimum occurs.

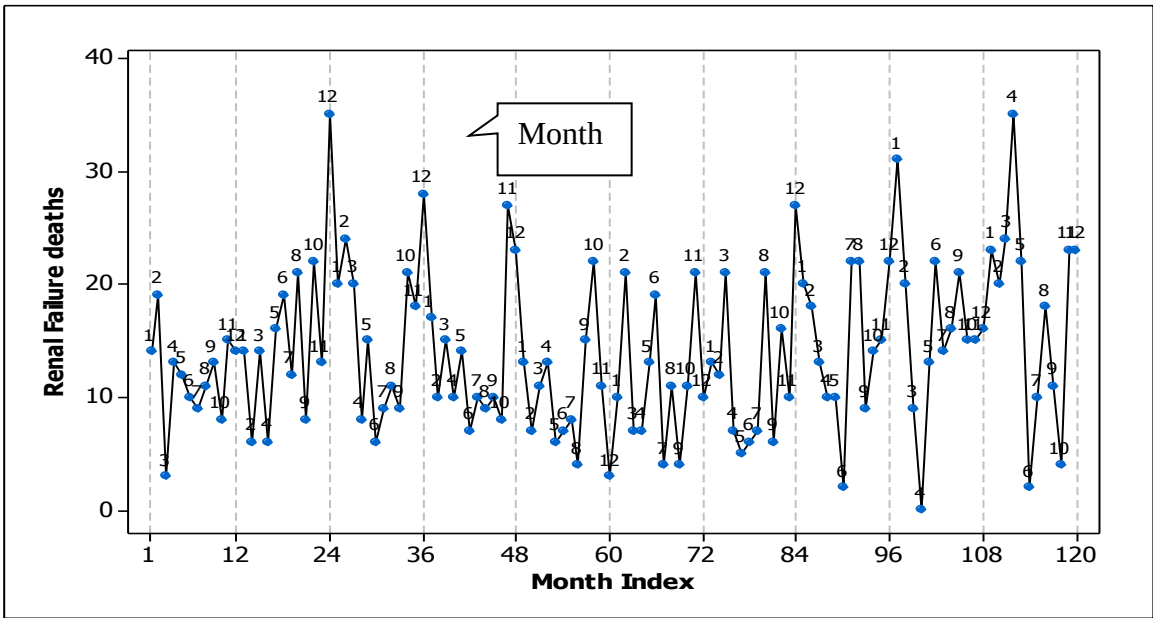

Figure 1 - Time series plot of Renal Failure Deaths for 10 years

Correlation analysis

Renal failure deaths showed correlations with minimum temperature, maximum temperature and rain fall (Table 1). However partial correlation analysis (Spearman) showed only minimum temperature is significantly correlated (–0.22, P=0.04) with renal failure death. Renal failure deaths did not show significant association with the water capacity of the tank, water issue pattern of the either of the canals and the farming seasons of the year (working pattern) (Tables 1).

Table 1 - Spearman Correlation coefficients between renal failure death and weather variables and significant levels

Variable	Spearman Correlation coefficient	Significant level (P)
Min Temperature	–0.35	<0.01
Max Temperature	–0.36	<0.01
Water Capacity	–0.01	0.89
Monthly Rainfall	0.19	0.03
Farming seasons	–0.12	0.21
Water Issue (R. Canal)	0.08	0.41
Water Issue (L. Canal)	0.07	0.47

Time lag of renal failure deaths and rainfall

Renal failure death patterns showed positive correlation with rainfall of lag zero (r = 0.23, P=0.01) and lag 12 (r=0.23, P=0.02) and interestingly negative correlation with lag 6 (r = –0.30, P <0.01) and lag 18 (–0.25, P=0.01). The implication of these correlations is that the disease develops either with the onset of rain or it takes one year to develop the disease after infestation. Note that lag 1 and 2 correlations are also significant confirming that around lag 0 there is a positive correlation.

Model fitting

Log linear model fitting revealed that rainfall and minimum temperature (ΔG^2 =5.85, P=0.02) affect on renal failure death. However, the goodness of fit statistic G^2 was 356.69 with 115 df (P<0.01)and thus model is inadequate. When the model is inadequate and it cannot be further improved by adding terms, then the model is said to exhibit over dispersion(MCCULLAGH and NELDER, 1989). Even after over dispersion was taken into account both rainfall and minimum temperature were found to be affecting on renal failure death. In fact there was an interaction between rainfall and minimum temperature on renal failure deaths (ΔG^2 =12.86 with 1 df, P<0.01). Furthermore this rainfall and minimum temperature interaction effect was consistent across yeas. In other word there was no three–way interaction of rainfall, minimum temperature and year (G^2=11.54 with 9 df, P=0.24). The parameter estimates from the fitted model are given in Table 2.

Table 2 - Parameter Estimates from the best fitting model

Parameter	DF	Estimate	Standard Error	Wald 95% Confidence limits		Chi–Square	Pr > ChiSq
Intercept	1	4.1774	1.1736	1.8773	6.4776	12.67	0.0004
rainfall	1	0.3692	0.1770	0.0224	0.7161	4.35	0.0370
Min_temp	1	–0.0671	0.0487	–0.1625	0.0284	1.9	0.1685
Rainfall×Min_temp	1	–0.0154	0.0075	–0.0301	–0.0007	4.2	0.0404

According to the parameter estimates when rainfall increases, number of renal failure death increases. Similarly, when minimum temperature increases number of death decreases. Implications are that during the raining season number of deaths increases and during the dry season, when temperature increases, number of deaths decreases. The negative interaction effect estimate implies that when both increases or decreases, number of deaths decreases and when one increases and the other decreases number of deaths increases. This outcome can be detected with data too.

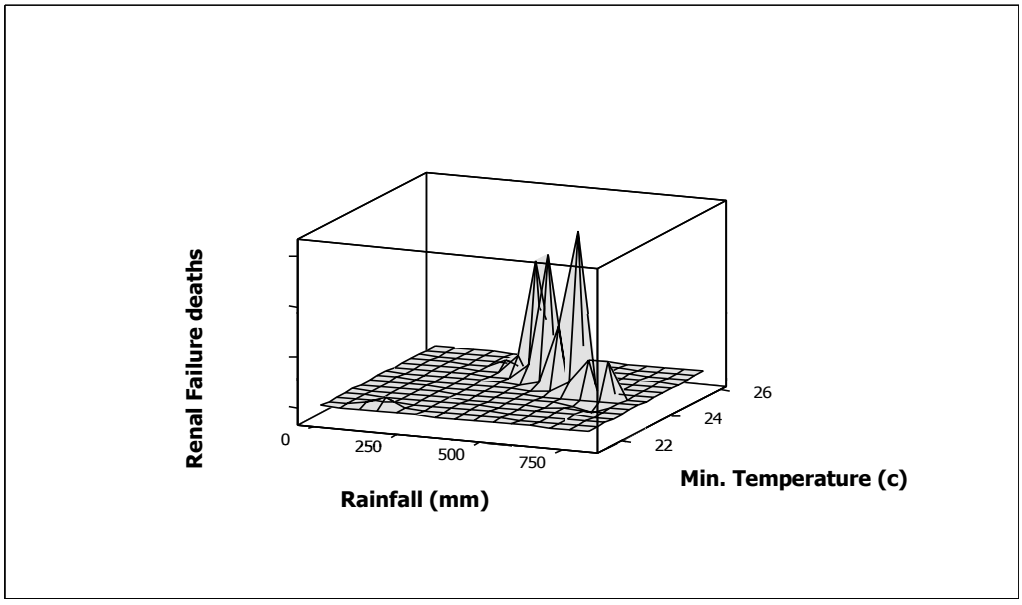

Figure 2 - Renal failure against rainfall and minimum temperature

DISCUSSION

Clear cyclical pattern in the renal failure mortality rate can be identified with high death rates in the months of November to January. This indicates the likelihood of deaths due to acute on chronic renal failure attributable to acute exacerbation of chronic interstitial nephritis.Histopathology suggests that aetiology of CKDu likely to be a toxin (Chandrajith et al., 2011b).Henceacute exacerbation of the disease could be due to higher exposure to the toxin during this period.

According to our findings renal failure deaths are significantly associated with rainfall and minimum temperature.Since all the CKDuaffected areas are located in dry zone of Sri Lanka November to January period is the wet season of this area. One of the important characteristic of the CKDu prevailing area is the availability of many reservoirs. Most of these reservoirs are of cascade irrigation system. During the dry season these reservoirs are concentrated with dissolved substances.If we assume that the aetiological factor of CKDu is a toxin and it is available in the concentrated water it is possible that water from these reservoirs contaminate the drinking water sources when there is heavy raining and when irrigation water is available.If it is so it would probably increase the mortality rates in this period.

Our results indicate that there is no relationship between renal failure morbidity and farming seasons of the year. Although generally there are two farming seasons in year paddy cultivation in May – September period is limited and entirely depends on tank water availability since there is hardly any rain in this period. But in November – January period, because of the rain water availability most of the farm lands are cultivated and people tend to do more hard work than in May – September period.Because of that even though there is no association with the farming seasons we cannot concludethat there is no association with their working pattern with CKDu.If the aetiological factor of this disease is a toxin which enters through drinking water, higher intake of toxin could be due to increased water intake to replace the increased sweat losses due to excessive work in November - January period.Factors like dehydration also may have effect

with the disease exacerbation which might enhance the renal damage and at the same time it would increase the susceptibility of the nephrons to nephrotoxins.

Generally temperature in November to January period is less compared to other months in Sri Lanka for the reason that it is positioned in the northern hemisphere of the globe. Courses such as dehydration would be increased in high temperatures. Therefore the effect of reducing temperature is mystifying. But it could be of biological importance which would encourage studies on biological toxins on CKD.

CONCLUSION

The results show that there is a significant increase in the mortality in the months November-January. Although rainfall & low temperature are related to high mortality rate these factors cannot directly cause CKDu. So increased mortality might be due to the increased exposure to the aetiological factor during this period, possibly due to contamination of drinking water sources, excessive work and increased water intake.

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An iconoclastic view of sanitation in modern Sri Lanka

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SRI LANKA: THE WHITE TIGER OF SOUTH ASIAN SANITATION?

Sri Lankan culture was historically characterized by the strong emphasis on good sanitation practices and hygiene. Archaeological evidence on well designed latrine systems are found in historic sites in Sri Lanka which date back to the 5th Century A.D. (Ferdinando 2006).Especially in the post-colonial period, Sri Lanka was widely commended for its excellent sanitation coverage and health indiceswhensome parts of South Asia were choking withuncontrolled open defecation.Currently the country has a sanitation coverage (access to improved sanitation) of 85.7%, which in par with developed countries(Global Analysis and Assessment of Sanitation and Drinking-Water 2011). The Sri Lankan success story of achieving widespread sanitation coverage is attributed to few reasons: 1. Historical traditions of good hygiene and personal privacy 2. High literacy rate achieved during the post-independence period 3. Reasonable average economic conditions that prevailed during mid 20th century. However this traditional complacency has been challenged by certain environmental issues that recently emerged in the rapidly reshaping landscape and politically economy of the country. Various environmental status studies in the past 20 years point towards three common environmental issues that can be fully or partly attributed to failed sanitation: 1. Degrading water quality in small streams 2. Degrading groundwater quality in urban and peri-urban areas 3. Acute eutrophication and nutrient enrichment in aquatic or wetland ecosystems.The most significant contaminants in both water and soil in the investigated areas can originate from improper, inadequate or malfunctioning sanitation infrastructure. The identified environmental issues can lead to direct and indirect social impacts in different time scales. It's widely accepted now that sanitation engineering is not only a science but also an art that should respond to the nuances of nature and society (Mara 1996; Matsui, Henze et al. 2001; Winblad and Simpson-Herbert 2004). Researchers and professionals across South Asia have questioned the suitability of certain widely used sanitation technologies, while others have opted for increased training and awareness on alternative sanitation methods (Calvert 1997; Calvert, Seneviratne 2002, Gosh 2005). A wide variety of sanitization technologies have been developed in the last 30 years to suit different eco-climatic and socio-economic conditions (Mara 1996, Winblad and Simpson-Herbert 2004, Crites and Tchobanoglous 1998). 1980-90 was declared as the International Decade of Water and Sanitation and improved access to sanitation was also identified as a Mellenium Development Goal (MDG7, Target 10). Though not adequate there had been a significant increase in the international aid and investment for sanitation in the last two decades. Despite the available variety of suitable technologies, the increased sanitation literacy among public and substantial state investments,the experiences around the world show that achieving truly sustainable sanitation is a difficult task. In this paper I investigate,taking Sri Lanka as an example, how the nexus of institutional, ideological (attitudinal) and political constraints hinder optimum use of available sanitation technologies to cater for divers eco-climatic and demand conditions encountered in reality. In an institutional perspective I discuss the possible causes that perpetuated the failure technologies and policies that pave way to environmental issues.

THE INCONVENIENT TRUTH

From the mid 1990s a series of environmental status studies in small streams and wetlands in urban and peri-urban areas in Sri Lanka has pointed towards possible contamination of surface and ground water by human excreta related pollutants. Table 1 gives a summary of few studies revealing alarming levels of water quality degradation in last two decades.

Table 1 - Summary of selected water quality studies

Parameter (Max)	Studies					
	1	3	4	5	6	Desirable Value[2]
BOD_5 (mg/l)	180.0	*NM*	*NM*	70.0	6.6[1]	4.0
Free NH_4 (mg/l)	8.8	*NM*	*NM*	15	*NM*	0.85
Fecal Ciloform (nos/100ml)	*NM*	7000	1950	*NM*	7250[1]	1000
Nitrates (mg/l)	*NM*	4.5	1.8	0.76	*NM*	10

[1] This is the 75th Percentile value, Max values were not given in this study

[2] Based on USEPA Ambient Water Quality Criteria (EPA 1986) and WHO Human Contact Criteria

NM = Not Measured

The Studies

1. Background study for 1st Colombo Flood Protection and Environmental Improvement project: Water quality in public waterways & wetland of Colombo, 1991 (CEA 1995)
2. Water quality studies in Pinga Oya - Mahaweli basin, 2002 (Herath 2003)
3. Water quality studies in Nanu Oya – Mahaweli basin, 2002 (Herath 2003)
4. Regular water quality monitoring by the Sri Lanka Land Reclamation and Development Corporation in the Colombo canal system , 2000-2004 (Hettiarachchi, Anurangi et al 2011)
5. Water quality monitoring in Kolonnawa Marsh, 2009-2010 (Hettiarachchi, Anurangi et al 2011)

All the water quality studies referred above were done in urban or peri-urban areas in Colombo and Kandy districts which recorded high sanitation coverage (Department of Census and Statistics- 2002 census on population and housing). All the above parameters are indicators of human waste related contamination (Chapman 1996, MtCalf and Eddie 2001). The Atlas of Geo-chemistry of Sri Lanka (Dissanayake and Weerasooriya 2001) prepared based on sampling done in the late 1990s reveal that the aquifers hydraulically connected to the metropolitan areas of Colombo, Kandy, Galle, Matara and Jaffna Nitrate (-NO_3) concentrations from 10-40 mg/l.The wetland site reports of Colombo Flood Detention Area Wetlands (CEA 1994), Bellanwila-Attidiya Marsh (CEA 1995a) and Bolgoda Lake (CEA 1995b) revealed a possibility of nutrient buildup in these wetlands due to certain ecological indicators such as rapid spreading of spreading invasive floating macro-flora such as Water Hyacinth and Water Luttuce . This fear was vindicated by a later study of Hettiarachchi and de Alwis et al (2009) which revealed excessive amounts of reactive Phosphate and Kjeldhal Nitrogen in soils of Kolonnwawa marsh. The authors pointed to the congested watersheds of the wetland that maybe releasing nutrients due to failed sanitation. They also clearly illustrated that the nutrient enrichment in the wetlands are causing an ecological regime change that may eventually transform the wetlands type from the native emergent marshes to woody shrub wetlands. The above studies provide ample evidence to the fact that despite the high sanitation coverage in the country, both surface and ground water resources are getting rapidly contaminated by human excreta related contaminants. The nutrient enrichment caused by certain contaminants are irreversibly changing certain urban ecological features such as wetlands and streams. Therefore it is unequivocal that the dominant sanitation technology used in these areas are not working and suitable for current loading levels as well the environmental conditions in the least in certain localities.

A SHORT HISTORY OF SRI LANKAN SANITATION

There is ample physical evidence for the existence of sophisticated sanitation systems and technology during the pre-colonial period in Sri Lanka. Historical narratives of South Asia generally agree that human excreta was associated with impurenessin the region and defecation essentially required privacy. In the cities defecation would have been done in enclosed spaces and the taboo task of collecting and disposing human waste was performed by people of certain casts.Most improved sanitation systems in pre-Colonial Sri Lanka are found in Buddhist monastery complexes or buildings of the elite. Folklore refers to open defecation at times. Therefore it is safe to assume that open defecation would have been widely practiced among rural commoners. However the defecation practices were reasonably well regulated by informal social institutions. Men and women used different areas and times for regular defecation and certain common areas were not allowed to be 'defiled' by feces or urine. Therefore during the pre-British times regardless of the fact that open defecation would have been more common, sanitation was a societal task. Intricate social institutions embedded in the cast system and religious learning was required to keep it operational.

The modern period of sanitation in Sri Lanka begins in the late 19th century during the British rule. It's essentially connected with two developments that took over the British Raj: 1. Advent of the water seal latrine or flush toilet 2. Passing of the public health lows in Britain during late 19th century. The water-seal trap patented by Alexander Cummings in 1775 and the flush toilet arguably invented by George Jennings in 1851 very quickly became the sanitation norm across the entire world. Then British public health laws such as the Public Health Act of 1875 were soon emulated in other parts of the empire during the ensuing years. In Sri Lanka, public health mainly came under the preview of the health sector. From the beginning of the establishment of Medical Officer of Health jurisdictions and appointment of Public Health Inspectors (PHI) sanitation became a responsibility of the health department. On the other hand a series of legislations Local Government Authorities (LGAs) were also vested with increasing powers and responsibilities on common amenities including sanitation. National Water Supply and Drainage Board of Sri Lanka (NWSDB) established in 1975 was also given a stake and a responsibility in sanitation. The bottom-line governing principle of sanitation in Sri Lanka has its roots in the public health laws of Britain which were mainly brought contain the waterborne epidemics. Therefore it mainly focuses on separating feces from human contact. The formal institutions that govern sanitation constitutes of three main types: 1. Local government by laws 2. Health department guidelines (ex: PHI manual) and 3. NWSDB act and internal guidelines. From early 1890s basic sanitation guidelines were incorporated in local government regulation (Sanitary Boards Ordinance of 1892)and later bylaws such as maintaining 50 feet between a latrine pit and drinking well. PHIs received training that essentially recommended the water seal latrine/flush toilet and cesspit. Few

LGAs such as the Colombo Municipal Council were given both the authority and funding for centralized sewage management. Again the focus was to separate feces from humans. The operations of LGAs and the Health Department staff became more streamlined with time and the Pardesheeya Sabhas Act of 1987 developed a mechanism that co-located PHIs at the LGA offices. Initially the projects to improve public health were handled by the Department of Health and sewage infrastructure development was handled by the relevant LGA (Eg. Colombo Municipal Council) or Public Works Department. With the establishment of NWSDB most of the projects for sanitation improvement and sewage infrastructure management passed on to that agency and Department of Health Along with the LGAs started playing a more regulatory role. However NWSDB also inherited the sanitation norms of its predecessors carried over from the British times.

There had been considerable investments on sanitation improvement in Sri Lanka from mid 1800s. The Colombo sewer scheme that collects sewage for different parts of the city and disposes through a sea outfall was inaugurated in 1855 Intermitt.ent community sanitation schemes and public toilet schemes have been carried out through the Health Department and LGAs. The major community sanitation improvement scheme in Sri Lanka was the Community Water Supply and Sanitation Project (1^{st} and 2^{nd}) carried out by NWSDB that supported the construction of 174,000 toilets in individual homes (Piyasena 2011). The project was funded (USD 64 Million) by the World Bank in 1992 to 2003. In the late 1980s NWSDB also constructed few centralized sewage collection and treatment systems in medium sized planned housing schemes. However, only about 2.3% of the Sri Lankan population is served by centralized swage management, rest use individual latrines with onsite disposal. All the sanitation improvement projects that provided individual latrines had designs with water seal/pour flush latrine cesspits or septic tanks. It should aslo be noted that only 10% of the funding for the water sanitation sector in Sri Lanka has been allocated for sanitation(Global Analysis and Assessment of Sanitation and Drinking-Water 2011). Most of the existing latrines have been built privately by the owners without any kind of financial or technical support.

The technical guidelines for sanitation infrastructure in Sri Lanka have developed significantly over time. Initially there were no written guidelines, the Health Department staff and municipal technical officers overlooked and advised where necessary with their basic training. Centralized sewers and treatment systems were designed individually based on standard engineering practices. However there was a latter trend of developing overall guidelines for sanitation infrastructure both by government agencies and non-governmental organizations. Table 2 gives a chronology and nature of these guidelines.

Table 2 - Details of some selected technical guidelines on sanitation (State and NGO)*

Guideline	Details
PHI Manual *Published by:* Health Department *Year:*1989 revised 2005	*Nature:* Official guideline for Public Health Inspectors *Main sanitation techniques outlined:* Septic Tank and Soakage Pit
SLS 745 *Published by:* Standards Institute of Sri Lanka *Year:*1986 revises 2002	*Nature:* National Standard for Sanitation Technology *Main sanitation techniques outlined:* Septic Tank and Soakage Pit; 2002 Revision introduced Anaerobic Filter and Constructed Wetlands for secondary treatment
NWSDB Design manual D7 *Published by:* National Water Supply and Drainage Board *Year:* 1989	*Nature:* NWSDB guideline for design of wastewater systems *Main sanitation techniques outlined:* Septic Tank and Soakage Pit (For decentralized sanitation)
CFRR manual *Published by:* National Housing Development Authority *Year:* 2004	*Nature:* Implementation guideline issued by the government of Sri Lanka (2005) for Rehabilitation Work after the Tsunami disaster *Main sanitation techniques outlined:* Septic Tank and Soakage Pit
Helvetas Sanitation Manual Published by: Helvetas Sri Lanka Year: 2002	*Nature:* Published as a technical guideline for community initiatives and NGO funded projects *Main sanitation techniques outlined:* Septic Tank and Soakage Pit, Dual pit latrine, Ventilated Improved Pit Latrine, UDDT

* *Table based on Hettiarachch and Hettiarchchi (2007)*

It's clear from the table that prime technology promoted by all these guideline is the water seal/pour flush and septic tank. In very recent times some initiatives have been taken to include secondary treatment technology, the 2002 revision of the national sanitation standard (SLS 745:2003) incorporated anaerobic filter technology and constructed wetlands as secondary treatment options for a Septic Tank system. Only the sanitation manual published by Helvitas Sri Lanka presented a mulit-optional guideline that also includes alternative sanitation technology.

ICONIZATION OF THE SEPTIC TANK

Human excreta was traditionally considered as impure in most communities of Sri Lanka. The British also introduced a sanitation regime that took separation of excreta from humans as the ultimate priority that matched well with this cultural trait. Though a variety of latrine types such as bucket latrines, pig latrines and open trenches e were used during the British time the water seal/pour flush[4]and cess pit (later septic tank) became *solution par excellence*. The rapid weakening of the cast system in Sri Lanka and the out migration of a large number of janitorial workers after independence would have strengthened the case for on-site disposal of swage with a pit. Most parts of Sri Lanka have environmental conditions suitable for cesspit pit or septic tank systems. Most Sri Lankan soil series are well draining and have good hydrological conditions. Therefore within this conducive context a bureaucracy trained in British sanitation norms eventually ingrained the onsite disposal of sewage with a cess pit and the use of water seal/pour flush latrine into all the institutions that govern sanitation and public health in Sri Lanka. The *de facto* solution became *dejure*. It was recommended by the PHIs and always used in government community sanitation schemes. Later with formalization of sanitation guidelines, septic-tank and soakage pit design became the recommended sanitation technology. In reality a wide spectrum of cesspits, partially lined pits and various improvisations of septic tank-soak way design are constructed in practice rather than a strict adherence to guidelines.A practicing sanitation engineer would know that most latrines presently in operation barely confirm to the guidelines. Toilets constructed by private owners, commercial enterprises or sometimes even the government/NGO funded schemes try to poorly emulate the pour flush/septic tank system rather than selecting the best sanitation technology for the given environmental or economic conditions.The sustained institutional and bureaucratic support for the pour flush toilet and septictank would have contributed to making it the aspiration of the masses and thus the politically preferred sanitation solution.

The pour flush toilet and septic tank combination is a time tested and effective sanitation solution. It has worked well in most parts of Sri Lanka and may have immensely contributed to the country's record in containing diarrheal and other hygiene related diseases. However Sri Lanka has considerable eco-climatic diversity and it has been globally reiterated by researchers that septic tank and soakage pit systems are not suitable in certain soil and geo-hydrological conditions. The suitability of having fixed norms for septic tank design and construction in all regions of the country has also been questioned (Werellagam and Hettiarachchi 2004). Even when a septic tank soakage pit system can operate without problems for the user it may have environmental impacts on the aquifer with excessive nutrient loading as noted by the research highlighted in this paper. It is also noted that though guidelines are elaborate they are not strictly followed in the ground level. Operational as well as economic constraints lead to compromised version of septic tank systems in areas where other alternative sanitation solutions may have been more suitable. The pour flush toilet and septic tank has been iconized as the necessary and sufficient norm within the institutional framework that governs sanitation. This makes it difficult to emphasize the need for further treatment of septic tank effluent with secondary treatment systems such as bio-filters or constructed wetlands in cases where it is necessary. A single solution being promoted by the institutions has gained it an iconic status among public and created a public opinion largely in favor of it disadvantaging the other sanitation techniques. The public preference of water seal latrine and septic tank combination was naturally followed by political support for it making diversification of sanitation solutions even more difficult. However it should be noted that the sanitation policy currently in the process of preparation by the Ministry of Water Supply and Drainage acknowledge the importance of selecting the appropriate sanitation technologies for different environmental and demand conditions. It proposes to assignthe Local Authorities and the regional staff of NWSDB with a responsibility of selecting specific geographically optimal sanitation solutions to.

UDDT: 'NEW KID OF THE BLOCK'

Independent to the mainstream sanitation industry a rather recent drive for alternate sanitation was launched by a diverse group of NGOs and researchers. Though this campaign received intermittent state and agency support, very little have been achieved on ground. During the late 1990s NWSDB carried out a pilot project to introduce Urine Diversion Dry Toilet (UDDT) in Matale district. Later Practical Action Sri Lanka initiated a project to popularize alternative sanitation where 118 UDDTs were constructed in Sothern and Eastern provinces. Few other NGOs also followed with smaller alternative sanitation campaigns, again mainly focusing on UDDT. In the 90s few individuals took initiative to construct bio-gas toilets in households and community centers. Handful of such units still exists and operates successfully in isolated households. Interest in alternative sanitation was renewed during the government and NGO responses to the Asian Tsunami disaster in 2004. Certain rehabilitation schemes introduced UDDTs for the newly built houses. In a significant move Amrican Red Cross built 50 UDDTs in different resettlement villages in the Southern province. Some non-governmental organizations worked on non-structural measures to make UDDT popular. The Sanitation Task Force established in 2006 among non-governmental organizations working on sanitation in Sri Lanka also called for better institutional recognition of alternate sanitation methods; again their main focus was UDDT. Practical Action Sri Lanka along with IFRC and UNICEF has done some ground work to introduce UDDT to the formal institutional framework.UDDTs

[4] The terms *water seal* and *pour flush* are used loosely and sometimes confusingly to refer to a toilet with a pedestal or pan (squatting pan) that has a S or P type trap and flushed (mechanically or manually) with water after use

worked well in certain households; however some of these organizations and the project staff admit in retrospect that UDDT has not gained the expected public acceptance despite their efforts[5].

Evidence shows that similar to its mainstream counterpart this campaign for UDDT has also promoted a single technology out of the wide variety of alternative sanitation / ecological sanitation designs. On the contrary to the actual need, the promoters of UDDT has become a rather narrow advocacy coalition trying to institutionalize another single solution.

A BABY STEP TOWARDS INTEGRATED SANITATION

The discussion points to two main outcomes. First, the recent research work and environmental status report from different urban and peri-urban areas in Sri Lanka clearly shows that significant human excreta related pollution of waterways and ecosystems that can be pointed towards failing sanitation is taking place. The current sanitation regime was very successful in achieving a high sanitation coverage in the country. It has created a culture that separates humans from excreta which is very effective in achieving better primary hygiene. However it fails to account for secondary effects of nutrient overloading or leaching contaminants into water resources under unfavorable environmental conditions.

Second, to provide solutions for these problems a broader variety of technologies should be adopted according to diverse environmental conditions of the country. The current sanitation regime is a result of long term institutional strengthening of a single technology, namely the Pour Flush toilet and the Septic Tank combination. The institutional preference given to a single technology has gained it strong favorable public attitudes and political support as well. This further strengthens the single solution approach within the institutional framework and makes it even harder to introduce new sanitation technology to the Sri Lankan market. All attempts to introduce alternative sanitation technology have failed to gain any reasonable success. A small advocacy coalitionthat seeks public and institutional acceptance for UDDT technology developed during last 10 years, but has not gained any notable success up to now. A truly integrated multi-option approach cannot be introduced to the ground level without careful institutional reform and a thorough multi-platform advocacy campaign. The following three initial institutional reforms– I think – will help break the interlocking institutional, ideological and political constraints discussed in this paper:

1. Incorporating a wide spectrum of sanitation technologies to the existing guidelines and standards
2. Provide in-house trainingon alternative sanitation technologies (both merits and demerits)to bureaucrats, technocrats and technicians involved in governance of sanitation in Sri Lanka.
3. Essentially include a session on alternative sanitation in community participation and consultation procedures in resettlement and community sanitation projects carried out by the government or NGOs.
4. Along with every building permit application issued by the LGAs, distribute a simple (layman's) leaflet with main points to consider in constructing a latrine and different options available.

I do not assume that the complex variables involved in determining the sanitation practices of a given locality can be controlled by institutional reform alone. The overwhelming ideological barriers or financial odds against certain sanitation options should be solved in their own merit. However given the fact that solidification of our current sanitation regime has its roots in the initial institutional preference given to a single technology, there's all themore reason to start its liquefaction process too with institutional reform.

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[5] Based on unpublishedreports and personal communication with former project staff

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Optimization on water consumption in Unilever Horana Plant

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INTTODUCTION

Water scarcity is a growing concern in every part of the world and now it is a bigger threat than a financial crisis. Scientific predictions on water availability anticipate a major water shortage by 2050 if the current consumption and pollution patterns continue to happen in the world. According to the principles of Integrated Water Resources Management the water resources should be equitably distributed among the three types of uses: Water for People Water for food and industry and Water for nature Over appropriation of water by one sector will inevitably lead to a resource stress in the other sectors. Agricultural and industrial sector is the largest water user in most countriesand generally commands political power and economic investments. The operations of the industrial sector especially are more prone to create inequity in the water sector due to three reasons:

1. It consumes large volumes of water that can be redistributed to potable uses or natural systems
2. Industrial sector accounts for the major portion of water pollution
3. Industrial sector usually managed by private firms or state agencies with very little public participation.

Therefore additional voluntary efforts are required in water management in the industrial sector to ensure equity and environmental sustainability.

Understanding the global risk on water crisis, in 2010 Unilever had derived its global strategy on sustainable growth as a multinational player FMCG category. Unilever Sustainable Living plan (USLP) is the commitment that Unilever had put forward to reduce its impact on environment, climate change in the global platform. In which Unilever will double its business by 2020 in while keeping its environmental footprint in the base line of 2008. This is purely a "BIAS FOR ACTION" initiative where actions are formulated towards achieving the predetermined target.

When it is come to Unilever Sri Lanka, being the biggest multi-category FMCG manufacturer in the country, worth of 32 Billion Sri Lankan rupees in terms of business turn over. Unilever has product portfolio covering Persenal care, Home care, Foods and savory and it holds the biggest brands like Sunlight, Lifebuoy, LUX, Signal, Surf, Pears, and Astra. All these brands are predominantly hold highest market share in the categories they operate. More than 95% of what is marketed by Unilever Sri Lanka is manufactured in within Sri Lanka at its two manufacturing facilities. The manufacturing facility in Horana handles 80% of the local production

In line with what Unilever global had initiated, Unilever Sri Lanka(USL) had taken many initiatives to reduce its impact on the environment, in terms of water management, energy conservation and other environmentally affected emission. The target is to bring down the environmental footprint of a product on its entire life cycle starting from sourcing of Raw materials, manufacturing, distribution and finally the end user impact during usage. This paper focuseson how Unilever manufacturing had made its commitment on water preservation on its manufacturing process (i.e. Horana Factory). The strategy on this water preservation has formulated covering three main areas as follows and necessary investments and resources had already furnished to fulfill the target of being a WATER POSITIVE site by 2015;

1. Optimization of portable water usage
2. Reuse of waste water
3. Harvesting rain water

OPTIMIZATION OF PORTABLE WATER USAGE

USL being a FMCG manufacture, most manufacturing process are water intensive and requires potable-quality water.The factory adheres to most stringent quality control procedures/ framework of environmental quality management systems in their manufacturing process such as Good manufacturing practices (GMP). Therefore all manufacturing processes are required to meet these series of internal environmental quality control standards unless the national regulations are more stringent. These processes are heavily depended on the water as it requires water starting form cleaning to cooling water in the manufacturing process.

Another thing to stress out that, Winning market is winning customers, as previously put forward, Unilever Sri Lanka being a multi category manufacture it has to absorb the highest and most complicated product mix in its product portfolio. Unilever Sri Lanka is catering to the one of the smallest market in the region but it demands not only complex but a rich product mix in their shopping cart.Therefore the challenge is remainedas to how fill customers'cases on time without compromising the expectations of the customers.In nutshell, the volume of the each product is low but rich in diversity (i.e. having same product in different choices, ex normal toothpaste and herbal toothpaste). At the manufacturing level the above is met by changing over manufacturing line form product A to product B once the weekly demand of product A is met. The switching from A to B needs thorough cleaningof entire vessels and lines. The challenge is, this exercise requires a significantamount of pure water for cleaning till the timeit is ready for feeding the product B. Needless to say that how many product change-overs are being taken place shop-floor to meet the above product mix. This situation gets worse when the production demand is rising and when new products or new regulations put in place to meet certain quality control requirements. As previously mentioned, the Food manufacturing in Unilever complies to Good Manufacturing Practice (GMP) standards and it is required to clean (CLIP) entire manufacturing process twice in a week to ensure the stringent hygiene standards met at the production level.

Considering all above, reduction or optimization on portable water usage without compromising the production efficiency is a tough challenge. Therefore the strategy on reducing the water usage was started with monitoring (i.e. by metering, as at today there are thirty five (35 no's) flow meters have fixed in the site in various locations to meter the individual consumptions). In the beginning the consumption in each of these meters recorded at three times a day and the results were recorded. After careful analysis of these data target for each and every process consumption points were established. At present the results are recorded on daily basis and analysis done on weekly basis. The approach on reduction was done by delegating end user where controlling of the same given to end uses by delegating the ownership. Then individual departments were encouraged to look in to new innovations of getting all means and ways to reduce water consumption on their specific processes. Some of initiatives those taken in factory wide are;

1. Run Strategy for optimized Change overs in all plants
2. Introduction for Pigging system Personnel care plant

The efforts had elided results by reducing factory specific water consumption from 3.4 to 2.48 during last twelve months. This was a remarkable achievement on USL journey towards sustainable expansion. The process is continued to monitor and take corrective actions on regular basis.

Figure 1indicates how the total factory wise water consumption hasreduced on yearly basis from 2009 to 2012 (YTD)

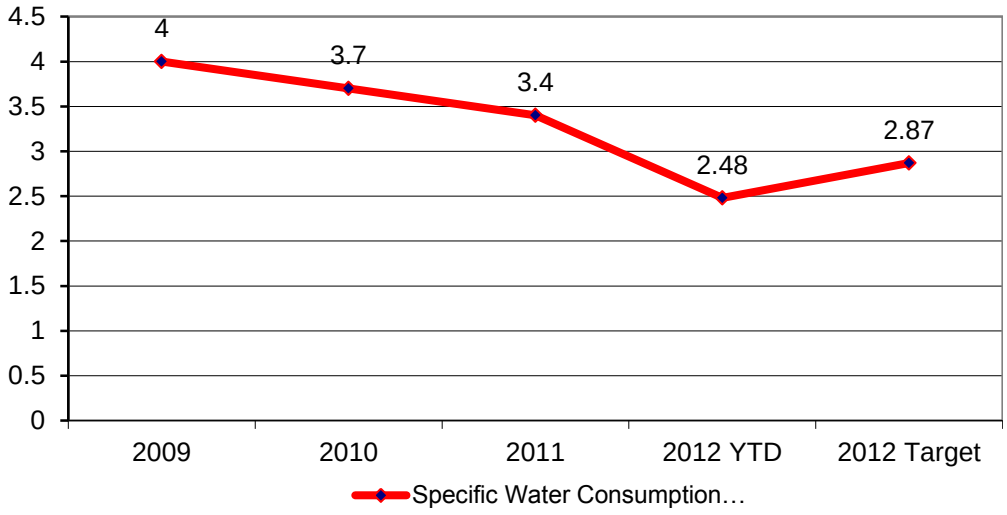

Figure 1 - Annual specific water consumption (ton/ton)

REUSE OF WASTE WATER

Unilever manufacturing site in Horana is generating approximately 300 $m^3$of effluent on a daily basis. The generated effluent at site is treated in the in-houseEffluent treatment plant in Horana which is capable of treating a hydraulic load of 306 m^3/dayto meet the National standards of treated effluent (Ref National Environmental Act, No 47 of 1980), Once the national standard for inland surface water disposal is met, then this water can be dispose to any canal or a stream that has perennial flow rate eight times or larger than that of the outflow of the treatment plant. However taking its responsibility for protecting environment, USL have taken steps to reuse this water in its own premises. This was to be done without compromising the stringent hygienic requirements to be followed as a food/ personnel care manufacture, where no contamination is allowed. USL had invested on building necessary infrastructure to utilize the treated water in

toilet flushing, cooling tower make up and for gardening. If treated water is not being reused on above processes, then this water requirement has to be compensated by potable water taking from the regular water supplier (i.e. BOI). At present more than 75% of treated water is utilized within the premises for process as described earlier on. This initiative had gained a very significant reduction on portable water usage (Fig 2); the chart is a comparison portable (RAW) intake from the supplier (BOI) vs. ETP treated water usage.

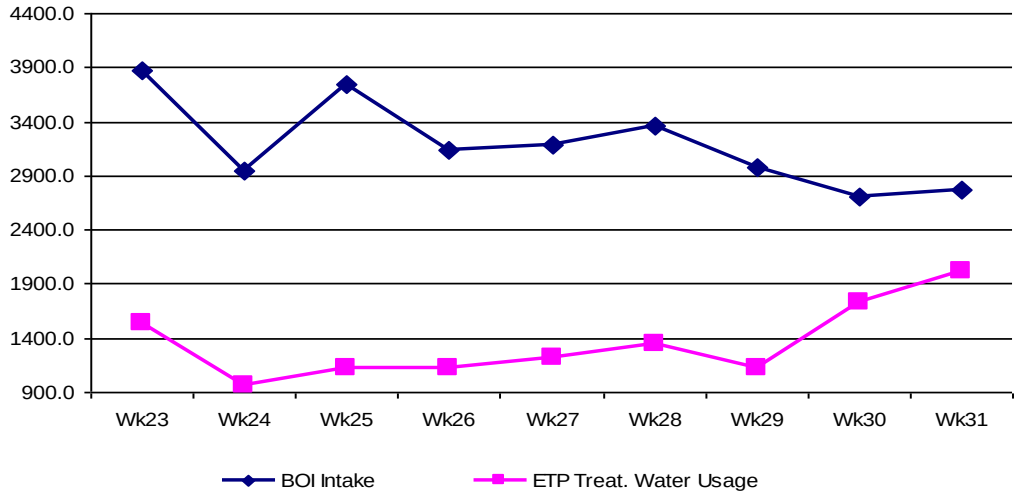

Figure 2 - Horana plant weekly water consumption by type of water

Plans are under way to utilize the 100% of treated water by installing a RO (reverse osmosis) plant, which will bring the quality of treated water to potable standards and can be utilized in any process, the proposed plan is to utilize this water in steam generation where it is expected that this yield 54,000 tons of potable water saving per annum. This will also enable USL to be a ZERO discharge site, where there will be no water discharge out of the premises.

HARVESTING RAIN WATER

USL Horana plant is located in wet zone of the country, which has an annual average rainfall of 2000-2500mm. The frequent rain impacts negatively on a manufacturing plant that still depends on certain labor intensive processes and requires efficient transportation of both products and raw material. However USL hasmanaged to convert hindrance in to a blessing. As a pilot project, Phase one of Rain water harvesting project had completed with an investment of 8Mn Sri Lankan rupees (probably this would be the very 1st Rain water harvesting project in FMCG category or any other industry). This will yield total 2500 m^3 per annum which accounts to be 2% of the total water consumption. The harvested water is used mainly for gardening and toilet flushing. Despite the still moderate percentage of clean water need replace by the harvesting system, its contribution is significant. This initiative further reduces the dependency of the factory on water from the national supply (i.e. BOI). This saves a large quantity of water for the supply system in Horana area and allows it be redistributed for new small private users in the region.

The above efforts had given their expected results towards achieving WATER POSITIVE site by 2015, where USL will put its all efforts get it.

CONCLUSION

The three steps taken by USL Horana factory under the global Unilever BIAS FOR ACTION initiative has contributed significantly in reducing

1. The industrial water demand by the factory and
2. Reducing the pollutant load discharged by it.

In the process it also develops a knowhow of water optimization practices that can be replicated in the other FMCG factories. Given the specialized nature of the FMCG industry in Sri Lanka developing such sector specific knowhow is important. The lessons of the initiative are well documented and the company is looking forward disseminate knowledge to other parties in future. It also plans to expand the water conservation and pollution minimization practices in the coming years.

Papers Accepted for YWPS

Papers accepted but not presented

Spatial variability of hydrogeological characteristics in relation to soil characteristics, along a landscape gradient in Bellanwila-Attidiya area

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ABSTRACT

Wetlands are unique ecosystems which are of imperative ecological, social and economic values which are habitually unseen and undervalued. It is comprised of unique components of soil, water and biodiversity which are interconnected. Specially, the involvement of wetlands in the functioning of water cycle and flood attenuation are some fundamental services provided by wetlands. Properties of wetland hydrogeology and soil and their relationships are poorly studied although these aspects are sensitive to human induced changes. Thus this study focuses on the impacts on land use changes on natural and man made landscape in and around an urban wetland, the Bellanwila-Attidiya Sanctuary.

Main objective of this study was to present a summary of spatial variation of ground water table, soil characteristics and develop maps using GIS in different land use areas: natural- wetland; manmade-functioning paddy fields, abandoned paddy fields, residential. This study was carried out for a period of 3 months and several random soil samples were obtained from all land use areas. Two hydrgeological parameters were measured namely, elevation of ground water table from the mean seal level and the depth of the ground water table. The following soil parameters were analyzed in triplicate, from the samples taken at the surface and at a one meter depth in the soil: physical properties; moisture content, temperature, soil type and soil colour and chemical properties; NO_3^- , PO_4^{3-}, SO_4^{2-}, Cl^-, Fe^{3+}, pH, salinity and electrical conductivity. All analysis were carried out according to Standard Methods and the GIS maps were developed using ArcView GIS 3.2.

Elevation of ground water table from the mean sea level showed a significant difference between all the land use areas ($p \leq 0.05$), except in between industrial area and residential area. The highest depth to the ground water table was depicted in industrial area while the lowest was in functioning paddy fields. Depth of the ground water table exhibited a positive correlation with pH, electrical conductivity and Nitrate of top soil and pH of bottom soil. Similarly it showed a negative correlation in moisture content, Phosphate and Iron (III) of top soil and moisture content, Sulphur and Chloride of bottom soil. Regression analysis was done to formulate a regression equation to determine the liaison between depth of the ground water table and soil parameters.

The findings evidently exhibit that the ground water table and soil properties are influenced by the variability in land use patterns. Thus, effective watershed management is crucial for healthy wetlands.

INTRODUCTION

Wetlands are an essential component of the environment. These ecosystems are unique ecosystems which are of imperative ecological, social and economic values which are habitually unseen and undervalued (Tooth, 2007). It is comprised of unique components of soil, water and biodiversity which are interconnected. Specially, the involvement of wetlands in the functioning of water cycle and flood attenuation are some fundamental services provided by wetlands (Mitsch and Gosselink, 2007). Wetlands have been promoted as being excellent "biological filters", habitat for fish and wildlife, carbon storage and holds tremendous promises for far-reaching scientific, commercial and social values (Winter, 2011). The losses in wetland quality and quantity as well as interconnectivity is increasingly evident in the past few decades and are often attributed to the enormous increase in population pressure and unsustainable development (Huang *et al.* 2012). As a result, many of the wetlands have partially or fully lost their pristine quality and have been transformed to modified ecosystems. Thus it is inevitable that the delicate balance of the three components is lost or disturbed which then influences their functions and values (Rachel and Moorhead, 1997). Although the reasons for the loss of wetlands have been identified the studying and qualifying impacts they cause to the ecosystem have received less attention. (Osbourneand Adcock, 1995)

Thus this study focuses on the impacts on land use changes on natural and manmade landscape in and around an urban wetland, the Bellanwila-Attidiya Sanctuary. This wetland is reported to be under immense development pressure and resulting adverse impacts due to the changes in land use patterns in the area. Main objective of this study was to investigate the changes in the soil and hydrological characteristic in the wetland and in the surrounding landscape. This

study presents a summary of spatial variation of ground water table, soil characteristics and develops maps using GIS in different land use areas: natural- wetland; manmade-functioning paddy fields, abandoned paddy fields, residential.

METHODOLOGY

The following study was carried out from February 2011 to April 2011, for a period of 3 months and the site was visited once in two weeks and soil samples were taken by using a soil borer in randomly selected places. Sampling was carried out in triplicate on each day. The study site represented by the wetland itself (WL) which is the main marsh and surrounding different land use areas i.e. functioning paddy fields (FPF), abandoned paddy fields (APF), residential area (RA) and industrial area (IA) (Figure 1).

Analysis of soil quality

The soil chemical properties viz. NO_3^- , PO_4^{3-}, SO_4^{2-}, Cl^- , Fe^{3+}, pH, salinity and electrical conductivity and physical properties viz. moisture content, temperature, soil type and soil color were measured at two levels: at the surface level (top) and at 1 m depth (bottom) from the surface. Samples were analyzed in the Soil Laboratory of the University of Colombo. Table 1 depicts the standard methods adopted to analyze soil samples.

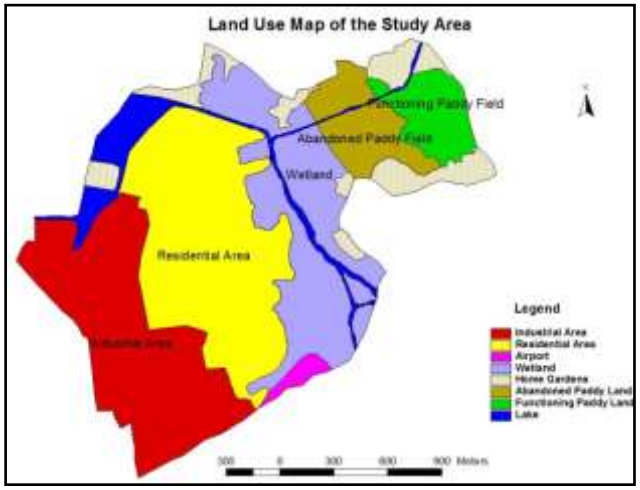

Figure 1 - Land use map of the Bellanwila-Attidiya area

Table 1 - Methods used in analysing physical and chemical parameters of soil

Soil Parameter	Method
Temperature	Soil thermometer at the sampling site. (Black, 1965)
Soil moisture cont.	Drying method (Black, 1965)
pH	pH meter dipped in a soil-water suspension 1:2 (Black, 1965).
Salinity	Salinity-Conductivity meter (Black, 1965).
Electrical conductivity	Salinity-Conductivity meter (Black, 1965).
Soil type	Drying method (Black, 1965).
Soil Colour	Munsell soil colour chart (Black, 1965).
Nitrate, Phosphate and Sulphate	UV visible Spectrophotometry (Clescer*iet al.* 1999).
Chloride	Titration, Silver nitrate method (Clescer*iet al.* 1999).
Iron (III)	Atomic absorption spectrophotometry (AAS) (Clescer*iet al.* 1999).

Determination of water table

At least 5 locations (either wells or bore holes) were identified at each land use area to measure the water table of the site. Depth of the water table of the each location was measured for 6 days throughout the study period with parallel to soil samplings. All together ground water levels in 27 locations were measured to determine the water table of the study area. Depth of the water table is the deepness of the water table from the surface level of the location.

Elevation of the water table from the mean sea level was calculated from the raw data collected as the depth of the water table and the mean sea level of the particular sampling location. The means sea level was measured using the 1: 10000 map of the study site purchased from the Department of Survey of Sri Lanka.
The formula for the elevation of the water table from the mean sea level is,

Elevation of the water table from the mean sea = The elevation from the mean sea level of the location - Depth of the water table

Developing GIS maps

The GIS maps were developed to indicate variation in physical and chemical parameters in relation to different land use areas. Further GIS was used to represent the study area and its land use patterns using ArcView GIS 3.2. Data were positioned in the soil triangle to define the soil type of each area. Soil colour was determined using Munsell soil colour chart (Black, 1965).

Data analysis

Pooling data for a particular land use area, means and standard deviations were determined for each parameter investigated. One-way analysis of variance (ANOVA) was used to compare soil properties among sites. Least Significant Difference (LSD) Multiple Comparison Analysis was carried out to identify which combinations of land use areas gave the significant difference from each other ($p \leq 0.05$) in aforesaid parameters. All statistical analysis was performed using SPSS version 16.0 for windows.

RESULTS

The results indicated that all chemical and physical parameters of soil varied across the land use gradient, except for temperature. The results are summarized in Table 2.

Table 2 - Mean ± SD of soil parameters along a land use gradient

	Land Use									
	Functioning Paddy Filed		**Abandoned Paddy Field**		**Wetland**		**Residential Area**		**Industrial Area**	
Chemical/ Physical Parameters Mean±SD	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom
Moisture Content (%)	43.08 ±4.16	37.51 ±3.75	42.35 ±3.34	36.66 ±2.37	62.66 ±4.37	60.35 ±2.63	49.57 ±3.36	50.85 ±3.24	17.07 ±2.12	21.96 ±2.25
pH	5.95 ±0.47	5.59 ±0.45	5.93 ±0.76	5.28 ±0.49	5.59 ±0.70	3.53 ±0.63	5.57 ±0.93	3.15 ±0.57	6.80 ±0.90	6.35 ±0.69
Salinity (ppt)	0.12 ±0.20	0.18 ±0.27	0.12 ±0.20	0.17 ±0.29	0.35 ±0.29	3.60 ±1.27	0.60 ±0.33	3.20 ±1.06	0.42 ±0.51	0.80 ±0.62
Temperature (°C)	29.08 ±1.53	27.58 ±1.69	29.67 ±1.53	28.83 ±1.88	30.42 ±1.30	28.25 ±1.19	31.00 ±1.12	28.83 ±1.21	30.75 ±0.99	30.08 ±1.44
Electrical Conductivity (µS)	366.15 ±14.07	552.28 ±13.74	391.73 ±13.34	404.92 ±13.82	824.30 ±17.02	6985.33 ±51.05	1548.78 ±20.07	5675.50 ±41.72	1436.05 ±24.62	2296.22 ±27.63
[NO3-] (ppm)	0.38 ±0.33	0.65 ±0.21	0.48 ±0.49	0.71 ±0.38	0.15 ±0.28	0.13 ±0.38	0.35 ±0.30	0.44 ±0.44	0.67 ±0.54	0.20 ±0.28
[PO4 3-] (ppm)	11.42 ±2.92	27.94 ±2.88	3.32 ±1.38	11.27 ±1.02	2.62 ±0.80	1.70 ±0.83	2.49 ±1.02	2.64 ±1.16	1.72 ±0.79	0.85 ±0.55
[SO4 2-] (ppm)	72.18 ±3.28	77.60 ±4.29	48.99 ±3.71	50.90 ±3.30	142.00 ±4.18	1461.06 ±27.48	247.04 ±5.90	540.14 ±27.58	180.03 ±8.76	230.69 ±12.27
[Cl-] (ppm)	0.28 ±0.07	0.47 ±0.68	0.28 ±0.06	0.30 ±0.25	1.25 ±0.63	5.01 ±1.17	2.42 ±0.83	4.31 ±0.91	0.99 ±0.65	0.31 ±0.24
[Fe3+] (ppm)	2.90	0.36	0.07	0.05	1.22	0.29	1.17	1.90	0.06	0.05

The highest elevation of water table from mean sea level was recorded in residential area while the lowest was observed in functioning paddy field (Figure 2). The highest depth to the ground water table was depicted in industrial area while the lowest was in functioning paddy fields. Both elevation of water table from the mean sea level and depth to the water table decreases in the gradient from south-west to the north-east of the study area.

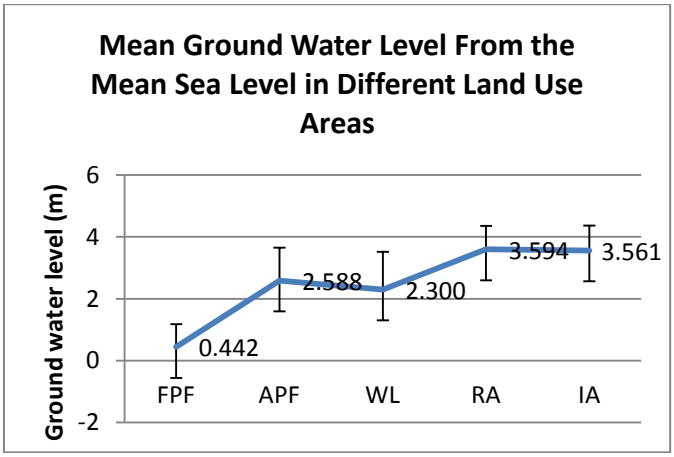

Figure 2 - Mean elevation of water table from the mean sea level in different land use areas

According to the Pearson Correlation Analysis between depth of the water table and soil chemical parameters using, significant correlation was observed between depth of the water table with soil physical and chemical parameters in top and bottom layers of the study area, at 0.05 significant level (Table 3). Depth of the ground water table exhibited a positive correlation with pH, electrical conductivity and Nitrates of top soil and pH of bottom soil. Similarly there was a negative correlation in moisture content, Phosphates and Iron (III) of top soil and moisture content, Sulphur and Chloride of bottom soil.

Table 3 - Summary table for correlation between depth of the water table with physical and chemical parameters in top and bottom soil layers

Depth of the water table	MC	pH	Sal	T	EC	N	P	S	Fe	Cl
Top	-	+			+	+	-		-	
Bottom	-	+						-		-

Correlation is significant at the 0.05 level (2-tailed)
Positive correlation (+), Negative correlation (-)
MC – Moisture content, Sal – Salinity, T – Temperature, EC – Electrical conductivity
N - $[NO_3^-]$, P - $[PO_4^{3-}]$, S - $[SO_4^{2-}]$, Cl - $[Cl^-]$, Fe -$[Fe^{3+}]$

From the regression done for the significantly correlated physical and chemical parameters in top soil layer, following regression equation was obtained. The ANOVA test results depicted that selected top soil parameters in the equation are significant at 0.05 significant level (Table 4). There is a significant difference between regression and residuals. That is the selected parameters for the regression equation have a significant contribution to the equation comparing to the neglected parameters in the equation.

$$\text{Depth of the water table} = 0.963 - 0.014\,[NO_3^-]_{top} + 0.00199\,[PO_4^{3-}]_{top} - 0.0730\,[Fe^{3+}]_{top} - 0.0102\,(\text{Moisture Content})_{top} + 0.0116(pH)_{top} + 0.000178\,(\text{Conductivity})_{top}, \quad r^2 = 0.794$$

Table 4 - ANOVA Test for the regression equation of depth to the water table and physical and chemical parameters of the top soil layer

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	2.512	6	.419	19.663	.000[a]
	Residual	.490	23	.021		
	Total	3.002	29			

Regression was done for all the significantly correlated physical and chemical parameters in bottom soil layer and following regression equation was obtained. The ANOVA test results depicted that selected bottom soil parameters in the equation are significant at 0.05 significant level (Table 5). That is the selected parameters for the regression equation have a significant contribution to the equation comparing to the neglected parameters in the equation.

$$\text{Depth of the water table} = 1.17 - 0.000011\,[SO_4^{2-}]_{bottom} + 0.0926\,[Cl^-]_{bottom} - 0.0224\,(\text{Moisture Content})_{bottom} + 0.0526\,(pH)_{bottom}, \quad r^2 = 0.692$$

Table 5 - ANOVA Test for the regression equation of depth to the water table and physical and chemical parameters of the bottom soil layer

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	2.204	4	.551	17.283	.000[a]
	Residual	.797	25	.032		
	Total	3.002	29			

DISCUSSION

Interest in assessments of aquatic systems is growing with the recognition that mere water quality data and animal and plant lists are inadequate for establishing standards that ensure healthy functioning of wetland. It is important to study ecosystem integrity for detecting cumulative impacts from diverse land uses in the surroundings. This study provides a comprehensive analysis of the influence of the surrounding landscape on the soil integrity of BellanwilaAttidiya wetland. This analysis will provide critical insights on how to sustain the ecological integrity of both natural and manmade landscapes. To our knowledge this is the first study to report soil quality of any wetland and the land uses in the surrounding area in Sri Lanka.

The changes of land use patterns undoubtedly endow with many social and economic benefits. However, they also come at a cost to the natural setting in an area. One of the major direct environmental impacts of development is the degradation of natural habitats (Munasinghe, 1993). Land use changes in the surroundings a vast increase in impervious surface, which can alter the natural hydrologic condition within a watershed(Barnes *et al.*, 2000)

The highest values obtained for all parameters were not evenly distributed. The pattern observed for the highest levels for each parameter on the surface was found as follows: - On the surface: NO_3^- – industrial area, PO_4^{3-} - functioning paddy fields, SO_4^{2-} - residential area, Cl^- - residential area, Fe^{3+} - functioning paddy fields, moisture content - wetland, pH – industrial area, salinity- residential area, electrical conductivity – residential area. At a 1 m depth the pattern was different: NO_3^- – abandoned paddy fields, PO_4^{3-} – functioning paddy fields, SO_4^{2-} - wetland, Cl^- - wetland, Fe^{3+} - residential area, moisture content - wetland, pH – industrial area, salinity - wetland, electrical conductivity – wetland.

On average, higher percentage of clay was found in bottom soil layers of some areas. Moreover, it was observed that top soil layers of residential and industrial areas also contained high clay percentage. In contrast, top soils of other three land use areas were dominated by silt. Highest clay percentage was observed in bottom soil of wetland.

In this study, it was revealed that the soil quality parameters of the landscape that has human influence are far reached than the natural wetland. Salinity, electrical conductivity and chloride level showed a significant variability in top and bottom soils in different land use areas. The decline of salinity and electrical conductivity levels were recorded as; *Top*: residential area > industrial area > wetland > functioning paddy field = abandoned paddy field, *Bottom*: wetland > residential area > industrial area > functioning paddy field > abandoned paddy field. Chloride levels in the top soil layer showed a similar declining pattern except for the fact that chloride level in industrial area was overridden by the chloride level in residential area, while the bottom layer resembled exactly the same. Increased chloride, salinity and electrical conductivity level of the wetland and residential area (Figure 3, 4 and 5), especially in the bottom soil layer indicates a sea water intrusion in the area. The density of saline water is much higher than fresh water. Hence sea water intrusion generally occurs through bottom soil layers. Studies focused on Bolgoda Lake which is connected to the surface network of the Bellanwila-Attidiya wetland, reported elevated levels of salinity in the channel system (Piyadasa and Chandrasekara, 2010) which might have consequently contributed to the elevated salinity levels in soil.

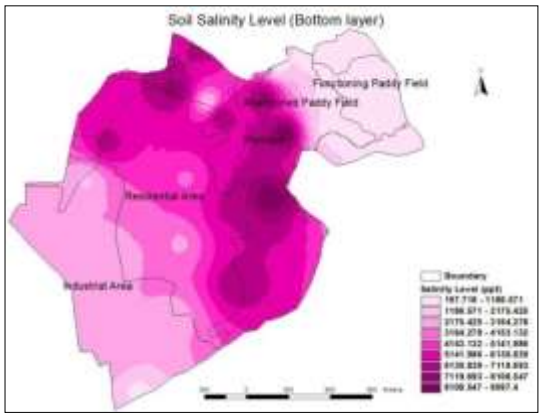

Figure 3 - Distribution of salinity in bottom soil layer in the sudy area

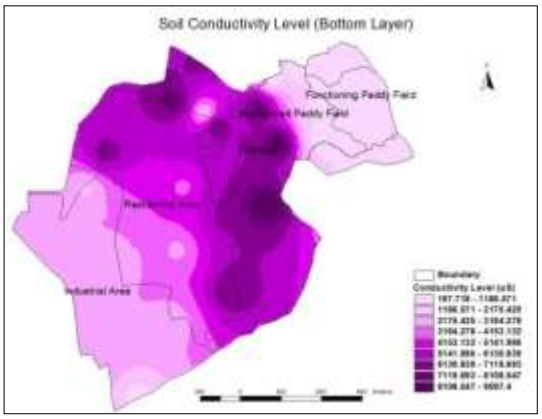

Figure 4 - Distribution of electrical conductivity in bottom soil layer in the study area

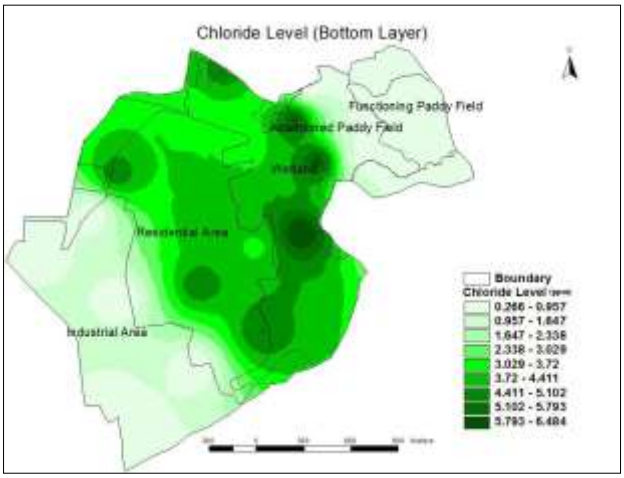

Figure 5 - Distribution of water soluble chloride in bottom soil layer in the study area

The findings evidently exhibit that the ground water table and soil properties are influenced by the variability in land use patterns. The GIS maps representing various chemical accumulations in the adjacent land use areas show how vulnerable the wetland ecosystem is to such anthropogenic effect in the study area. Especially following GIS maps reveals that soils of agricultural and industrial areas have been enriched with high concentrations of nitrates and phosphates comparing to other areas. High accretion of nitrates was recorded in the top soil of the industrial area, while paddy cultivated area depicted high accumulation nitrates in bottom soils (Figure 6 and 7). Thus both top and a bottom soil layer of the paddy cultivated area werehighly contaminated with phosphates (Figure 8 and 9). The higher ground water table in industrial and residential area may probably facilitating leaching of nutrients to the wetland ecosystem. Similarly interconnection of wetland with cultivated areas via surface water and channel systems possibly helps out to infiltrate agro-chemicals in to the wetland ecosystem. Local agricultural, industrial and residential activities have direct impact over the quality of the wetland (Gregoire*et al.,* 2008). Thus, effective watershed management is crucial for healthy wetlands.

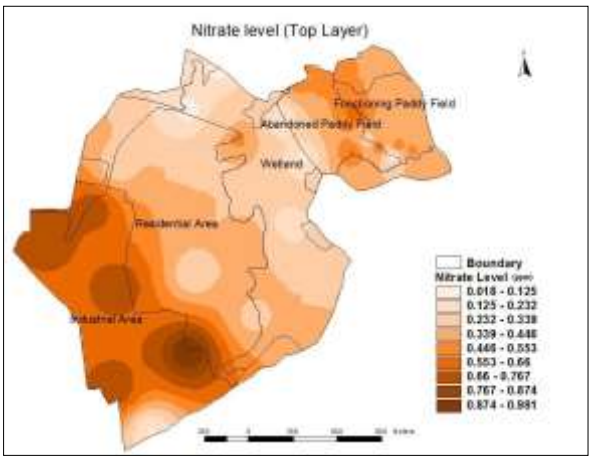

Figure 6 - Distribution of soluble nitrates in top soil layer in the study area

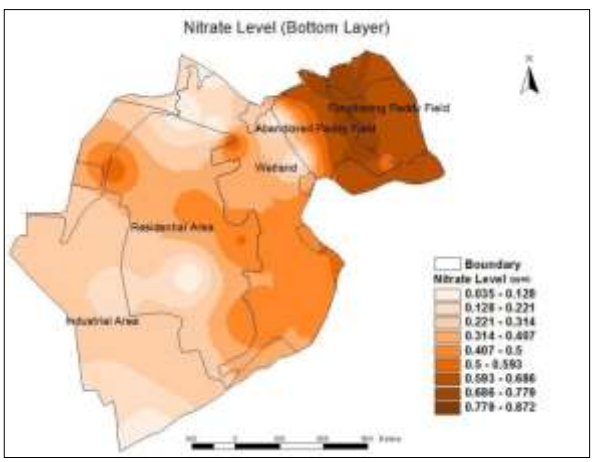

Figure 7 - Distribution of soluble nitrate in bottom soil layer in the study area

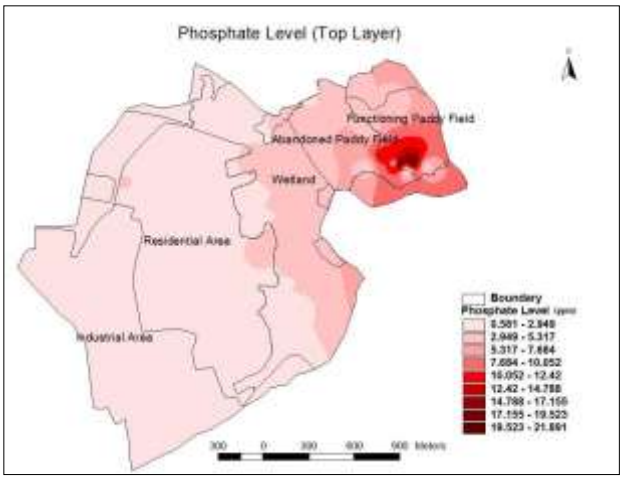

Figure 8 - Distribution of oluble phosphate in top soil layer in the study area

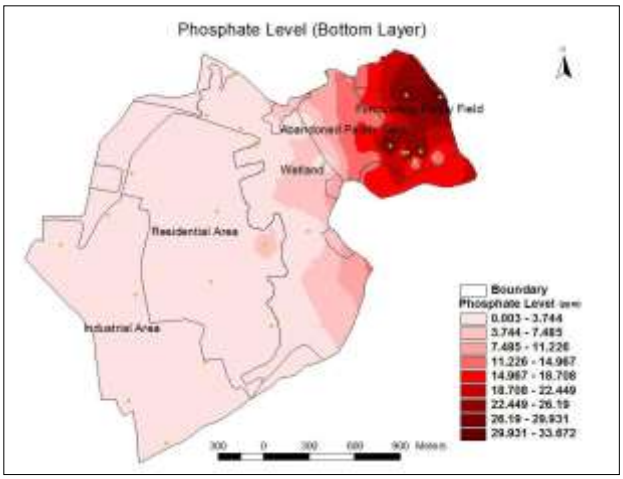

Figure 9 - Distribution of soluble phosphate in bottom soil layer in the study area

The impacts of human activities have considerably accelerated in altering natural conditions of soil and elevation of water table from mean sea level in the area. A majority of the wetlands in Sri Lanka are facing a range of threats that are posed by harmful human activities and Bellanwila-Attidiya marsh is one of such wetlands that has been seriously impacted due to anthropogenic activities and being an urban marsh (IUCN, 1990). Though wetland ecosystems act as a natural cleansing complex of many of the chemical pollutant discharge in to the environment, excessive addition of these pollutants to the environment by human impacts may retard the function of the wetland ecosystem. Excessive nutrient loads of phosphorus and nitrogen fuel eutrophication and the subsequent anoxia in the eco system (Odada*et al.*, 2006). Hence we should be more vigilant on out activities, especially the one which might adversely impact the environment in long run.

The lack of wetland studies reporting physical and chemical soil properties in the country makes it difficult to compare the levels that were found in this study. This study should be extended to include other important parameters including soil carbon contents and redox potentials. Nevertheless, these results could use as baseline data in wetland conservation planning.

ACKNOWLEDGEMENTS

Authors gratefully acknowledge the financial and logistical support provided by the University of Colombo.

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Effect of rectangular lining of irrigation canals in Matara district

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BACKGROUND

With the advancement of the global water crisis, local governments are increasing their investments inirrigation sector to save water namely, promotion of advanced irrigation technologies for water saving,timely renovation of irrigation canals, construction of a large anti-infiltration structures etc. Totaleconomy of an irrigation project depends on the cost of water transportation and the loss of waterduring the transportation.

Table 1 - Capacity and canal dimensions source - Irrigation Water Management Training Manual 07. FAO 1992

Capacity (l/s)	Trapezoidal canals				Rectangular canals	
	Unlined canals		Lined canals		Only lined canals	
	b	h_1	b	h_1	b	h_1
25	20 - 25	15 - 25	15 - 20	20 - 25	20 - 25	25 - 30
50	20 - 30	20 - 30	25 - 30	20 - 25	30 - 35	30 - 35
75	25 - 35	25 - 35	25 - 35	25 - 30	35 - 45	35 - 40
100	30 - 35	25 - 40	30 - 35	30 - 35	40 - 45	35 - 45
125	30 - 40	30 - 45	30 - 35	30 - 40	45 - 50	40 - 50
150	30 - 45	30 - 45	35 - 40	35 - 40	45 - 50	45 - 55
175	35 - 45	35 - 50	35 - 40	35 - 45	50 - 55	45 - 60
200	35 - 50	35 - 55	40 - 45	35 - 45	50 - 60	50 - 60

Source: FAO, 1992

As shown in the Table 1 and Figure 1, rectangular cannels need more excavations which involve highercost than trapezoidal cannels to have same flow rate. Furthermore, with the increment of the dischargerate, rectangular cross sections need higher depth compared to trapezoidal cross section for the samedischarge.

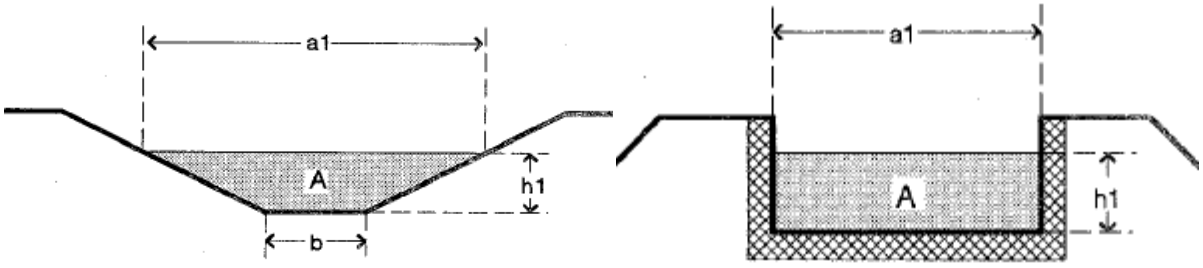

Figure 1 - Cross Sectional Views of Trapezoidal and Rectangular Cannels source - Irrigation Water Management Training Manual 07. FAO 1992

Unlined cannels show 40 % loss of water during the transportation, compared to cannels having concrete lining (Sivaling L.Y in 1982). According to Mohammed A,T (2012), the average rate of transport efficiency in the irrigation canals with stone and gravel-cement mortar lining was observed as the highest rate, 90.27 %, and in concrete lining and traditional channels were 87.32% and 53.82 %, respectively.

ISSUES ADDRESSED AND CURRENT STATUS

According to a field survey conducted by authors, wood shattering is used at the field level for theconstruction of concrete canals and parties involved in the construction process are reluctant toconstruct trapezoidal shape wood shattering compared to rectangle shape at the field level due toconstruction difficulties. Furthermore, lining of irrigation canals are done by using manual labor and it islabor intensive and time consuming process. It was found that in present

method of concrete liningneed 10 days with one skilled and four unskilled labor units to complete one length water stock havingwidth and height of 1 meter and length of 11.1 meters. Contractors have to spend nearly 61000.00rupees for the labor cost and total construction cost is about 183,300.00 rupees.

Relevance of above to role and function of institution, to water sector and national developmentagenda

Therefore, there is a need for better construction process to reduce the overall cost involvement andimprove the conveyance efficiency to economize Sri Lankan irrigation projects in future. Present paperdiscusses a new method for constructing irrigation cannels using stackable trapezoidal concretestructures.

OBJECTIVE

To determine the appropriate dimensions for proposed stackable trapezoidal concrete structuredeveloped to construct irrigation cannels

RESEARCH METHOD

As shown in the Figure 2, two different trapezoidal concrete structures will be tested for handling andtransportation convenience, ease of stackability during cannel construction, ease of taking offsetcannels after construction and removing and reconstruction flexibility.

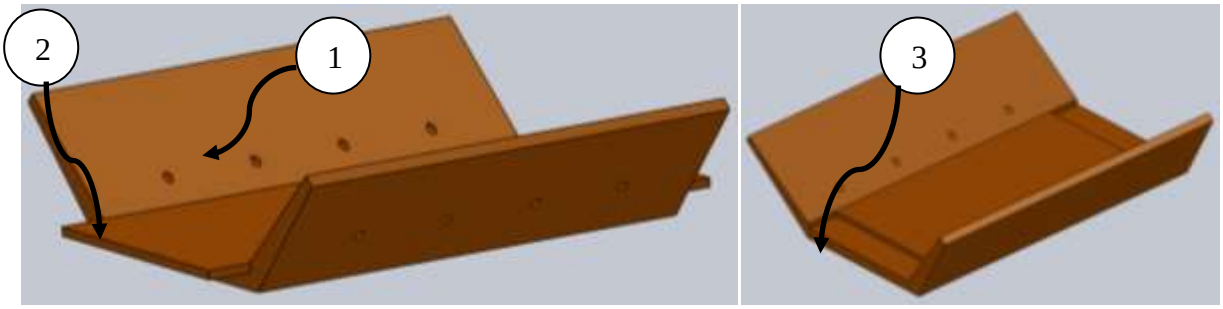

Figure 2 - Top and Bottom trapizoidal structures

1. Weep Holes 2. Top extension 3. Bottom slot

Weep holes were kept to collect lateral water flow. Trapezoidal structures will be fabricated in such a way that one could well stack upon other. Top trapezoidal structure always has two extensions which could be fit on to slot provided in the bottom trapezoidal structure. Therefore, field installation will be much easier than present practice.

An irrigation scheme will be selected within the Matara District for the study purposes. Three irrigation cannels having flow rate of 25 l/s, 125 l/s and 200 l/s will be selected to represent cannel sizes and dimensions with respect to high flood and full supply levels.

A bio board developed by the Department of Agricultural Engineering, University of Ruhuna using coir fiber and fiber glass gum will be used as the molding material. In order to optimize the appropriate length of the concrete structures, lengths having 0.5 m, 1.0 m, 1.5 m, 2 m, trapezoidal molds will be constructed using bio boards. Concrete trapezoidal top and bottom structures will be fabricated with respect to the cannel dimensions having above mentioned flow rates. Time consumption, labor involvement, and cost will be evaluated for both existing and proposed method of constructions. Visual and field surveys will be conducted to observe the handling and transportation convenience, ease of stackability during cannel construction, ease of taking offset cannels after construction and removing and reconstruction flexibility.

POTENTIAL BENEFITS OF ADOPTION/RECOMMENDATIONS TO INSTITUTION, SECTOR AND COUNTRY

Main advantage of having these stackable trapezoidal concrete structures could be identified ashandling and transportation convenience, ease of stackability during cannel construction, ease of takingoffset cannels after construction and removing and reconstruction flexibility. Therefore, present methodof cannel construction would be a better alternative to institutions those who conduct irrigation projectsas well as the irrigation sector in Sri Lanka.

CONCLUSION

Present method of cannel construction could be identified as a time consuming and laborious methodwhich involves high initial cost and low irrigation water conveyance efficiency. Therefore, there is a needto find alternative methods to reduce time factor and the labor involvement in the construction process.Proposed method is equipped with precast stackable trapezoidal concrete structures where time andlabor involvement could be reduced while improving the water conveyance efficiency. Hence, presentresearch study could be justified for further research and development work.

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Health effect of concentrated water from reservoirs of high prevalence area for chronic kidney disease of unknown origin in Sri Lanka on mice

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ABSTRACT

There is threateningly high prevalence of chronic kidney disease due to tubulointerstitial disease ending as chronic renal failure in the North Central Region of Sri Lanka. The epidemiology of the disease shows distribution of these patients around the some water reservoirs and most of them are farmers. The low prevalence of the disease among the in villagers who use water from the natural springs was observed. The aim of the study is to find the potential effects of concentrated water of the reservoirs in the high prevalent area by mouse bioassay.

Water of Padaviya reservoir supplying water to a high disease prevalent area was concentrated fifteen times by evaporation, exposing to sunlight from the month of May to July. The test group of mice (20) and control group (15) were fed with concentrated reservoir water and water from non prevalence area(Kandy) respectively for a period of 6 months and the kidneys were examined histopathologically for the evidence of renal disease. Water samples were analyzed for Fluoride, Na +, K+ , heavy metals and for cyanobacterial toxins microcystin & cylindrospermopsin .

The analysis of concentrated water samples from Padaviya reservoir from May to July showed significantly high content of fluoride (2.25 $\pm$0.7mg/L), Sodium (225$\pm$ 62mg/L) ($p<0.05$) than control samples. However, no increased levels of heavy metals were detected. The analysis of water samples showed presence of Deoxy cylindrospermopsin(1.28 ug/L - DCYN) as the predominant isomer present over cylindrospermospsin (CYN) which is unusual. At the end of 6 months interstitial nephritis was detected in 45% of test mice andonly6.5% of control group ($p< 0.001$)

The results show the ability of the water of this reservoir to induce interstitial nephritis that could be due to the high salinity, fluoride or due to DCYN. Although present in low levels, the possibility DCYN to induce interstitial nephritis needs to be investigated further as the epidemiological evidence is in favor of a cyanobacterial toxin. The long term effects and safe levels for DCYN in drinking water & the effect of salinity & high fluoride content of water needs to be studied.

INTRODUCTION

Chronic Kidney Disease (CKD) is defined as either kidney damage or decreased kidney function (decreased GFR) for three or more months. It is characterized by progressive destruction of renal mass with irreversible sclerosis and loss of nephrons over a period of months to years, depending on the underlying etiology (1). CKD is a slow progressive disease, requiring dialysis or transplantation at the end-stage. CKD is an emerging health problem all over the world and is often associated with poor prognosis and that incur economic burden on patient, family, community and the country as a whole.

The common causes of CKD include diabetes mellitus, hypertension, urological diseases and glomerular nephritis. Toxins, collagen vascular disease and infections are the rare causes of CKD(2). When CKD is not related to the known causes which have already been identified, it is labeled as CKD of unknown etiology (CKD-U). This particular type of nephropathy is reported in several countries over the last few decades including Balken countries (3), Sri Lanka (4) and recent reports in Nikaragua and El Salvador (5).The epidemiology of the CKD-U in Sri Lanka shows distribution of patients around some water reservoirs of the North Central Region(NCR) of the country. Histopathological studies have revealed tubulo interstitial nephritis at early stage of the disease which is suggestive of a toxic etiology. There is a possible propensity for it to be more prevalent among men who engaged in agriculture, typically around the age of 40-60 years (6).

Researchers have come up with several possible risk factors for the disease, including high groundwater fluoride content in some affected areas, bleaching of heavy metals such as cadmium from agricultural chemicals into water sources,

exposure to inorganic pesticides and fertilizers, and usage of aluminum vessels to store drinking water. Bandara JM *et al* carried out a study in which higher levels of dissolved cadmium (Cd), iron (Fe) and lead (Pb) was detected in five reservoirs of the affected region. According to the study the urinary Cd excretion in CKD patients were increased that indicating chronic exposure to Cd. They concluded that CKD prevalent in north central Sri Lanka is a result of chronic dietary intake of Cd (7).

KRPK Herath *et al* carried out a study to establish any relationship with fluoride, aluminium utensils and chronic renal failure. The study revealed that the presence of fluoride in natural water and high amount of contaminated aluminium intake through food web may be a potential factor for the prevalence of kidney disease in the dry zone of Sri Lanka(8).

In addition to the etiologies related to the heavy metals the epidemiological evidence showing similarity in the variations of incidence over time in CKD-U and alcoholic liver disease in the North Central Region of Sri Lanka indicates the possibility of a toxic etiology with hepatotoxic & nephrotoxic effects(9). As significant number of the patient population consume water from shallow dug wells located close to the irrigation canals fed with water from the reservoirs indicate the possibility of water solubility of the toxin. Presence of the renal disease in patients who consumed only boiled cooled water indicates the possibility of heat stable nature of the toxin. The characteristics of the unidentified toxin/s may be compatible with toxins produced by the cynobactirea which are common in the reservoirs in NCR (10). This epidemiological evidence shows the possibility of cyanobacterial toxins as another likely etiological agent in CKD-U.

The NCR of the country where the chronic kidney disease is abundant is characterized by intricate network of man-made reservoirs and canals that provide water for paddy cultivation and for human and livestock use from pre Christian era up to date. However, CKD-U is abundant only in few locations of the dry zone namely North Central Region of the country. Agriculture is the most important sector of the Sri Lankan economy mainly in NCR. Almost 100 percent of the lands in NCR are fed by the rain or irrigation system as large and small reservoirs and irrigation canals(11). The evaporation rate of the reservoirs, canals and agricultural lands are very high it is above 5mm per day(12). There for the opportunity for concentration may be common in these reservoirs and canals. One of the major problem associate with this irrigation system is salinity development in paddy fields. According to the report from the Ministry of agriculture the observations show that lack of surface drainage is the main cause of salinity development in Sri Lankan paddy fields and also identify that salinity development in canals dug wells and reservoirs. The problem is commonly observed in flat valleys and its occurrence is mainly confined to those positions in the flat valley where interflow streamlines from adjacent landscape emerge within the valley (13).

Considering the above facts, due to high evaporation, salinity, irons, heavy metals, toxins and other components exist in water may be concentrated in shallow wells, reservoirs, and cannels. The literature shows that 92% of CKD-U patients consumed water from shallow wells. Therefore the objective of this study to identify and demonstrate the health effects of concentrated water of the padaviya reservoir by using animal experimental model (mouse bioassay).(14,15)

METHOD

Fifteen liters(15L)of water from the Padaviya reservoir were collected by using “grab” sampling technique and allowed to evaporate until one liter(1L) exposing to direct sunlight . The evaporation pan was used to concentrate water and precautions were taken to avoid contaminating with dust, particles and vapor from the external environment.

Five samples were concentrated from the month of May to July at Irrigation department Padaviya and levels of cyanotoxins such as Cylindrospermopsin, Deoxy-cylindrospermopsin and Microcystin were measured by using Liquid chromatography–mass spectrometry (LC/MS/MS) and Liquid chromatography /photodiode array (LC/PDA) respectively in each sample.

Consequently heavy metal and iron levels were also measured in five water samples including Fluoride, Na+,K+, Cd, Mn, Cu, Fe, Co, Ni, Zn, As, Hg, TI, Pb etc usingInductively coupled plasma mass spectrometry (ICP/MS) method at National Environmental Toxicology Laboratories, University of Queensland, Queensland.

The test group of mice (20) and control group (15) were selected from the same batch for the study. Test group fed with concentrated reservoir water from the Padaviya reservoirs and water from non prevalence area fed with control group respectively for a period of 6 months. Only recommended foods provided for mice during the experiment period. Both case and control mice were euthanized and kidneys were examined histopathologically for the evidence of renal disease.

RESULTS

The analysis of concentrated water samples from Padaviya reservoir for above three months showed significantly high content of fluoride (2.25$\pm$0.7 mg/L), Sodium (225 $\pm$62 mg/L) ($p<0.05$) than control samples. However, no increased levels

of heavy metals were detected. Table 1 shows the results of the analysis of water samples before concentration that reflect the original content of the elements present in reservoir water .

Table 1 - Analysis of water samples before concentration (original water samples) from May to July and control sample from Kandy area.

Sample collected	F mg/L	Na ug/L	K ug/L.	Cr ug/L.	Mn ug/L.	Fe ug/L	Co ug/L	Ni ug/L	Cu ug/L	Zn ug/L	As ug/L	Cd ug/L	Hg ug/L	Tl ug/L	Pb ug/L
1. End May	0.172	16060	1483	0.04	9.69	1.57	0.65	0.29	0.51	167	0.19	0.00	0.00	0.00	0.19
2.Early June	0.187	22367	2542	0.02	4.47	1.53	0.21	0.14	0.35	354	0.20	0.00	0.00	0.13	0.07
3. End June	0.108	10169	1009	0.01	3.86	1.06	0.06	0.11	0.29	128	0.08	0.00	0.00	0.04	0.02
4. Early July	0.152	16513	2015	0.02	16.71	2.26	0.12	0.38	0.71	295	0.15	0.00	0.00	0.07	0.12
5. End July	0.210	20340	1966	0.02	1.87	1.54	0.08	0.31	0.72	88	0.21	0.00	0.00	0.00	0.03
Control Kandy	0.0075	2624	1752	0.00	0.58	5.57	0.01	1.62	1.71	36.11	0.02	0.01	0.00	0.00	0.00

The analysis of water samples for common cyanotoxin showed presence of Deoxy cylindrospermopsin(average 1.28 ug/L - DCYN) as the predominant isomer present over cylindrospermospsin (CYN) which is unusual (Table 2)**.**

Table 2 - Analysis of water samples for cyanobacterial toxin

	Cylindrospermopsin Micrograms/lire	Deoxy-Cylindrospermopsin Micrograms/lire	Microcystin Micrograms/lire
1. End May	Nil	0.80	Nil
2. Early June	Nil	0.84	Nil
3. End June	Nil	0.84	Nil
4. Earl July	Nil	0.71	Nil
5. End July	Nil	3.75	Nil

The end of 6 months mice were euthanized and interstitial nephritis was detected in 45% of test mice andonly6.5% of control group ($p< 0.001$).

Table 3 - Number of mice euthanized in each group

	Test group (Padaviya water)	Control group Kandy water)	Total
Normal	11	13	24
Interstitial Nephritis	9(45%)	2(6.5%)	11
Total	20	15	35

DISCUSSION

According to the findings of this study, significant number of mice had interstitial nephritis (65%) after feeding concentrated water for six months and the type of CKD is similar to the CKD-U in NCR. When considering the life span of mice, six months period proportionately equals to over 35 years of human life span therefore the animal model pretend the attributes of chronic kidney disease in NCR.

Geochemically and hydrologically, the NCR of Sri Lanka has some unique features. The marked drought alternating with seasonal rainfall and excessive evaporation cause salt to concentrate in the surface and shallow well water. These features have a major impact on human health in this region bearing in mind that the majority of them obtain their drinking water directly from the shallow wells(4).

Padaviya is one of the largest reservoir in CKD-U affected area which supplying drinking water for over 1000 families directly and feeding water for thousands of shallow wells in this region. According to the analysis, significantly high fluoride levels were noticed from the month of May to July in five consecutive samples compared with the water from

non CKD-U prevalence area. The average fluoride contents of unconcentrated and concentrated were 0.168 mg/L and 2.25 mg/L respectively. This is considered sufficient to cause damage to the kidney, when there is continuous ingestion of fluoride. It is known that kidneys are among the more sensitive body organs in their histopathological and functional responses to excessive amount of fluoride. It may also be possible that fluoride combines with other elements such as sodium also found in high concentration in the water. The continuous ingestion of fluoride rich and salt rich water could well effect on kidneys resulting interstitial nephritis on mice. However it is very clear that more detailed investigation of geographical, hydrological and medical are necessary to unravel cause of CKD-U in North Central Region. However high levels of heavy metals such as Cd, As , Pb were not detected.

Water samples were analyzed for common cyanobacterial toxin such as Deoxy- Cylindrospermopsin, Cylindrospermopsin and Microcystin. However only DCYN was detected in all five samples. According to the literature, the toxic effects of DCYN were poorly described.

CKD-U now causing the serious concern in NCR can also be attributed to the quality of surface water from which drinking water is obtained. Even though the cause of CKD-U is still uncertain, excess fluoride, salt and cyanobacteria toxins may well turn out to be contributory factors.

CONCLUSION

The results show the ability of the water of this reservoir to induce interstitial nephritis that could be due to the high salinity, fluoride or due to DCYN. Although present in low levels, the possibility DCYN to induce interstitial nephritis needs to be investigated further as the epidemiological evidence is in favor of a cyanobacterial toxin. The long term effects and safe levels for DCYN in drinking water & the effect of salinity & high fluoride content of water needs to be studied.

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Menik river basin is example for need of proper support for water resource management

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THE PROBLEM

Efficiently conserving, managing and utilizing water resource of an area could be fulfilled by having sound understanding of the availability, variability and quality of the water resources in the area. Thoroughly understanding could only be developed through detailed investigation, research and long-term data collection and analysis.

Rainfall in Sri Lanka has multiple origins of monsoons, convections and depressions, which contribute a major share of the annual rainfall when considered together. The mean annual rainfall of the island is more than 1500mm and it hardly falls below 1000mm, with a maximum precipitation at highlands, which is over 5000mm. Therefore, it is difficult to suggestthat Sri Lanka has a problem in water-resources.Nevertheless, such problems do exist. Rainfall is strongly seasonal and in the North Western and South Eastern parts of the Island, where the dry climate conditions exist, there are sever water shortages during the months of June, July and August, when the low rainfall is combined with high evaporation rates due to dry climate conditions. Groundwater resources that are of poor quality and limited extent compound surface water shortages in these regions.

The Menik River starts at Passara Divisional Secretariat Division in Badulla District and falls in to sea beyond Yala National park area in Moneragala District. Twenty five percent of its catchment area lies within the upper catchment and its mean rainfall is 1875mm. Tea plantation and forest cover dominant the vegetation types in the upper catchment area. Another 25 % of the catchment area lies within middle catchment area falling in intermediate and dry zone and its mean annual rainfall is 1625mm. The surface cover of this area is dominated by paddy and sugarcane cultivation. The water requirements of the area also include a sugar processing industry located in Buttala. The balance 50% of the catchment lies within lower catchment area, falling in the dry zone, which experiences an annual mean rainfall of 1300 mm. The surface cover of this area is dominated by shifting cultivation (chena) and the national wildlife park. The basin boundaries cover parts of Passara, Badalkumbura, Buttala and Kataragama Divisional secretariat divisions and Yala national wildlife park. The total population coverage within the basin exceeds 271, 681 as at early 2000.

The surface runoff is estimated as 322 $x10^6$ m^3, while the observed flow volume to the sea is $298x10^6m^3$. The annual water utilization for irrigation requirement is 41.8 x 10^6m^3 while the total demand projection by year 2025 is about 70 x 10^6m^3 for irrigation, 11.41 x 10^6m^3 for drinking water and 6.4 x 10^6m^3 for industry and others while the base flow requirement is estimated as 1.1 $x10^6m^3$. The river flow in the Menik Ganga is fluctuating drastically during the year and it reaches minimum levels during the period from June to August each year.

Severe water shortages during certain periods are being observed in the recent drought and this situation is expected to be aggravated in the foreseeable future due to continuous increase in demand for water and the associated poor water resources management practices. Therefore a detailed assessment of water resources availablity in the basin and a catchment plan for the management of available water resources that involves user community within the basin are critical to minimize possible water shortages in future.

THE CATCHMENT

The Menik river basin is located in the dry zone of Sri Lanka. The total area ofthe basin is 1,272 km^2 and it flows over an approximate length of 120 km to the coast (Dissanayake, et al., 2008).The basin is spatially spread over parts ofBadulla and Monaragaladistricts in Uva province and a smallpart ofHambantotadistrict in Southern province of the country. There are a number of smalldams (named as anicuts in local terms), which have been constructed over the years and recently a large reservoirwas also commissioned to transfer water to the adjacent KirindiOya basin and also to regulatethe downstream flow in the dry season, in order to maintain the environmental flow and satisfythe downstream user requirements as well.

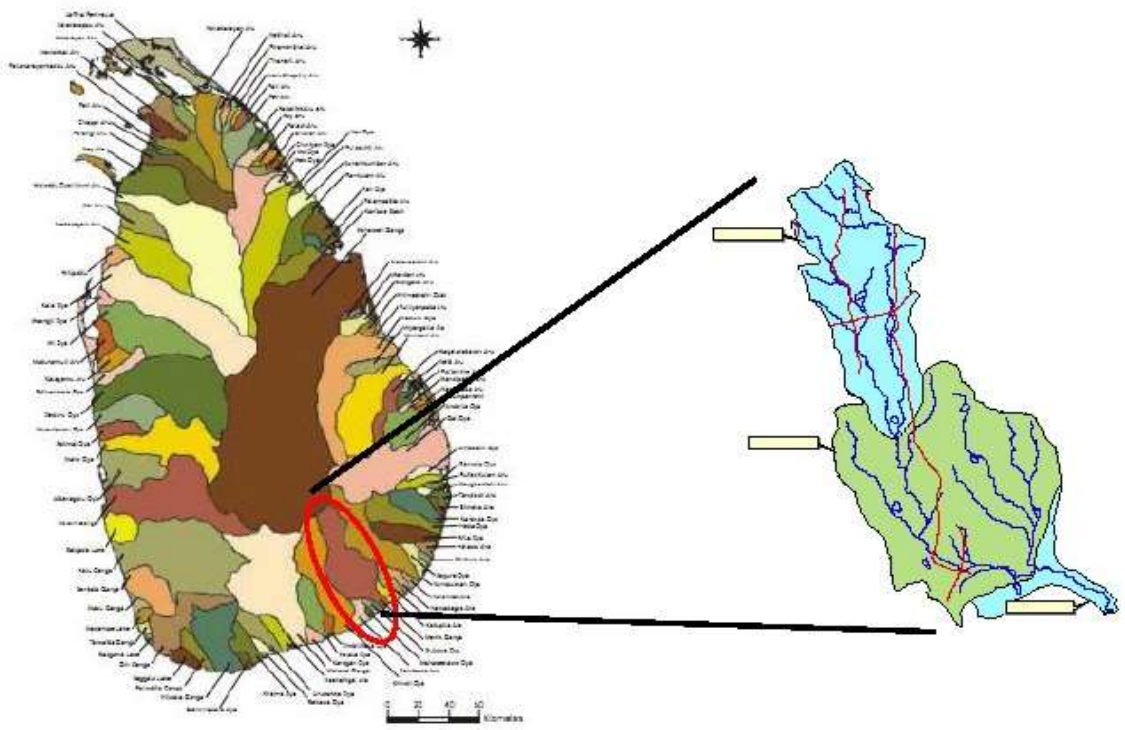

Figure1 - Map of river basins - Sri Lanka (Abstracted from "Sri Lanka National Water Development Report")

Figure 2 - Menik Ganga River basin (Abstracted from "Water Resources Inventory Study for Southern Sri Lanka ")

Average annual rainfall varies from over 2500mm in the upstream to less than 1000mm in the coastal area. Tea plantations widely use in upper catchment, but middle part cultivation is tend to paddy and sugar cane; in the lower catchment forms part of the Yala National Park.

Groundwater occurs in basement complex gneisses, which form aquifers of low yield, producing water of generally poor quality.

CONFLICT

In Sri Lanka, the responsible for allocationingwater resources in river basinsis not under a soul authorization of an organization. Several organizations are using their own strategies for abstracting water from river basins. There is no well-defined water allocation methodology for any of the users. Thus several technical organizations that share the water of Menik river basin, it is not being done based upon technical decisions. Unfortunately, at the moment this is being done only based upon political decisions that are being made to satisfy the user requirementson short-term basis. The organizations are not analyzing the future scenarios based on past records. According to that conflict among water users occur, especially during the dry spells.

In addition, it is very important to consider the requirement of water demand for religious festival in Kataragama. Over a one million peoples attract to the Kataragama in festival season during the July and August. During past decades, river did not fulfill the water requirement during the holy season.

Furthermore, water requirement of Yala National Park, Pilinnawa coastal wetland and Grass land and Yala fisheries management area and Yala Marine protected area are also not being fulfilled during the dry season.(Dissanayake, et al., 2008)

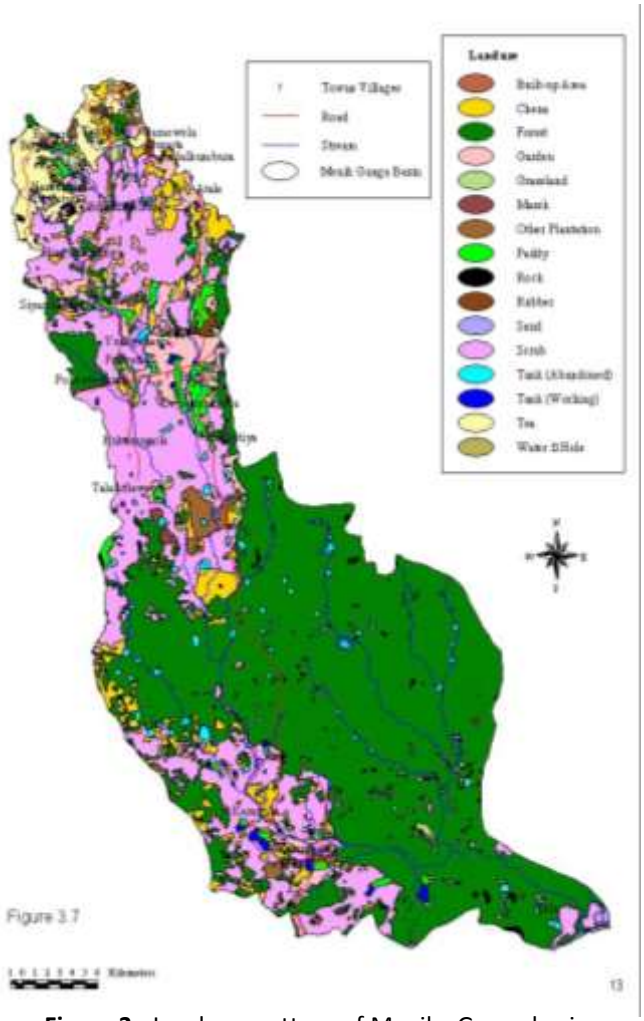

Figure 3 - Land use pattern of Manika Ganga basin
(Abstracted from "Water Resources Inventory Study for Southern Sri Lanka")

Water quality issues are also exist in the river basin. Main issues in the upper catchment are pesticides used in tea plantation are being washed into the river flow and the presence of fecal pollution due to lack of sanitary facility provided for tea estate workers. Sugar factory and distillery has being discharging polluted water to the river; affect to the paddy farmers and domestic water supply schemes as well.

Shallow wells are also used to cater requirement of water within the catchment. However, excessive hardness, excessive fluoride and high iron content are crucial problems in shallow wells.

THE WAY FORWARD

In the recent years water scarcity has become a global issue. Population growth, urbanization, climate change and water quality degradation are some of the major reasons to increased demand for quality water resources. When the demand increases, the supply, water resources development and water allocation criteria become that much more important. Otherwise conflicts can arise when different water users compete for limited water supply available. The basins where water shortages occur have to consider in water allocation in a sustainable manner. Integrated water resource management principles have to be adapted to successfully achieve the long term goals.

- Involvement of stakeholders into the management process will be dramatically changed the integrated water resource policy in the MenikRiver. Involvement and participation of local communities will help to eliminate the conflict that arises in the management of water resources in the basin.
- Water resource management policy in Menik basin has to be sequentially monitored and management instrument has to be changed according to national, social and economic priorities.
- Presently, water management in Sri Lanka is based on the relevant administrative district and divisions. However, proper management is to be based upon a catchment as a hydrological unit. Fundamental institution has to be established for fulfill the goal.
- In Sri Lanka, past hydrological data are not available in required places and the available data are not properly maintained. Thus effective water resource management cannot be done. Due to these reasons, comprehensive

hydrological monitoring network, including meteorological stations, ground water monitoring points and flow gauging stations has to be established.

- Several factors such as hydrological, social, economical and cultural have to be considered whenfollowing an integrated water resource management system. When the following IWRM, good decision making system is to be implemented.

RECOMMENDATION AND CONCLUSION

- One institution has to be established under ministry of water supply and drainage and coordination with organizations that are to use the water resources in the basin and monitor the water quality, water issues in the basin.
- Most of the residences, located along the waterways in the up-countrydo not have a proper sanitation system and their living standards are poor. Thus fecal pollution has been begun at the area that lived. To prevent the issue, they should beresettled in places away from the highland and waterways with proper sanitation system.
- Wealthy people are tending to settle in highland. This should be prohibited and they should be kept away from the green cover of the highland.
- During the recent years, wildfires have been occurred frequently in Menik basin, thus the forest cover is being reduced. The most common cause for the wildfires is human negligence. Prevailing laws has to be strengthened and implemented to prevent the huge damages to forest and also settlement in the highlands has to be minimized.
- In the lower part of the basin, paddy crop is the most common crop that has being used in the field. It consumes more water than the other crop types. Flood irrigation is the most popular method in cultivation. Farmers are not willing to take other water efficient crops for cultivations. Thus their attitudes have to be changed. Also water saving methods has to be introduced to the farmers such as drip irrigation, rotation of crops etc.
- Water resource management committee in Menik river basin has been established and it's continuously monitoring the water issues that relevant to water quality, demand. Currently it is successfully continuing and takes remedial actions accordingly.
- Water quality monitoring system has to be implemented within the catchment and to be progressively monitored water quality within the catchment.
- Large area of the Menik basin is flat; Construction of reservoirs in the Menik basin will impact on the society and environment. Thus comprehensive analysis has to be done before doing that.

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Provision of water requirement for drinking and cooking to a chronic kidney disease (CKDU) prone area in North Central Province of Sri Lanka: A case of Sandamaleliya Village in Mahawilachchiya DSDivision

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INTRODUCTION

Chronic Kidney Disease of unknown etiology (CKDu) is an unsolved problem and is begun to spread in Sri Lanka over the past decade. Many research studies are carried out and many hypotheses have been developed regarding the cause and prevalence of this problem. Higher concentration of Fluoride and Hardness in ground water;pollutants such as Arsenic(As), Cadmium(Cd), Uranium(U), and Chromium (Cr); toxin from excessive usage of agrochemicals and fertilizers; toxin released from blue green algae; usage of Aluminum pots for cooking as a substitution for clay pots and malnutrition in childhood are some of them. However the actual cause of this problem is still unknown. If an exact relationship can be identified, specific measures could be adopted to prevent or at least minimize the prevalence of the disease.

The geographical distribution of CKDu appears to be higher towards the North Central Region of the country in which North Central, Part of North Western and part of Uva provinces are included. The population at risk are scattered in North Central province with high prevalence at Madawachchiya, Padaviya, Kebithigollewa, Rambewa and Nuwaragampalatha central Medical Officer of Health (MOH) areas. Due to the lack of potable pipe borne water coverage, most of the people living in these areas basically depend on ground water sourceswhich have been proven as unsuitablefor drinking and cooking purposes via water quality testing repots due to high concentration of Fluoride and Hardness. Those ground water sources are also getting dry during the dry season resulting water scarcities.

In addition to the CKD problem, the Dental Fluorosis and the Skeletol Fluorosis have also been identified as major water borne diseases observed among the people who are consuming water which is contaminated with the presence of excessive amount of Fluoride in North Central Province of Sri Lanka.

BACKGROUND

Since 1954, Anuradhapura city area is being provided with treated potable pipe bornewater extracted from surface water sourcesand the prevalence ofCKDu problem is very rare in this area. Depending on this experience of NWS&DB it can be suspected that there may be a direct relationship with the consumption of water contaminated with Fluoride / Hardness and the Chronic Kidney Disease (CKDu) though it has not been proven yet scientifically.Considering this fact, it was decided to carry out a pilot project in provision of potable water requirement (for drinking and cooking) of a CKDu prone area by the Regional Support Centre – North Central (RSC-NC) of NWS&DB inparallel to the World Water Day celebration in 2012. Project was decided to implement not only as a study on effect of potable drinking water and CKDu but also as a measure of enhancement of living standard of the people in selected area by providing an essential utility.

After making of several discussions with the health authorities of North Central Province, Sandamaleliya village in Mahawilachchiya MOH area of Anuradhapura district was selected to implement this project where considerable numbers of CKDu patients have been reported so far. Burning Sensation of Stomach resulted with the drinking of ground water in this Sandamaleliya area was a very common complaint made by the villagers.

OBJECTIVES

Describing on experiences of RSC-NC of NWS&DB in provision of water requirement for drinking and cooking to the CKDu prone area of Sandamaleliya, presentation of findings for the parties who are interested in seeking of causes for CKDu and provision of recommendations on organizations who are involved in supply of drinking water in areas having water scarcities have been included among the objectives of this paper.

ADAPTATION PROCESS

As the first stepon planning of a feasible method of distributing the water requirement for drinking and cooking of villagers in Sandamaleliya area, data relate to the sectors of geographical, climatic, land usage, water usage, population, socio-economic and cultural etc. were collected adjoining with the relevant officials. (Refer Table 01).

Figure 1 - Location of Sandamaleliya Village
Source: PAC Report on Sandamaleliya Water Supply Project – NWS&DB

Table 1 - Descrition of Sandamleliya area

District	Anuradhapura
DS Division	Mahawilachchiya
GN Division	Sandamaleliya
MOH area	Nuwaragampalatha Central
Village	Sandamaleliya
Land extent	95 ha
Household Units	104
Population	520
Annual Average Rainfall	1000 – 1500 mm
Average Temperature	33°C
Health Condition	Higher no. of CKDu patients are reported with dental fluorosis and skeletol fluorosis
Drinking water Facilities	Deep Tube wells & shallow wells with higher concentrations of Fluoride and Hardness

Source: PAC Report on Sandamaleliya Water Supply Project, NWS&DB

A layout map containing the locations of each of household units were prepared by making walkthrough surveys. After analyzing the data collected through surveys, it was found that the distribution of potable water from Anuradhapura Sacred City Water Supply Scheme (ASCWSS) by using Water Tankers (Water Bowsers) as the most feasible option to be selected as the mode of distribution.

Thereby the water requirement for drinking and cooking in CKDu prone area of Sandamaleliya was supplied by using Water Bowsers from Anuradhapura Sacred City Water Treatment Plant Supply Scheme where the Tissawewa tank has been utilized as the raw water source.In order to supply of water, a water bowser had to travel a minimum distance of 30km from ASCWSS to the village of Sandamaleliya. This water is filled to 1,000 litre capacity PE tanks placed at the

locations identified during surveys in planning stages, jointly with the Public administrative bodies and Community Based Organizations (CBOO) which are operated in those villages. Special attention was taken to locate these water storage tanks in order to have a good accessibility by each and every family of the village. According to the calculations performed during design stages, one PE water tank was allocated for the usage of three household units. Each of household unit was provided with 2Nos of plastic water cans in order to collect the daily water requirement for drinking and cooking which had been estimated as 20 litres per household. Responsibility on protection of each of PE water tank and the extraction of water by adhering to the daily allocations was granted to a selected household unit out of consumers of a particular tank by maintaining proper recordings and agreements prepared by NWS&DB.

It was considered that the indirect benefit which is gained by enhancing the health condition of the people is more important than the gaining of profit for NWS&DB through the above mentioned water supply arrangement. Therefore an arrangement was made only to cover up the incurred cost of NWS&DB for supply of diesel for water bowsers by collecting a very low amount of money from the consumers through the relevant CBOO. According to the calculations, one PE tank should be filled twice a month and thereby an amount of Rs. 340.00 had to be collected from each of household unit for a period of one month.

Continuous water supply to Sandamaleliya area was ensured by filling water tanks at regular intervals as per the schedule.A questioner survey was done after five months of the project implementation adjoining with the officials of the health sector.

Photo 1- Filling of water tank via Bowsers

Photo 2 - Collection of water

OUTCOME OF THE INTERVENTIONS

Post researches carried out by the officials of health sector have proven that the enhancement of the severity of CKD patients has got reduced in the areas where the water for drinking and cooking demand was supplied. And also the consumers of water have mentioned that the burning sensation on their stomach prevailed earlier has also been lapsed with the consumption of potable water supplied by NWS&DB and the desire on drinking of water has been increased compared to earlier.

THE WAY FORWARD

It is expected to monitor the health condition of CKDu patients in Sandamaleliya area adjoining with the health sector authorities for a substantial period of time in order to obtain more accurate findings. Expansion of the programme of supply of water requirement for drinking and cooking to the other areas having a higher prevalence of CKDu is expected through the experience gained in the case of Sandamaleliya.Source of funding are expected to sought from outside donors to carry out these type of water supply programmes depending on the success of the pilot project which was carried out in the village of Sandamaleliya.

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Assessment of Groundwater Quality in Jaffna Peninsula for the Establishment of a Long-term Groundwater Monitoring Network

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ABSTRACT

Geology in Jaffna peninsula is comprised with five types of significantly distinguished features. Miocene Limestone and the Red bed cover the top middle part of the peninsula while Dune sand/Beach sand restricted into Eastern costal region and as a thin layer of northern costal from Karainagar side to Point Pedro. Rest of the inland is occupied by Unconsolidated Brownish Gray costal sand and marginal areas covered by Lagoon/Estuarine deposits. It's noted that the groundwater quality is varies and interrelated with these geological setup in the region.

Shallower and deeper aquifers encountered in Jaffna, Nallur, Chavakachcheri & Pachchilaippallai divisional secretaries were studied for the establishment of long term monitoring program which leads to identify Groundwater occurrence & quality distribution. These areas were selected based on the issues identified by available information on groundwater quality. This comprehensive assessment study is provided a platform to acquire sustainable utilization & proper management of Groundwater resources in the Peninsula for future economic and rural development activities. In this study, initial assessment of groundwater occurrence and its physical/chemical quality distribution was carried out for identification of long term monitoring points in the pilot area. In-situ testing for selected parameters and further comprehensive analysis including physical, chemical, bacteriological &heavy metals were performed. Aquifer parameters were estimated based on the analysis results of test pumping carried out at different aquifer types in the area. The hydrogeological condition of the sub-surface was interpreted using 1D & 2D resistivity surveys.

More than 17 Nos. of physical and chemical parameters of groundwater were analyzed for the selection of long term monitoring locations.Out of 92 water samples analyzed, 79% samples in dry season and 84% in wet season are exceeded the desirable level for EC prescribed by the WHO standards. Furthermore, 13% samples of each period is exceeded the permissible level resulting an issue for the dinking purposes of this groundwater. No health-based guideline values are proposed for Na by WHO. However, the Clconcentrations and Na concentrations are observed in excess of about 200 mg/l which may be objectionable toconsumers because of the taste of the water (WHO, 2004). About 15% of studied wells are exceeded their permissible level for hardness of the groundwaterexpressed as mg/l CaCO3 equivalent in each periods while almost half of the samples having higher hardness values than the desirable level. This is mostly the result of Ca and Mg from dissolved limestone.Further, there is a possibility to saline water intrusion in Karaveddi-Chavakachcheri DSD boundary. This indicates by the present groundwater quality of the study area.Based on the all chemical analysis results and identified problems in the different zones of the study area, the monitoring network comprising 38 wells which were selected for the long term groundwatermonitoring.

BACKGROUND OF THE STUDY AREA

The study area (in between 9.518° & 9.765° N of latitudes and longitudes of 79.994° & 80.455°) located in the Northern Province of Sri Lanka. This terrain which existed at the northern most part of the country separated from the mainland forming a peninsula and surrounded by the Indian Ocean and Kilali Lagoon. The Jaffna peninsula has an extent of 260,000 acres with a population of 831,112 (1981, Census). But the study area restricts to only four DS divisions namely Jaffna, Nallur, Chavakachcheri of Jaffna district and Pachchilaippallai of Kilinochchi district. The majority of landuse within the area is occupied home gardens, Palmyra, coconut and paddy lands. However most of lands are still abandoned due to prolong war conflict of the country. Main lagoonal deposits which covered the area is known as Jaffna lagoon, Uppu Aru and Vadamarachchi. The area is almost flat and characteristically associated with marshy lands, lagoonal marshy areas, sand dunes and red earth soil beds covering the underlain limestone layer. The highest elevation is about 12-15masl at Thelippalai area.

The region is in the temperate semi-arid climatic zone of the country and average temperature is 28° - 32° C and does not vary widely throughout the year. The average annual rainfall is 1,543 mm according to the rainfall data collected between year 2000 and 2005. 82% of the total annual rainfall in the Peninsula is received by North east monsoonal period starting from October to December. In general, rest of the year is almost without any significant amount of rainfall. Evaporation is approximately 2250mm per year whereas the corresponding total rainfall is 1150mm. Out of the

total area (1025 km^2) of Jaffna district, the land area is occupied with the extent of 929 km^2 and inland waters with 96 km^2 extent according to the Road and Town Atlas published by the Survey Department of Sri Lanka,. Kilinochchi district is off 74 km^2 inland waters with comparison to the 1279 km^2 of total area.

Highly Karstified Miocene sedimentary Limestone formations encountered within shallow depth in most of the area. All the shallow groundwater found within the cavities originated from the infiltration of rainfall and this shallow groundwater forms mounds or lenses floating over the saline water (Panabokke, Perera). The monsoon rain is the only recharge component to the system. There are four other types of geological basement can be identified originated from sedimentary background; Lagoonal and Estuarine deposits, Unconsolidated Brownish Gray costal sands, Red beds and Dune sands. Since the study area belongs to peninsula separated from the whole island mass, there is no any river basin can be identified. Valuku Aru which traverses South-Eastern from its origin in the central Mallakam area does not reach to the study area. The area is lack of any definitive surface drainage system since no streams network could be identified except scattered small scale pond system in the peninsula which is also effective groundwater recharge source for the region. Therefore approximately 100% of water resources existed in the peninsula could be regarded as off groundwater. Dense network of interconnected caverns, fractures and fissures in the limestone aquifer is the most highly productive aquifer in the region.

The concerned area for this study is of shallower and deeper aquifers encountered in Jaffna, Nallur, Chavakachcheri & Pachchilaippallai divisional secretaries to establish a long term groundwater monitoring network which provided a platform for sustainable utilization & proper management of groundwater resources in the Peninsula for future economic and rural development activities. These areas were selected based on the issues identified by available information on groundwater quality. The activities of this study were basically focused for the initial assessment of water quality in the region spatially as well as temporally which leads to identify quality distribution.

OBJECTIVES

The Main objective is establishment of a monitoring network in the selected pilot area for long term assessment of hydrogeochemistry in the region**.** Specific objectives are determination of groundwater use and identification of the influence of agricultural practices, bacteriological pollution and other factors to the groundwater of the Peninsula and furthermore, to interpret the hydro-chemical evolution of groundwater from the limestone aquifer by determining the chemical characteristics and the most relevant controls on the groundwater composition.

Scope of the work

- To carry out survey related to sanitation facilities available in the Jaffna town area
- Identify appropriate monitoring well locations that will provide necessary data to fulfill the objectives of the monitoring program.
- Propose the frequency of both groundwater level measurements and the water sampling for each well assigned in the network.
- Provide the best information currently available regarding the specific hydrogeologic unit(s) monitored by each well.
- Reference the procedures and associated quality assurance requirements to ensure proper protocol being practiced in the monitoring of quantity and quality of groundwater.

METHODOLOGY

Existing aquifer types and the basic Geology, Structure and topology were studied with the help of previous researches done in the area. There is no any comprehensive study has carried out on the occurrence and quality distribution of groundwater by long term consideration. The preliminary reconnaissance survey including some awareness programs to the stake holders and community was done at the initial stage. This lead to obtain the information on the issues identified and the availability of data at leading government as well as non-governmental organizations. During the initial field inspections, the necessary information on the issues and water resources were gathered. In addition, in-situ tests were performed to analyze pH, EC, TDS, Salinity (using HACH HQd Portable Meters) and Nitrate, Phosphate concentrations (HACH DR/890 Datalogging Colorimeter) of the water samples using Field test kits.

Based on the results of in-situ tests and other issues identified at the area, 52 shallow wells were selected out of 112 visited locations as initial sampling points for chemical analysis during the peak time of the dry season in August 2011. In addition, chemical analysis was done for another 40 shallow wells in the same dry season. Most of these wells are used for drinking purpose while some are only for domestic uses and very few were abandoned at the time of sampling. The analysis included with full chemical analysis, selected heavy metal analysis and bacteriological analysis if required.

After the wet season (December-January) same sampling procedure was followed up for chemical analysis at 68 selected locations out of 92 previously studied wells. Some locations have been omitted due to similarity of the water chemistry and considering the aquifer formations, hydrogeological set up and also due to defense restriction in certain areas.

In advance bacteriological analyses were done in selected 13 shallow wells in Jaffna and Nallur urbanized area with parallel to wet seasonal water quality study. These tests were done at the field itself by a chemist using HACH MEL/MF Portable Incubator Laboratory.

During the sampling procedure, water samples were collected into specifically recommended plastic bottles with air tight capping for the laboratory analysis. Samples for the determination of cations were acidified to pH<2. Concentrations of cations were determined by atomic absorption spectroscopy (AAS). Nitrate and phosphates was preserved by adding conc. H_2SO_4 to the samples. The accuracy of the analysis was estimated from the ionic balance error (Freeze and Cherry, 1979), which is within 5% for all samples.

Geophysical survey done at selected locations to study the sub surface conditions using 1-D resistivity methods by ABEM 1000 Resistivity meter and further 2-D imaging resistivity survey method (*AGI SuperSting R8/IP* 8-channel memory earth resistivity meter) was applied to get subsurface 2D visualization in the important target areas.Test pumping carried out at different aquifer types in the area and the analyses results of those tests were used to estimate the aquifer parameters.

RESULT AND DISCUSSION

Table 1 - Comparison of number of wells exceed the SLS drinking water standards in Dry and Wet periods

Parameter	No of wells Exceed the SLS Standards			
	Dry season (Total No. of wells =88)		Wet season (Total No. of wells =70)	
	MDL	MPL	MDL	MPL
Color	0	0	54	12
Turbidity	2	0	10	3
pH	3	0	3	1
EC	73	12	58	9
Total Hardness	44	14	38	11
TDS	71	16	56	10
Total Alkalinity	82	29	63	19
Fe	1	0	0	0
F	32	6	40	1
Ca	17	8	9	2
Mg	3	3	6	0
Cl	48	8	24	5
SO_4	13	6	3	2
NO3	-	1	-	2
PO4	-	4	-	3

MDL: Max. Desireable Level, **MPL**:Max. Permissible Level

Table 01 are shown the number of wells which exceeded the SLS drinking water standardsfor 15 Chemical/ Physical parameters been analyzed during dry and wet periods. Same sampling locations were used in both periods except some of the wells which have been excluded after dry season analysis results.Most of the variables are skewed positively and include outliers. Therefore the variables were log transformed for improving normality of the variables. Subsequently, all 15 variables were standardized to their standard scores (z-scores) and only 88 wells from dry period were used to statistical analysis.

According to this statistical summary of the analysis, there exists a considerable water quality problem in Electrical Conductivity (EC), total Dissolved Solids (TDS), Total Alkalinity (TA), and Total Hardness (TH) in water for both dry and wet periods. Fluoride, Chloride and Calcium concentrations are being reached to the maximum permissible levels and in contrast less Fluoride content is another water quality issue in some areas in the peninsula.

Table 2 - Summary of water quality analysis in dry period (Aug/Sep 2011)

Parameter	Total Count	Mean	Minimum	Maximum
Turbidity (NTU)	88	0.518	0.060	6.400
pH	88	7.386	6.900	8.100
EC (µS/cm)	88	2142	155	18460
Total Hardness (mg/L as Ca)	88	460.2	68.0	7207
TDS (mg/L)	88	1365	102	12183
Total Iron (mg/L)	88	0.110	0.010	0.400
F (mg/L)	88	0.560	0.00	2.100
Salinity (ppt)	88	1.127	0.100	10.90
PO4 (mg/L)	88	1.032	0.200	8.000
Ca (mg/L)	88	93.60	11.50	1347
Mg (mg/L)	88	54.90	1.200	933.0
Na (mg/L)	88	308.0	30.00	2135
K (mg/L)	88	45.30	2.100	346.0
Total Alkalinity (mg/L)	88	367.0	109.0	735.0
Cl (mg/L)	88	531.0	15.10	7280
SO4 (mg/L)	88	137.7	1.000	2600
NO3 (mg/L)	88	1.726	0.100	26.00

Water quality analysis for dry season hasbeen distinguished several shallow water lenses that createddifferent water quality changes within nearby areas.

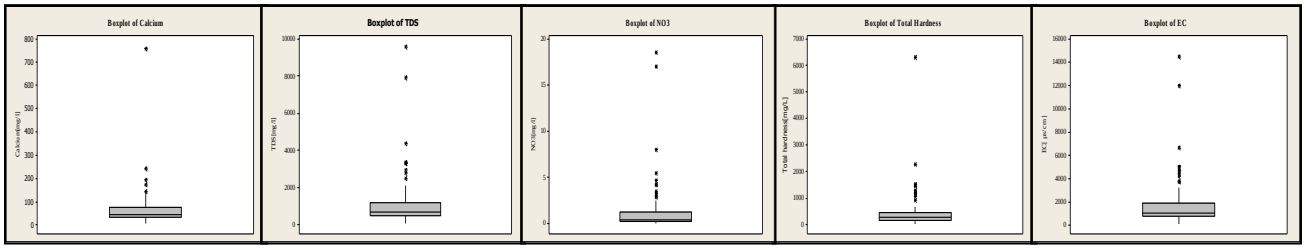


Figure 1 - Water Quality Analysis after Wet Season (Jan/Feb 2012)
(Box plots for shorter range variables of wet seasonal analysis)

Wet season analysis data concludes that TDS has the widest range than other variables. TH, TA, Na and Cl has considerably higher ranges. But Fe, F, Ca, Mg, K, PO_4, SO_4 and NO_3 have shorter ranges. Beside these shorter range variables, again all the variables are positively skewed. One outlier has been identified considering all the parameters and therefore only 69 samples were used to interpret the wet seasonal data.

Table 3 - Statistical analysis data for wet season

	Calcium (mg/L)	TDS (mg/L)	NO_3 (mg/L)	Hardness (mg/L *as Ca*)	EC (µS/cm)
Q1	168.75	33	0.2	538.0	825.0
Median	271.5	44.7	0.4	707.0	1091.0
Q3	461.0	76.275	1.275	1217.75	1912.5
IQ Range	292.25	43.275	1.075	679.75	1087.5
N	70.0	70.0	70.0	70.0	70.0

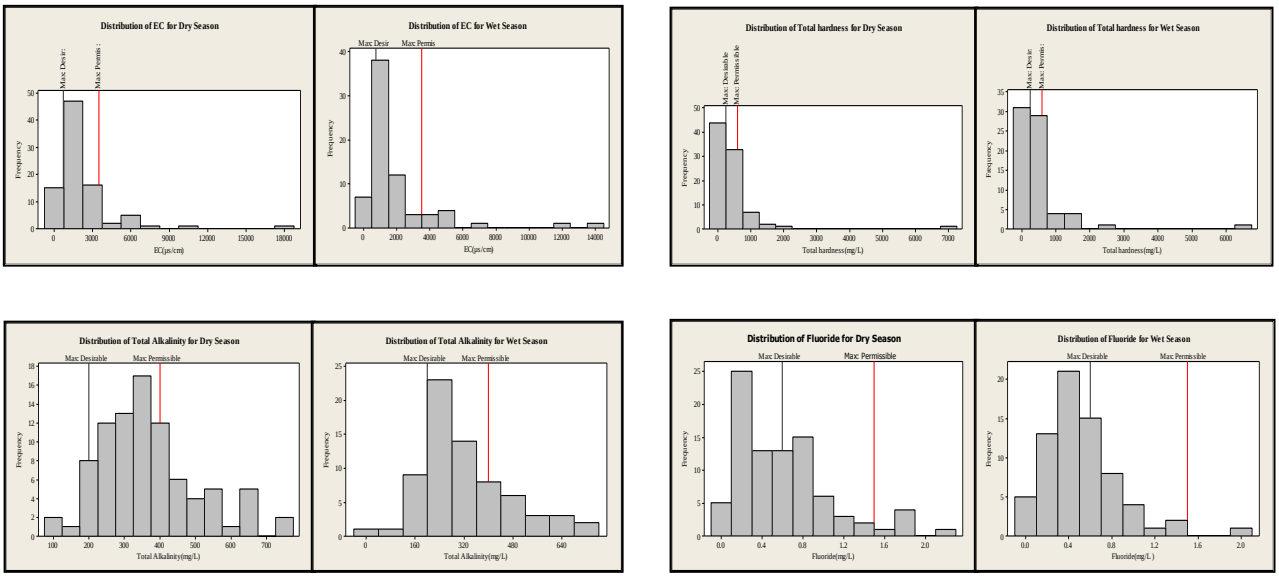


Figure 2 - Graphical representation for seasonal changes in selected parameters
(Comparison of histograms for dry andwet periods)

Groundwater Quality

Nitrate concentration of Groundwater is significantly high in Kondavil-Kopai Red Earth underlying area. High yielding shallow aquifer compare with the rest of the study area may be easily contaminated by excessive application of Agrochemicals. And there is a slight indication of Sea water intrusion in Ariyalai and possibility to development of such a situation in Karaveddi DSD boundary Lagoonal area too. Shallower fresh water lenses created by the fine sand in Iyakachchi area is extended to the South eastern coastal side. HACH portable Bacteriological in-situ field instruments were used to carry out the Bacteriological Analysis. Selected 13 numbers of dug well locations in Jaffna & Nallur town area were not indicated a bacteriological contamination in this particular time period.

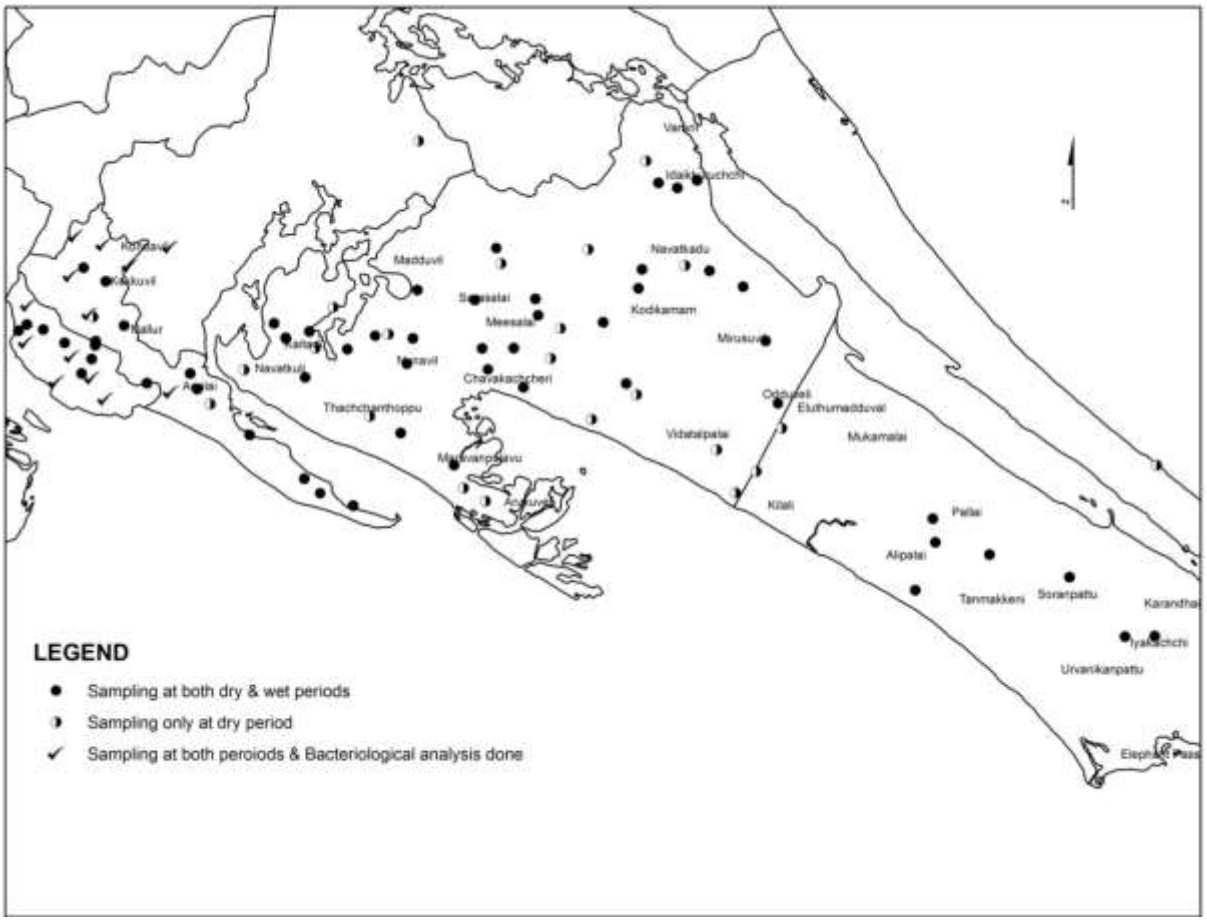


Figure 3 - Spatial distribution of the groundwater quality in dry and wet periods

Table 4 - Bacteriological in-situ analysis results after wet season (Feb2012)

Well No.	Location	pH	PO4 (mg/L)	NO3 (mg/L)	Total Coliform	E-Coli
JS31	Kopai South	7.7	0.6	3.5	Nil	Nil
JS49	Jaffna	7.5	0.6	0.5	Nil	Nil
JS50	Thirunelvely	7.6	0.6	2.9	Nil	Nil
JS51	Kondavil	7.5	0.6	4.7	Nil	Nil
JS55	Iruvalai Road	7.6	0.3	3.3	Nil	Nil
JS57	Kondavil	8.0	0.6	0.8	Nil	Nil
JS60	Kurunagar	7.6	8.0	5.5	Nil	Nil
JS62	Chundikuli	8.2	1.0	3.0	Nil	Nil
JS63	Koddady	7.2	0.9	0.2	Nil	Nil
JS65	Oddumadam	7.3	0.7	18.5	Nil	Nil
JS72	Pasiyoor	8.2	1.1	0.3	Nil	Nil
JS73	Maniyamthottam	8.1	0.5	0.3	Nil	Nil
JS76	Kokuvil East	7.8	0.7	0.4	Nil	Nil

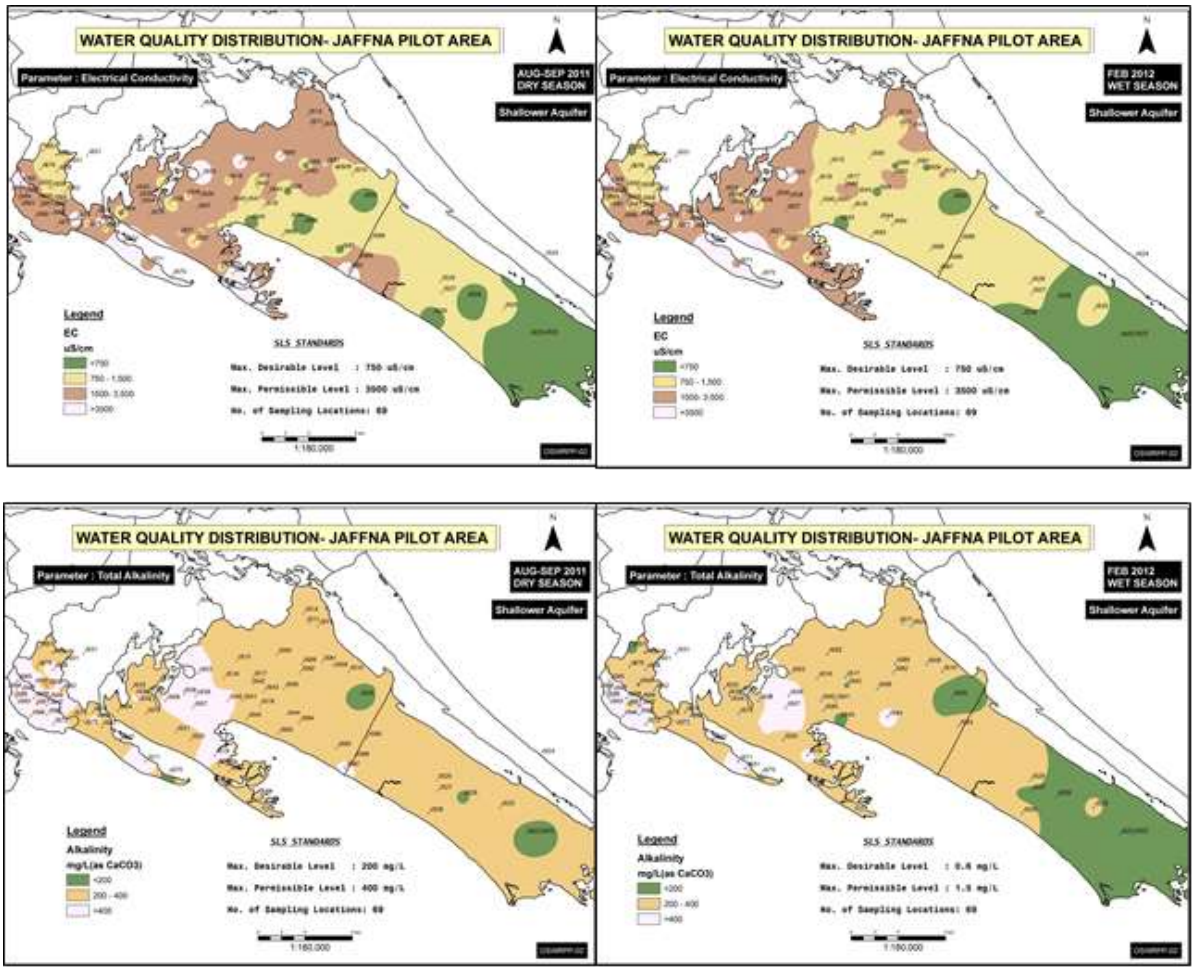


Figure 4 - Seasonal changes in EC and alkalinity quality distribution in shallow groundwater of study area

Interpolated spatial distribution of the Groundwater quality in each sampling periods (by Inverse Distance Weighted method using ArcGIS 10 software) implies that temporal variations of quality distribution patterns and shown in above figures.

Subsurface condition

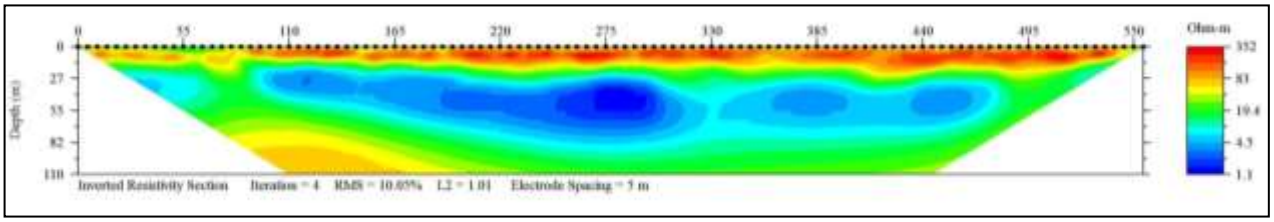
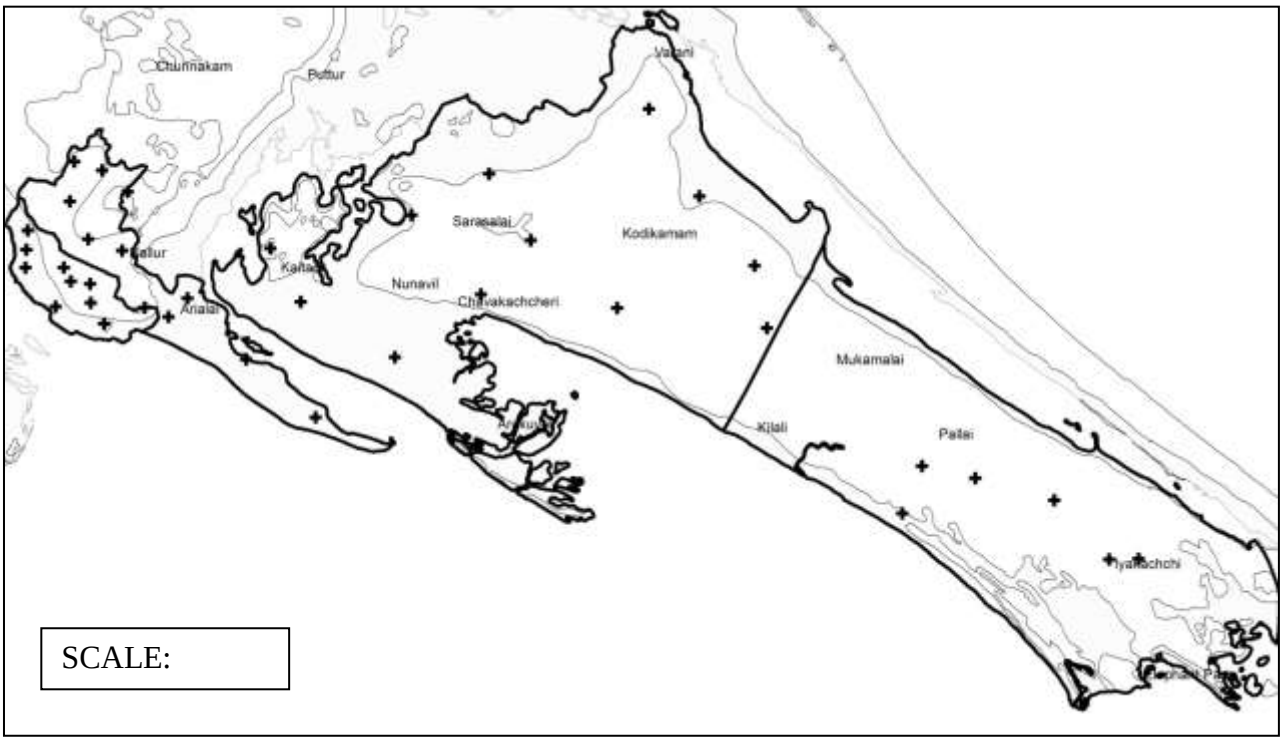


Figure 5 - Different sub surface layers identified by 2D Resistivity Survey done at Kondavil

The area is underlain by comparatively high resistive top soil (Red earth) formations and then the karstified Limestone which is more than 100m thick. 1D resistivity survey carried out in different geological natures in the area implies the deeper (>20m-30m) Groundwater quality may be objectionable to the consumers because of the taste.

Proposed Long-Term Shallow Groundwater Monitoring Network



Fiure 6 - Spatial map for selected GW monitoring network

LIMITATIONS RELATED TO FIELDWORK

One of the major limitations to the fieldwork in the study area was the lack of enough Hydraulic head data and water quality analysis data in the limestone aquifer due to the lack of monitoring boreholes. Therefore study was mostly restricted to shallow aquifer system.

Some high security zones cannot be accessed and sampling was not done in those particulararеas for this quality assessment.

RECOMMENDATIONS

The proposed Monitoring Network is comprised of 38 shallow wells and it is recommended tomonitor the water level and water quality on quarterly basis. This could be carried out at peak time of the dry period, after the infiltration of rain water and in between these two seasons.

In the case of Nitrate issue in Red bed areas, it is recommended to monitor the Nitrate levels on monthly basis at the selected wells.

It is also recommended to control the excessive applications of agrochemicals in high sensitive areas of the Groundwater contamination through awareness and guidance by the relevant Governmental or Non-Governmental agencies.

Further, it is observed that the Nitrate in groundwater sources utilized for the most of water schemes are indicated higher level thus require a mechanism such as lowering the NO3 levels by mixing better quality water sources which are required to be explored in the region.

ACKNOWLEDGEMENT

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Water footprint of milk production under less-intensive medium-scale cattle farming conditions of Sri Lanka: An analysis

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ABSTRACT

Water footprints of animal products such as milk and meat are reported to be high. Meanwhile, it has been predicted that the global consumption of animal products, particularly that of developing and middle income countries such as Sri Lanka will increase sharply in next two decades. In this context, means of producing animal products at high water efficiency are of importance. On a one hand, water footprint (WF) of a product indicates how efficiently water has been utilized during the production cycle of a particular product. On the other hand, an analysis of the WF is important to identify suitable strategies to make the production process more water efficient. Under the less intensive-small-medium scale dairy production systems prevail in Sri Lanka, WF value of milk production can assumed to be high. No studies has been done to determine the WF of milk production under actual farming conditions of Sri Lanka. The first objective of this study was to calculate the WF of milk production of a typical, medium scale less-intensively managed dairy farm. The second objective was to identify the possible strategies to reduce the WF of milk production. The production conditions and parameters of the dairy unit of the Farm of the Faculty of Agriculture, University of Ruhuna were used for the analysis. Secondary data was used when necessary. The herd was of a Jersey x Indian and Jersey x Friesian crosses. Calves and heifers were grazed while milking cows were under cut and fed system. A mixture of coconut poonac and rice bran was used as the concentrate feed for milking cows. Feed water, drinking water and servicing water were the main components of the WF. The WF of dairy cow milk production under the conditions studied was calculated to be 1528.44 m^3/ ton of raw milk. Servicing and drinking components of the total WF was very low. However, it was found that animals were not given adequate amount of water. Under the conditions studied, feed water accounted around 99% of the total WF. The milk yield of the cows was well below their genetic potential and thus a great potential exists to reduce the WF by improving the management conditions. Of the feed water component, forage and concentrate feeds accounted 82% and 18%, respectively. Appropriate use of concentrate feeds with forage also identified as a mean of reducing the WF. It was concluded that exploitation of the full genetic potential of the cattle through good management practices is of importance to reduce the WF of milk production.

INTRODUCTION

By 2025, it is estimated that around 5 billion people, out of a total population of around 8 billion, will be living in countries experiencing water stress.Consequently, increasing water scarcity and insecurity will lead to more deaths from drought and water-borne disease, political conflict over limited resources, and loss of freshwater species (Arnell 1999). In facing the water scarcity and insecurity it is imperative to find water efficient production means. Water footprint is a measure of how efficiently water has been used in the production of a commodity. The water footprint of any animal product is larger than the water footprint of crop products with equivalent nutritional value. The water footprint per gram of protein for milk is 1.5 times larger than for pulses. (Mekonnen and Hoekstra, 2012). In these circumstances, some have proposed that global animal product consumption should be reduced to face the challenges of water scarcity. For example, Renault and Wallender (2000) have shown that a reduction of 25% of all animal products in the developed countries' diet generates approximately 22% of the additional water requirements expected by the year 2025.However, it has been predicted that the global consumption of animal products, particularly that of developing and middle income countries such as Sri Lanka will increase sharply in next two decades (Steinfeld*et al*., 2006. In this context, means of producing animal products at high water efficiency are of importance.

On a one hand, water footprint of a product indicates how efficiently water has been utilized during the production cycle of a particular product and thus can be used to compare different products. On the other hand, an analysis of the WF can be used to identify suitable strategies to make the production process more water efficient. Assuming that the dairy management system in Sri Lanka is of a mixed system, Champagain and Hoekstra, 2003 have reported that WF of milk production in Sri Lanka was 2560m3/ton. Since assumptions and the production parameters used in the above study do not reflect the actual farming conditions prevail in Sri Lanka, it is important to determine the WF of milk under actual farming conditions of Sri Lanka. The first objective of this study was to calculate the WF of milk production of a typical, medium scale less-intensively managed dairy farm. The second objective of this study was to use WF value to identify the possible strategies to reduce the WF of milk production.

MATERIALS AND METHOD

The water foot prints of dairy cow milk production under the current production conditions and parameters of the dairy unit of the Farm of the Faculty of Agriculture, University of Ruhuna were used as the model for the analysis. The farm (6.2 N 80.46E) is located in Low Country Wet Zone.2 (WL2) of Sri Lanka. Mean temperature and relative humidity were 28^0C and 78%, respectively. The herd was of a Jersey x Indian and Jersey x Friesian crosses. Calves and heifers were grazed during day time and housed in an open paddock during night. No night feeding was given for calves and heifers. Milking cows were under cut and fed system. Each milking cow was fed 30 Kg of fodder CO3 per day. In addition, 3 kg of coconut poonac and rice bran (1:1) mixture was fed to each milking cow, daily as a supplementary concentrate. Heifers were also fed 2 kg of coconut poonac: rice bran mix per day. Milking was done only once a day.

The average milk yield of a dairy cow was 2089.8 kg per lactation. The length of the calf and heifer periods was 1 and 2 years, respectively. The total milk yield of a cow over 9 lactations was 18808.2 kg.

The methodologies used by Mekonnen and Hoekstra, 2010; Champagain and Hoekstra, 2003) were used with minor modifications. The main component of the WF was feed, drinking and servicing water. The steps of WF calculation and the ingredient composition of the diet are given in Table 1. WF values and the product fractions of the feed ingredientswere collected data basses. Assuming the daily fodder grass intake of claves, heifer and milking cows are 8, 25, 30 kg respectively, the total fodder grass consumption was calculated to be 119.72 ton for the duration of productive life span. The total concentrate consumption was calculated to be 8.75 ton for the productive life period.The feed water component consists of both water footprints of the various feed ingredients and the water that is used to mix the feed. The mixing water component was calculated by assuming that it takes 0.5 liter of water to mix the 1 kg of concentrate. To determine the water in consumed feed amount (fodder grass + concentrates), the WFs of each feed ingredient was multiplied by the amount of the respective ingredient consumed by a dairy cow during it's productive life time. The daily drinking water requirements of claves, heifer and milking cows ware 2.35, 6 and 6.75 kg,respectively. The servicing water component was the sum of water required for cleaning utensils, milking cows and cattle shed.

Table 2 -The steps of WF calculation

Feed ingredient	Quantity	WF(m^3/ton)	Pf	WF*Pf	TFI (ton)	Water (M^3	Milk ton
Coconut poonac	0.50	834.00[1]	1	834.00	8.75	3,648.75	
Rice bran	0.50	3,168.00[2]	0.1	316.80	8.75	1,386.00	
Fodder grass		197.77[2]	1	197.77	119.72	23,677.02	
Water for feed preparation						4.38	
Drinking water						27.41	
Servicing water						3.65	
Total water requirement						28,747.21	
Milk yield							18.8082
Water foot print						1,528.44	m^3/ton
Water requirement at different physiological stages							
Calf						578 (2%)	
Heifer						4454 (15%)	
Milking cows						23714 (83%)	

[1]Hoekstra and Hung (2002)
[2]Mekonnen and Hoekstra (2010)

PF - Product fraction WF - Water footprint TFI - Total feed intake

RESULT AND DISCUSSION

The total period a cow gives milk is much longer than it spends as a calve and a heifer. Furthermore, the consumption of forages, concentrates are also higher for milking cows than calves and heifer. Consequently, the water "requirement" during the calf, heifer and the lactation periods were 2, 15 and 83% of the total water requirement. Delayed sexual maturity and commencement of the production period are common in local small and medium scale dairy farms where

management practices are poor. Recalculation of the data showed that each of delaying year of sexual maturity and the commencement of lactation increased the WF value by 2 and15%, respectively. Good feeding and the fertility management practices are always recommended to optimize the production capacity of a dairy heard.Results of this study emphasize the importance of those practices from water utilization efficiency perspective as well. Under ideal conditions, aJersey x Indian and Jersey x Friesian crosses commences her lactation at 30 moths of age. Therefore, reduction of WF value by optimizing the reproductive efficiencies is fixed within those biological limits.

The WF of the Dairy cow milk production under the current production conditions and parameters of the dairy unit of the Farm of the Faculty of Agriculture, University of Ruhuna was calculated to be 1528.44 m3/ton. This value is slightly lower than the average WF reported by Chapagain and Hoekstra (2003); 1738 m^3/ton for grazing system. Furthermore, same study estimated the WF of dairy industry for Sri Lanka as 2560m^3/ton. Differences in the production parameters used in the computation processes of two studies may be the main reason for the above discrepancy. Chapagain and Hoekstra (2003) have assumed that the dairy production system of a country depends on its per capita income. Accordingly, they have used a set of common production parameters assuming that Sri Lanka practiced a "mixed system" of cattle management. Since, the present study used the actual on farm production parameters in the computation process, the value reported herein could be considered more realistic than that reported by Chapagain and Hoekstra (2003).

Indicating the great influence of feed in the WF of milk production, compared to drinking and servicing water (0.09 and 0.01%, respectively) the contribution of feed for the WF was 99.9%. It was interesting to note that the drinking water requirement determined under the present study was much lower than that reported by Chapagain and Hoekstra (2003); 123 m^3/animal. It is widely accepted that inadequate provision of water is a critical factor that reduces the milk production in Sri Lanka. Analysis of the data of the present experiment shows that even a two fold increase in the provision of drinking water to cattle will have a negligible impact on increasing the WF of the milk production. In contrast, increased milk yield associated with the supply of adequate amount of water will reduce the WF. It is also noted that the provision of adequate supply of drinking water is essential from animal welfare point of view as well. Therefore, importance of ensuring adequate supply of drinking water for dairy is identified as critical to reduce the WF.

The servicing water requirement determined in this experiment was also lower than the value; 15.7m^3/animal, reported by Chapagain and Hoekstra (2003). The servicing water is mainly influenced by the water used for the cleaning of cattle shed.

Even though the average milk production of the herd studied was 2089 Kg/lactation/cow, the genetic potential of a Jersey*Indian or a Jersey*Friesian cross is around 2500Kg/lactation. It was calculated that the WF could have been as low as 1277m^3/ton had the herd achieved its full genetic potential. This indicates the importance of achieving the full genetic potential of the animal in reducing the WF. As discussed earlier, improvements in reproductive efficiencies are limited and thus main emphasis should be placed on other management practices.

Due mainly to two reasons, dietary manipulations are identified as the most practical way of reducing the WF of dairy cow milk production. Firstly, the contribution of feed to the WF is as high as 99%. Secondly, opportunities to alter the feed are higher and flexible. The contribution of each feed ingredient to the total feed water is shown in Table 2.

Table 2 - Contribution of each feed ingredient to the total feed water

Ingredient	% in the diet	Contribution to feed water (%)
Copra cake (CC)	3.4	12.71
Rice bran (RB)	3.4	4.83
Fodder grass	93.2	82.45

Despite being by-products, WFs of coconut poonac and rice bran were higher than that of fodder grass. Furthermore, contributions of above concentrates to the total feed water were higher than the respective percentage of those materials in the diet offered. Whereas, contribution of fodder grass to the total feed water was lower than the percentage of fodder consumed. However, feeding of fodder alone does not necessarily reduce WF since the above practice greatly reduces the milk yield. For efficient conversion of feed resources into milk, ruminants require a certain amount of high quality feedstuffs as well, in addition to pasture and fodder. Therefore, a careful analysis is needed to determine the appropriate fodder:concentrate ratio that minimizes the WF. Mixed farming system which is more or less similar to the conditions of the model farm used in this study is the most prominent dairy production system in Sri Lanka. Globally, mixed farming systems have the largest share of total milk (90 per cent) production and mixed farming is the main system for smallholder farmers in many developing countries (FAO, 1995). Hence, good feed and nutrition

management practices of those systems are of paramount importance not only from for general livestock productivity but also from water productivity perspective.

Due mainly to the lower product fractions of their respective main product, the water footprints of coconut poonac and rice bran were low. Use of this kind of agricultural by-products appropriately along with fodder seems to be effective towards lowering the WF. Computer software are widely used to formulate nutritionally balanced low cost rations for livestock. It would be incorporate water footprint aspects as well into these software so that rations would not only are balanced for nutrients, low cost but also water efficient.

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Awareness on changing pattern of rainfall intensity and existing adaptation strategies on agriculture at some irrigable areas of Batticaloa district

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ABSTRACT

The agricultural sector in Sri Lanka is highly vulnerable to climate change as this primary production highly linked with the natural resources. Therefore, the study on the present change in climatic condition, awareness and socio economic status of the people in order to accept the adaptation strategies are very important in implementing any adaptation practices or projects against climate change to a particular area. In this view, this research was conducted at ten irrigation command area of Batticaloa district during the period from January 2011 to May 2011 to assess the socio-economic condition of farmers, awareness on climate changes for its adaptation on agriculture. The primary and secondary data were collected through questionnaire survey, key informant discussion and direct observations. Both quantitative and qualitative research methods were used in the data analysis.

The results show that, 70% and 61% of the farmers are aware about the changing pattern and the increasing trend of rainfall and drought respectively. However, realization on the changes in rainfall patterns, cyclone/storm and loss of vegetation were responded as less than 10%. Also it was found that the climate change reduces the agricultural production and increases the poverty of the sample population in several ways. As far as the adaptation is concerned, 43% of the farmers are adapting a new agronomic practices in paddy cultivation such as reuse of drainage water, increase the number of ploughing, shifting the cultivation period and use of tolerant crop variety. However the agronomical adaptation percentage of the farmers were less compare to the increased trend of climate change. It is also found that adaptation relevant to water resources such as the use of micro irrigation; rain water harvesting and waste water irrigation are at low level. It is also concluded that the awareness on recent climate change impacts on productivity among the people residing in the study area is inadequate. Therefore, conducting awareness programme by the respective authority will create awareness among those people.

INTRODUCTION

Climate change is not only a major global environmental problem but also a developmental issue of great concern to Sri Lanka (IPCC, 2007).Sri Lanka, being an island is especially vulnerable to all identified impacts of climate change including rise in land and sea surface temperature, changes in amount of precipitation and pattern, increase in extreme climate events and rise in sea level (Eriyagama *et al*, 2010). Theimpacts of climate change effects on water resources, agricultural livelihoods and environment of Sri Lanka. Climate change impacts have alternating the agricultural activities in rural area. These issues affect the socio-economic condition and reduce the productivity, consequently leads to the poverty. Therefore farmers' awareness on climate change impacts is contributing to adapt or mitigate the negative effects of climate change. The magnitude of people's awareness on adaptation depending on attitude, knowledge and skills of the individual.Farmers should be identify and quantify the impacts through the way of developing a strategy to adapt with the change of climate. However, recent extreme climatic events moderate the Batticaloa district's agricultural livelihoods by various ways. Therefore, the study was conducted to investigate the status of farmers' awareness on climate change impacts on agricultural livelihoods such as paddy cultivation, highland, and livestock rearing. Also, the study was tried to find out the available adaptation strategies and magnitude of adaptation to increase the production of irrigable areas of Batticaloa district.

METHODOLOGY

The study was conducted atten representative villages on irrigable areas of Batticaloa district, which are irrigated by three major irrigation schemes such as *Navagiri, Unnichchai*and *Rugam* (Figure 01).

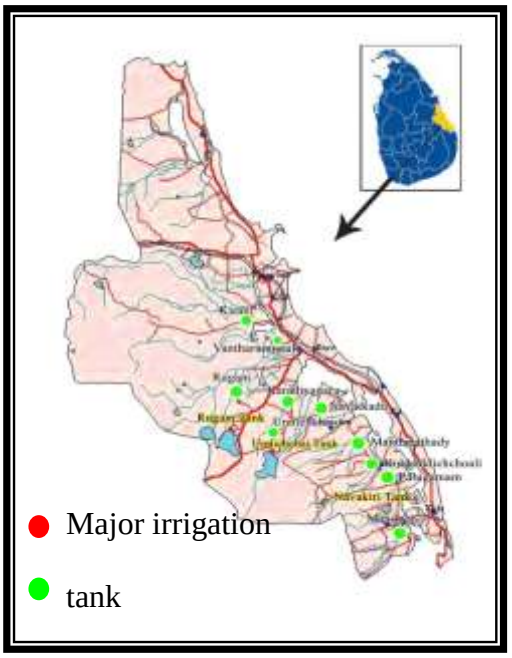

Figure 1 - Location of the study area

The relevant data were collected from primary as well as secondary sources. The primary data were collected through formal household questionnaire survey among 100 farmers, key informant discussion and direct observation. The secondary data were obtained from the Irrigation Department, Department of Agriculture (DOA), Meteorological Department, Agrarian Services Center (ASC), Kachcheri Batticaloa, Central Bank Report (2009), Census and Statistical Report (2009), and published literatures.Questionnaire wasinitially developed from personally interviewing of randomly selected 20 farmers in the study area. Purposive sampling and stratified random sampling techniques were used as the major methods of sampling. The filled questionnaires were checked for completeness, coded and data were analyzed by using SPSS (Statistical Package for Social Sciences) version 11.5, MS Excel version 2007 soft ware for windows.

RESULTS AND DISCUSSION

Farmers' Awareness on climate change impact

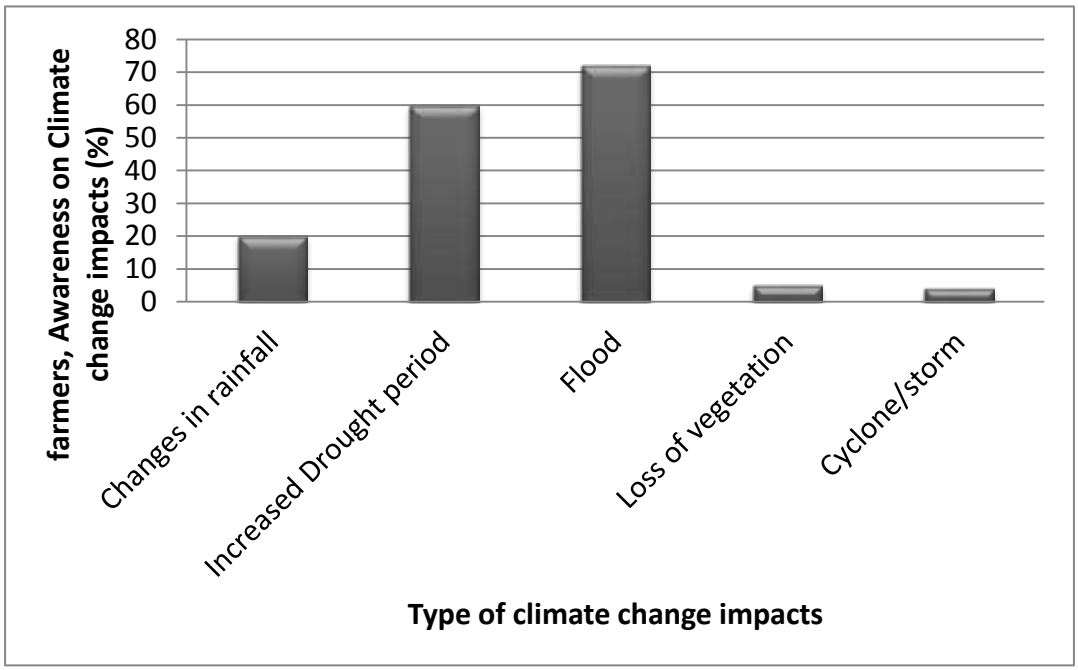

Figure 2 - Farmers' awareness on climate change imact

The figure 02 shows, most of the respondents were aware about the recent trend of flood (72%) and drought (60%) as the impact of climate change, more or less similar percentage (4%) of respondents werereported that,loss of vegetation and cyclone/storm also as animpacts of the climate change. People awareness on the changes in rainfall patterns (20%)

were at low level compare to the drought and flood. Because, the effect like rainfall patterns and intensity are unpredictable by farmers' knowledge. Also farmers suffered and directly affected by drought and flood compare to other climate changes.

Farmers' awareness on effects of climate change on farming activities

The study reveals that, 90% of respondents were reported that climate change impacts were affecting their crop yield. In addition, 35%, 20% and 16% of the respondents in the study area also reported that the climate change affect their livestock production, inland fishing, and other non-framing activities such as cashew processing respectively. Agriculture is one of the most vulnerable sectors as this primary production activity is highly linked with the natural resources of the environment. Herath and Dharmakeerthi (2010) reported, the effect of climate change on agriculture is due to three major impacts, namely temperature rise, rainfall variation and carbon fertilization effects. Johnston *et al* (2010)also stated, warmer conditions can reduce yields of crops by preventing pollination. For an example, rice yields decrease by 10% for every 1^{o}C increase in minimum temperature during the growing season. Similarly, the yield reduction in these study area may also be due to the increased temperature and reduced water availability.

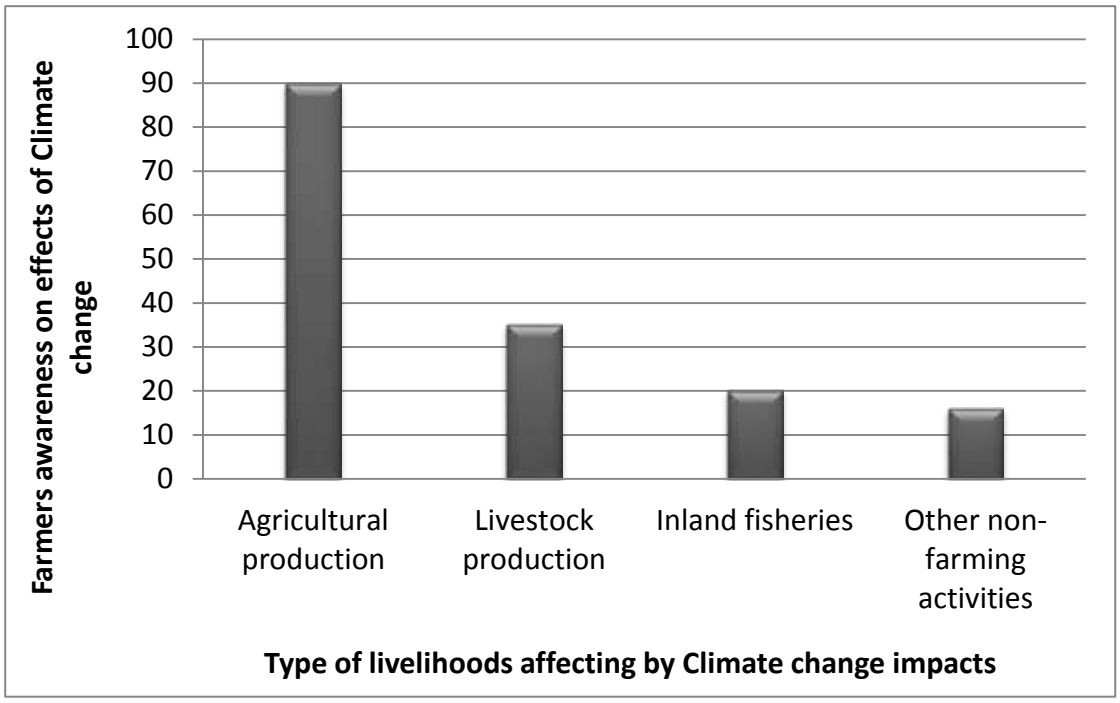

Figure 3 - Farmers' awareness on effects of climate change on farmin acitivities

Since the climate change impact on different livelihoods, farmers directly experienced with farming activities compared to other livelihoods of this area. Therefore, the magnitude of awareness higher in agriculture compared to others.

Farmers' awareness on climate changeeffects on Socio Economic conditions

Table 1 - Farmers' awareness on effects of climate change on Socio Economic conditions

Type of socio economic characters affected by Climate change impacts	Awareness Percentage	
	Yes	No
Reduced productivity	38	62
Poverty	66	34
Housing, water and sanitatio	13	87
Education of children	12	88
Proples' health	8	92
Environmental issues	4	96

Table 1, shows thathigher number of farmers reported that climate change isreducing the productivity and enhance the poverty, because the main occupation is agriculture (mostly paddy cultivation) in the study area and thus it is highly susceptible to the climate change impacts like increased drought and flood. However, less number of farmers reported, climate change impacts arevery less on health (8%) and environment (4%). Lack of the knowledge of the respondents were the main reason for least aware of the impacts namely health and loss of cultivable area. Because, loss of cultivable area in the eastern province is now become a problem due to the salinization of land. Drop of productivity and reduction

of yield leads to increase the poverty level of the farmers. Intense and prolonged flood periods are characterized by mass displacement of population, and water, food shortages. However, the capacity to adapt the change is very closely linked to socio economic factors such as poverty, diversification of income sources, level of education and access to infrastructure and technology.

Farmers' awareness on adaptation strategies in Agriculture

Most of the respondents (57%) were not adopting new agronomic practices in rice cultivation. Nearly 20% of the paddy farmers are reusing the drainage water from major irrigation tanks with theassistance of the lift irrigation system for short duration rice varieties (BG 300 and At 307). Since increase the ploughing frequency may lead to reduce weed population and increase soil nutrient condition, some of the respondent (23%) increased the number of plough from 4 times to 6 times before sowing of paddy to improve the yield by improving the rooting and retard the growth of weed.

Most of the farmers are with lack of knowledge and hesitate to adopt new methods and technologies, thusthey are not adopting new agronomic practices of rice cultivationlike System of Rice Intensification (SRI).75% of the Farmers in the study area are only doing paddy cultivation because of the climatic condition, soil type and water availability of this irrigable area. Among them 45% of farmers were reported that they are cultivating lodging resistant varieties (BG 300) to avoid the yield losses by high rainfall intensity during the harvesting periods. In addition, the farmers (21%) choose this BG 300 variety due to the short duration (3 months) inorder to overcome the inadequate water availability during short growing seasons.

Adaptation strategies to minimize the sudden spread of pest, diseases and weeds

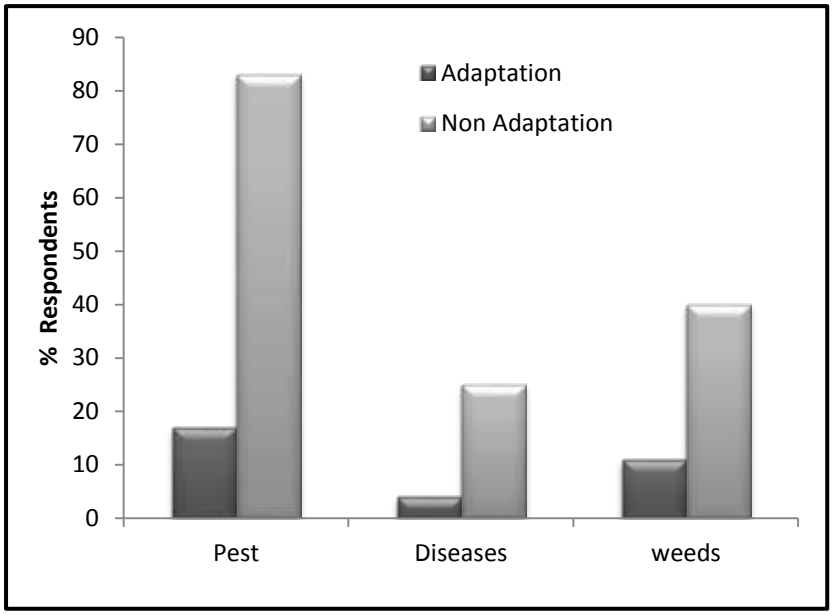

Figure 4 - Adaptation against pest, disease and weeds

Figure 04, indicates that most of the farmers were not adapted to the sudden impacts of pest, disease and weeds caused by the climatic changes during the cultivation. Because of the adverse climatic conditions such as prolong flooding and moisture the pest, disease and weeds spreads / grown in paddy cultivating area. Sudden outbreak of the pest is the most important problem during the adverse climatic condition and adaptation measures were less compare with non-adaptation like traditional pesticide application. However, less numbers of the respondent (30%) were reported the disease spread is due to the climate change.Meanwhile most of the sample respondent using the control measures i.e using inorganic pesticide (53%) and chemicals (25%) to control pest and diseases. However, still some of the farmers using some environmentally safe techniques like organic pesticide application (16%) for pest and manually (40%) controlling the weeds. Majority of the farmers (48%) are facing the problem of the attack of Brown plant hopper (BPH), fungal disease (14%) and water weeds (30%) in paddy cultivation by shifting seasonal timing due to adverse climatic conditions.

Effective and efficient use of water resources

Around 75% of crops are rain-fed in the study area. In many areas, irrigation is not technically or economically feasible, so improving water management is essential. Implementations of micro irrigation system and moisture conservation techniques are the most important strategies in irrigable areas which were not practiced by the farmers for high land crops in these areas. Most of the farmers were using kerosene water pump and agro well or tube well for the irrigation.However, they are not practicing new adaptation methods for increasing water use efficiency such as drip

irrigation and sprinkler irrigation (only 3% of the farmers are using micro irrigation methods). The reason for less usage of the modern irrigation system may be due to the high initial cost, lack of knowledge and awareness of an appropriate technology to enhance great water usage efficiency through drip and sprinkler irrigation systems. Many farmers (55%) are irrigating the vegetable crops by the lift irrigation. As far as the paddy cultivation is concerned, the farmers are utilizing rainwater (*Maha*) and bulk water allocations (*Yala*) to irrigate the paddy field. Obviously, it is apparent that, paddy cultivation indicates the lack of adaptation in the effective and efficient water use.Further, the study revealed that, there are three types of rain water harvesting system existing in this irrigable area, named as roof top rain water harvesting, deepening the tank by siltation and small scale pond. However, most of the farmers do not use the water from rainwater harvesting tank/pond to irrigate the crops except runoff harvesting pond in some areas. Because rainwater harvesting method is depends on three main factors: seasonal collection, intensity of rainfall and roof coverage. In most houses the roof coverage for harvesting was not properly maintained, which may affect water collection in dry periods because occasional rains during inter-monsoonal periods do not fill the tank to its capacity. In addition, investment for the rainwater harvesting tanks need high cost (Bandara*et al*, 2010).

CONCLUSION

Drought and rainfall pattern are the major climate change impacts in these irrigable areas which severely affect the agricultural productivity and increase poverty level of the rural poor farmers. The farmers aware on direct effects of climate change impacts compared to hidden changes such as drought and flood. Therefore; the awareness has to be created among these farmers to choose the best adaptation techniques to maintain the high yield. Agricultural adaptation like agronomic adaptation and use of new improved crop varieties are practiced by farmers, however the agronomical adaptation percentage of the farmers were less compare to the increasing trend of climate change. It is advisable to use the water efficiently through alternate irrigation methods such as sprinkler and drip for the highland crops that will be an effective and efficient in these areas.

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Annex 1

Young Water Professionals Symposium
Themes and Aspects Covered

TOPIC	SUBJECT AREAS
Optimizing Water Utilization	Water for sector, Irrigated agriculture, Water supply - surface and ground water, Water Quality issues – health / sanitation, Hydropower including small hydro, Commerce and industry, Urban planning, Basin planning and management
Improving Water Delivery	Delivery services including improved quality control, Technology options, Conjunctive use, recycling/reuse, Infrastructure construction and management, Management information systems, Forecasting, Demand management/supply augmentation. Floods / drought management.
Good Governance	Inter / intra sector coordination, Sector conflicts and institutional cooperation, Organisational/institutional arrangements, Legal basis, Stakeholder/ beneficiary participation.
Economic / Financial feasibility	Economic basis for investment, Financing/ cost sharing, Tariffs, Water and poverty, Food Security, Costs of O&M, Public / private partnerships
Environmental sustainability	Environment degradation / mitigation, Wetlands, Biodiversity and Ecosystems
Cross cutting themes	IWRM, Capacity building in water resources. Climate change adaptation and risk management.

Annex 2

Young Water Professionals Symposium - Technical Sessions

(Salon Anthurium – Galadari Hotel)

22nd November 2012 (Day One)

10:45-11:00 Hrs.	**Registration**	
Session 1	**(11:00-13:15 Hrs)**	
Session Chair:	**Ms. Badra Kamaladasa** Director General Irrigation Department	**Rapporteur: Mr. M. Aheeyar** Head Env.and Water Resources Mgt- HARTI
11:00-11:05	Introductory comments by Session Chair / Clarifications	
11:05-11:20	Flood mapping using Synthetic Aperture Radar in the Kelani Ganga and the BolgodaBasins, Sri Lanka *Presenter: Ms. C. Kudahetty*	
11:20-11:35	Improvement of the safety and acceptability of drinking water supplied from irrigation tanks by proper selection of unit operation *Presenter: Ms. Dilini Hapuarachchi*	
11:35-11:50	Knowledge, attitudes and practices of urban poor women on water and sanitation: acase study in Mahaiyawa slums, Kandy *Presenter: Ms. C.R. Semasinghe*	
11:50-12:05	Discussion	
12:05-12:20	Sustainable use of runoff harvesting tanks in smallholder farming system: a case study at Vellavelli area of Batticaloa District *Presenter: Mr. T. Venuthasan*	
12:20-12:35	The impact of extensive agriculture on groundwater chemistry in the eastern part of Sri Lanka *Presenter: Mr. K.D.A. Samaraweera*	
12:35-12:50	Importance of water as a construction commodity *Presenter: Ms. K.G.A.S. Waidyasekara*	
12:50-13:05	Discussion	
13:05-13:15	Summing up / Rapporteurs Report	
13:15 -14:15 Hrs.	**Lunch**	
Session 2	**(14:15–17:00 Hrs)**	
Session Chair:	**Dr. Herath Manthrithilake** Head Sri Lanka Development Initiative-IWMI	**Rapporteur: Dr. Deepthi Wickramasinghe** Senior Lecturer University of Colombo

14:15-14:30	Geographical distribution of chronic kidney disease of unknown origin in Sri Lanka in the region of irrigation reservoirs *Presenter: Mr. J.M.K.B. Jayasekara*
14:30-14:45	Studying the effect of super water absorbent polymer and watering capacity on growthof tomato under Plant House *Presenter: Ms. Nilanthi Fernando*
14:45-15:00	Impact of climate change: Socio economic impacts of drought on farmers in Hambantota District *Presenter: Ms. Vindya Hewawasam*
15:00-15:15	Impact of agricultural activities on groundwater quality and its suitability for drinking in Valikamam area, Jaffna Peninsula *Presenter: Ms. Sutharsiny Arasalingam*
15:15-15:30	Discussion
15:30-15:45 Hrs.	**Tea/Coffee**
15:45-16:00	The significance of addressing water related Issues through a right based approach in Sri Lankan context: right to water *Presenter: Ms. Dilini Pathirana*
16:00-16:15	Degradation of the Maha Oya vital ecosystems and its impacts on the communities *Presenter: Ms. Chamila Weerathunghe*
16:15-16:30	Local technologies for removal of hardness in groundwater *Presenter: Mr. S. Saravanan*
16:30-16:45	Discussion
16:45-17:00	Summing up / Rapporteur's Report

End of Sessions - Day One

23nd November 2012 (Day Two)

08:30-08:50 Hrs.	**Registration**	
Session 3	**(09:00-14:30 Hrs.)**	
Session Chair :	**Prof. Nimal Gunawardena** University of Peradeniya	**Rapporteur: Dr. M.M.M. Najeem** Senior Lecturer University of Kelaniya
09:00-09:15	*Pseudomonas aeruginosa* in bottled drinking water in Sri Lanka *Presenter: Ms. A.T. Herath*	
09:15-09:30	Sanitation and water pollution in small towns: a case study from Pilimathalawa *Presenter: Ms. Kumudu Herath*	

09:30-09:45	Environmental degradation and associated impacts by agricultural water pollution in upcountry of Sri Lanka *Presenter: Ms. Hemanthi Henegama*
09:45-10:00	Analysis of priorities in achieving environmentally safe sanitation: a note for policy Reformation in sanitation and water nexus. *Presenter: Ms. Indika Gunawadana*
10:0-10:15	Discussion
10:15-10:30 Hrs.	**Tea/Coffee**
10:30-10:45	Performance of selected water treatment plants in the Central Province *Presenter: Ms. S.R.S. Udeshi*
10:45-11:00	Impact on groundwater quality in Puttalam area due to over extraction and improper agricultural practices *Presenter: Mr. K.M.S.M. Kumarasinghe*
11:00-11:15	Heavy metal pollution and burden of aquatic animal health: a pilot study from an urban wetland in Sri Lanka *Presenter: Ms. Priyadarshani Somasekaran*
11:15-11:30	Discussion
11:30-11:45	Quantification of potential impacts of urban and peri urban agriculture and forestry,Sri Lanka, on climate change *Presenter: Ms. Nilanthi Jayathilake*
11:45-12:00	The role of environmental factors on the pathogenesis of renal failure *Presenter: Mr. E.W.S. Chameera*
12:00-12:15	An iconoclastic view of sanitation in modern Sri Lanka *Presenter: Mr. Missaka Hettiarachchi*
12:15-12:30	Optimizing Water Utilization in Horana Unilever Plant *Presenter: Mr. Anil Weerasooriya*
12:30-12:45	Discussion
12:45-13:00	Summing up/Rapporteur's Report
13:00-13:30 Hrs.	**Panel Discussion** Current challenges in the role of YWPS for transformational impact in the Sri Lankan water sector. (Panel-Prof Ajith de Alwis, Dr Meredith Giordano, Mr. Nalaka Gunawardene,Mr.Missaka Hettiarachchi)
13:30-13:40	**Hrs. Closing remarks by Chair SLWP Ms Kusum Athukorala, followed by lunch.**

Annex 3

Presentations - Summary of Discussions

Day 01
Technical Session 1

1. **Flood Mapping using Synthetic Aperture Radar in the Kelani Ganga and the Bolgoda Basins, Sri Lanka**
   Chamindi Kudahetty and Rogier van der Velde

   Comment
   Has any work been undertaken in the Kalu Ganga basin, which is prone to floods and salt water intrusion?

   Response by Ms. Kudahetty
   She is not aware of any work in this area.

   Comment
   If flood mapping is to be done for other river basins, for example, Kalu Ganga, howmuch will the maps cost?

   Response
   These maps are available free of charge from the European Satellite Space Agency for research purposes.

2. **Improvement of the Safety and Acceptability of Drinking WaterSupplied from Irrigation Tanks by Proper Selection of Unit Operations**
   H. A. D. P. Hapuarachchi

   Comment
   According to the study local powder activated carbon also has been tested and proved to be useful. Is the dosage and contact time comparable with the Australian PAC? If so, it will result in a considerable amount of savings for the country. Is local activated carbon is a viable option.

   Response
   Wood based activated carbon has a higher absorption capacity. In this study COD was used as a parameter. More than 75% of COD can be removed using local coal based and coconut activated carbon. It is necessary to check for removal of toxin but the facilities to do so are not available.

3. **Knowledge, Attitudes and Practices of Urban Poor Women on Water and Sanitation: A Case Study in Mahaiyawa Slums, Kandy**
   C. R. Semasinghe

   Comments
   Wastage and consumption of water can be minimized by giving individual connections to the houses, and charging a low rate. The Water Board in Colombo has introduced this system. Is there such a scheme in Kandy?

   Response
   The Kandy Municipal Council does not have such a programme planned at present.

4. **Sustainable use of Runoff Harvesting Tanks in Smallholder Farming system: A Case Study at Vellavelli Area of Batticaloa District**
   T. Venuthasan

   Comment
   Is it safe to use water collected in concrete tanks for drinking purposes as the water is not being purified.

   Response by Mr. T. Venuthasan
   Only 3% of the water is used for drinking, the rest is used for irrigation because its quality is not good.

Comment
Is the run off water being collected straight away and can this water be used to recharge ground water without constructing tanks.

Response
There are two types of tanks - open tanks and concrete tanks. The former can be used for recharge purposes but the quality will have to be considered because if pollutants enter the ground water system the entire system will be polluted. In the concrete tanks, water is collected through tank filtration and boiled thereafter.

Comment
How will you make an impact of your research findings?

Response
Construction has been done, but maintenance is the problem. There are a lot of empty run off tanks built by NGOs that are not being used by farmers; they breed mosquitoes and are a health hazard. It is important to renovate them to increase capacity and remove siltation. The maintenance system has to be improved rather than concentrate on construction

5. **Impact of Extensive Agriculture on Groundwater Chemistry in the Eastern Part of Sri Lanka**
   K. D. A. Samaraweera

Comment
How could the ground water parameters be linked to management practices?

Response byMr. Samaraweera
It is not possible to reduce agricultural activities in the area but it is possible to manage the amount of fertilizer that is being added. As the increase in the amount of phosphate in shallow water is a problem non phosphate fertilizer could be introduced for paddy cultivation.

Comment
Although researchers have suggested the reduction of the usage of fertilizer it may not be feasible to do so as subsidies are given by the government and farmers are encouraged to use fertilizer.

Response
Agriculturalists will have to be made aware of the pollution caused by fertilizer and to apply it at intervals so as to reduce its concentration. Awareness programmes with farmers and other relevant agencies have to be organized.

Comment
Irrigation water will get contaminated. Is it necessary or recommended to introduce, in addition to surface drainage, sub surface drainage system to the paddy fields to reduce water getting into ground water.

Response
The study is on-going and it will focus on this after the monitoring period.

6. **Importance of Water as a Construction Commodity**
   K.G.A.S Waidyasekara

Comment
Is it possible to make this information available to the Water Board?

Responses by Ms. Waidyasekara
Research data can be made available to the Water Board.

Comment
Conservation of water has to be a part of green building.

Response
Water efficiency and optimization is one of the parameters of the green assessment system and will be done for the entire project life cycle. Benchmarks and indicators specific for the construction sector will be developed. The building assessment system is being analysed to ascertain the priority to be given to water conservation. This will be done for the entire project life cycle and not only for the operational phase. As benchmarks and indicators are not available but not for the construction sector unlike for buildings bench marks and indicators specific for the construction sector will then be developed.

Comment
Is data available for the percentage of total water use that goes into construction?

Response
There is no research on this aspect and the quantity of water that is being used by the construction sector is still unknown. She said that many argue that it is a negligible amount but without knowing the actual usage it is not possible to make a statement. The NSWDB has no separate category for the construction sector, which is combined with the industrial sector. It is necessary to look at the source of water, for example potable water is used for concreting, which is almost equal to drinking water. Interviews with contractors in the urban areas showed that pipe borne water is used. However, a director of the Water Board, in an interview said that the construction industry is not encouraged to use potable water except in special cases.

Comments
The reuse and recycling of water that is used for construction will provide good dividends.
Consider water, river sand and construction nexus in future research.

Technical Session 2

7. Geographical Distribution of Chronic Kidney Diseases of Unknown Origin in Sri Lanka in the Region of Irrigation Reservoirs
J.M.K.B. Jayasekara

Comment
Fertilizer is used throughout the country. But why is the disease found only in certain areas. It is difficult to find a settlement without water bodies in the North Central Province. The highest concentration of small tanks is in Nikaweratiya, Kotavehara, Mahawa, but there is no CKD-U in those areas. The question then is why is it found only in the Padaviya tank area?

Response by Mr. J.M.K.B. Jayasekara
New patients can be found in Nikaweratiya while Nikawewa was identified as a new location in 2006. The disease is spreading and is not confined to a single location. However when considering only the geographical distribution with similar conditions there are farmers who are cultivating in Hambantota, and some parts of the Kurunegala district but CKD-U is not found in those areas. There is a correlation between reservoir density and the incidence of CKD-U. In Hambantota for instance, the reservoir density is comparatively low as compared to the North Central Province.

Comment
Did the study find a relationship between agro well density and the high incidence of CKD-U?

Response
An epidemiological study was carried out after which other factors were identified. The male to female ratio was 2.4:1, most of the patients were farmers, and over 94% of patients consume water from shallow dug wells. Only about 5% use deep ground water. That was the reason for identifying the reservoir concentration and CKD-U distribution.

Comment
One of the problems facing the Water Board is insufficient data on prevalence to extend treatment to areas that have concentrations of high fluoride and high conductivity and other chemicals as these aggravate the problem of CKD-U.

Response

A comprehensive data base of over 15,000 patients and a data set on fluoride levels in wells in the North Central Province are available. A map on fluoride distribution in North Central Province and other areas is being prepared and will be overlapped with CKD-U and the fluoride maps. All the data can be shared with the Water Board and NSF.

Response by a representative of NSF

It was also brought to the notice of the participants that the National Science Foundation has relevant data, which can be shared.

Comments

- A suggestion was made that since several studies presented related to irrigation and high chemical usage from Jaffna, using of *pathaha* or small structures to tap water, intensive agriculture in Ampara and the use of agricultural chemicals, and another study from Ampara to supply water from the irrigation tank that is having blue green algae looking into all these options and the prevalence of CKD-U in those areas so that it would be possible to come to a conclusion.

- It was also suggested that a review of the problem should be undertaken since a large number of research studies had been conducted on CKD-U.

8. Studying the Effect of Super Water Absorbent Polymer and Watering Capacity on Growth of Tomato (*Lycopersicon esculentum* Mill) under Plant House

T.N. Fernando

Comments

Is regular irrigation necessary?

Response by Ms.T.N. Fernando

No, it is not necessary as the water in the polymer is released to the soil gradually.

9. Impact of Climate Change: Socio-economic Impacts of Drought on Farmers in Hambantota District

Vindya Hewawasam

Comment

The Standard Precipitation Index (SPI) had been built based on rainfall data spanning 50 yrs and presumably it will be used for predicting drought. Rainfall patterns have been very erratic and given the unpredictable nature of the rainfall pattern, how accurately can the index predict the future situation?

Response

SPI is a drought monitoring tool and not a drought prediction tool. However, the prevailing conditions can be monitored. For example, the south west monsoon starts in May and ends in September and if the monsoon is delayed this event can be monitored using the SPI. It can be used to issue early warning and to inform farmers that drought conditions will continue according to the prevailing conditions. However, it cannot forecast future droughts. Therefore farmers can be made aware to adopt appropriate measures to minimize the adverse impact of drought.

11. The Significance of addressing Water Related Issues in a Rights Based Approach

A. Pathirana

Comment

When discussing rights and legal aspects it is always necessary to look at the law and law enforcement. People are afflicted with chronic kidney diseases, unknown and deaths are caused by this disease. There is a constitutional right to have access to safe drinking water. However, there is a paradox - with kidney diseases, death and affliction on the one hand and the right to access to water. Is it possible to use the legal process for redress in this crisis situation?

Response

The right to life is not recognized in the Constitution, only implied. Therefore it is not possible to access legal remedies for the violation of human right to water until water is recognized as aright.

Comment
The importance of distinguishing between the right to water and water rights was pointed out. The latter becomes private property and that becomes a political issue.

Response
The right to water is for domestic and personal use including drinking water and that would take priority over other uses.

12. Degradation of the Maha Oya Vital Ecosystems and its Impacts on the Communities
Chamila Weerathunghe

Comment
What isthe status of the case filed by the Environmental Foundation Ltd. regarding Maha Oya in the Supreme Court?

Response
The court case is ongoing but the Mines Bureau and the Geological Survey have banned mining entirely for three months to enable the river to restore and regenerate itself.

13. Local Technologies for Removal of Hardness in Groundwater
S. Saravanan, S. Nishani and M. Thushyanthy

Comment
What effect does the treatment process have on the filter and how often has it to be cleaned?

Response by S. Saravanan
Calcium and bicarbonate sediments will form and these have to be removed from the filter. Cleaning can be done easily about once a week.

Day 02
Technical Session 3

14. Pseudomonas *aeruginosa* in Bottled Dinking Water in Sri Lanka
A.T. Herath

Comment
As 50% of the sampled bottled water was found to be contaminated and more than 1000 illegal brands are reported to be in the market what guidelines could consumers use when selecting a brand of bottled water?

Response by Mr. A.T.Herath
Consumers should check the seals, the expiry date and date of manufacture. The shelf life of bottled water is only one year.

15. Sanitation and Water Pollution in Small Towns: **A Case Study of Pilimatalawa**
Kumudu Herath

Comment
Is it feasible to havean on site sewage treatment method?

Response by Ms. Kumudu Herath
It is not possible to set up on site sewage treatment due to lack of land, land ownership or free space in these congested areas. Therefore, it is necessary to set up a centralized treatment system although the former is better.

Comment
There is an urgent need to develop a different type of sanitation system for small towns or 'strip towns' perched precariously, usually in between a stream and a road or a cliff and a road.

16. **Environmental Degradation and Associated Impacts by Agricultural WaterPollution in Upcountry of Sri Lanka** - Hemanthi Henegama

Comment
Why is there adiscrepancy between better knowledge of the estate community and their poor attitudes to sanitation?

Response by Ms. Hemanthi Henegama
The estate community is aware of hygienic practices as the PSTD had done several programmes but the knowledge gained is not put into practice due to habit and attitudes. She said that the estate management has to even assign a person to clean their toilets. The attitudes of the village were much better as compared with the town and estates.
Therefore attitudinal and behavioral change is essential to improve sanitation especially in coastal areas and in the estate sector.

17. **Analysis of Priorities in achieving Environmentally Safe Sanitation: A Note for Policy Reformation in Sanitation and Water Nexus**
Indika Gunawadana

Comment
The setting up of an apex body has been a recommendation. However, it is better to look at the structures and the different layers that exist – with 1.3 million public officials, and identify the loopholes and weaknesses in the existing system and reform and strengthen the different levels of the institutional framework rather than set up an apex body.

18. **Performance of Selected Water Treatment Plants in the Central Province**
S.R.S. Udeshi Rathnayaka

Comment
As two of the seven parameters considered had problems and considering the nature of the waste that is coming in to the streams and the treatment challenge are these types of treatment plants are adequate for cities and are additional treatment steps necessary.

Response
The plants need to be upgraded. As industrial pollution is high, new testing methods have to be introduced. A suggestion was made for using activated carbon that can absorb the odour and taste while other sophisticated methods used to measure heavy metals.

Response by arepresentative of the Water Board
It is possible to check all the parameters as new technology is available but if such technology is introduced the cost of the water to the consumer will increase. At present water is provided according to Sri Lanka standards. However, the Water Board will have to adopt new levels of treatment as the Sri Lanka Standards Institute is revising the standards.

19. **Impact on Ground Water Quality in Puttalam Area due to over Extraction and Improper Agricultural Practices presented**
K.M.S.M. Kumarasinghe

Comment
It was suggested that a literature survey be conducted before starting a research project. A previous study by Kuruppuarachchi of the same area showed much lower levels of nitrate, nitrogen and phosphorus but the present study shows much higher levels of contamination in the entire area and nitrate nitrogen values are much higher than WHO recommendations.

20. **Heavy Metal Pollution and Burden of Aquatic Animal Health: A Pilot Study from an Urban Wetland in Sri Lanka**
Priyadarshani Somasekeram

Comment
Why was the present location selected?

Response
Bellanwila – Attidiya area was selected as it was polluted due to industries in the area and waste that is dumped in the wetlands.

Comment
Although the data presented on Colombo waterways and wetlands look scary according to other studies the situation is not that serious. If the present study illustrates that heavy metal levels are affecting frogs and other aquatic life then it is a major magnification issue.
That might be a significant finding and it would be necessary to look at ambient water quality standards that are available now. Is it possible that it is magnification in frogs and whether this aspect had been studied? There are several measures to identify accumulation, heavy metals are absorbed through their skin.

Further, the study focused on the amphibians, namely the frogs but it is possible that the same sort of pollution is taking place with the fresh water fish. If so, the deposit of heavy metal in fish would be a serious issue.

Response
Fish were also studied but although a clear impairment of fish species was observed heavy metal analysis was not done. However, there are studies on the accumulation of heavy metals on fish as well as other aquatic organisms.

21. Quantification of Potential Impacts of Urban and Peri Urban Agriculture and Forestry, Sri Lanka on Climate Change
N. Jayathilake

Comment
Presently a large number of capacity development programmes are being conducted and in this context what kind of institutions are proposed and what are the approaches proposed for capacity development?

Response by Ms. N. Jayathilake
Capacity development is proposed for local authorities.

22. The Role of Environmental Factors on the Pathogenesis of Renal Failure
E.W.S. Chameera,

Comment
Fertilizer is used throughout the country but the disease is found only in certain areas.
It is difficult to find a settlement without water bodies in the North Central Province,. Although Madawachchiya was mentioned as having the largest concentration of small tanks Nikaweratiya, Kotavehara and Mahawa have the highest concentration of small tanks, but there is no CKD-U in these areas.

Response by Mr. Chameera
The common factor between low and high prevalent areas of CDK-U is the reservoirs.

Comment
Most of the studies concentrate on the downstream, but downstream water comes from the upstream. Therefore it would be useful to ascertain the characteristics of the upstream.

23. An Iconoclastic View of Modern Sanitation in Sri Lanka - Missaka Hetitarachchi

Comment
What are the preferences for the pour flush?

Response
- There is an attitudinal problem as people are reluctant to use rainwater for flushing of toilets.
- There is also a capacity problem as treated water is used for flushing toilets.

- Incorporate a wide spectrum ofsanitation technologies to existing guidelines and standards, which at the moment focus on a single technology.
- Provide in house training on alternative technologies to bureaucrats.
- As community consultation is an essential part of projects, including a session on alternative sanitation in community sanitation projects carried out by the government or NGOs
- Distribute a simple leaflet along with every building permit application issued detailing alternatives to be considered in the construction of toilets.

Comment
When people upgrade their status in life they want to upgrade their toilets. UDDT has worked in the Eastern Province in a project implemented by Oxfam. This is because there was no other option as there is no water for flushing. Another reason for their acceptance is because of the fertilizer that can be got from those toilets.

School sanitation projects failed because toilets are given when there is no water for them. Twenty three percent of schools in Nuwera Eliya have no toilets because of the lack of water. In such situations where there is no water the UDDT will work. Since Sri Lanka is engaged in major resettlement in the North and East it is an opportune time to engage in a major drive to introduce the UDDT toilet.

Response
UDDT and other technologies have been tried in Sri Lanka, as for example bio gas toilets. These toilets have been in use for about 20 years in Kegalle. Therefore there are good solutions that have been implemented and are working well in the country. The main reason why people aspire to have a pour flush latrine is because of its ionization. This trend has to be broken. The bureaucrats have to realize that there are different solutions depending on the environment.

Annex 04

Young Water Professionals Symposium

22nd and 23rd November 2012

List of Participants

Technical Sessions (Presenters)

1. Ms. A.T. Herath – University of Moratuwa
2. Mr. Anil Weerasooriya – Unilever Sri Lanka
3. Ms. C. Kudahetty – Water Resources Board
4. Ms. C.R. Semasinghe – International Water Management Institute
5. Ms. Chamila Weerathuge – Dilmah Conservation Group
6. Ms. Dilini Hapuarachchi – Mahaweli Authority of Sri Lanka
7. Ms. Dilini Pathirana – University of Colombo
8. E.W.S. Chameera – University of Peradeniya
9. Ms. Hemanthi Henegama – University of Peradeniya
10. Ms. Indika Gunawardena – University of Peradeniya
11. Mr. J.M.K.B. Jayasekare - University of Peradeniya
12. Mr. K.D.A. Samaraweera – Water Resources Board
13. Ms. K.G.A.S. Waidyasekare – University of Moratuwa
14. Mr. K.M.S.M. Kumarasinghe – Water Resources Board
15. Ms. Kumudu Vinodya Herath – University of Peradeniya
16. Mr. Missaka Hettiarachchi – University of Queensland, Australia
17. Ms. Nilanthi Fernando – The Open University
18. Ms. Nilanthi Jayathilake – International Water Management Institute
19. Ms. Priyadarshani Somasekaran – University of Colombo
20. Mr. S.Saravanan – National Water Supply and Drainage Board, Jaffna
21. Ms. S.R.S. Udeshi – University of Moratuwa
22. Ms. Sytharsiny Arasalingam – International Water Management Institute
23. Mr. T. Venuthasan – Care International, Baticaloa
24. Ms. Vindya Hewawasam – Ministry of Environment

Technical Sessions (Other)

01. Prof. Ajith De Alwis – University of Moratuwa
02. Ms. D.C.S. Elakanda – Mahaweli Authority of Sri Lanka
03. Mr.D.R.R. Karunaratne – Water Resources Board
04. Dr. Deepthi Wickramasinghe – University of Colombo
05. Mr. Gamini Jayasinghe – Central Environmental Authority
06. Ms. Kusum Athukorala – Sri Lanka Water Partnership
07. Mr. Lalith Dassanaike – International Water Management Institute
08. Mr. M.I.M. Aheeyar – Hector Kobbekaduwa Agrarian Research and Training Institute

09. Mr. Leelangani Wanasundara – Rapporture
10. Dr. M. Samad - International Water Management Institute
11. Ms. Mala Ranawaka - International Water Management Institute
12. Mrs. Medhani Jayakodi – Irrigation Department
13. Dr. Meradith Giordano - International Water Management Institute
14. Dr. M.M.M. Najim – University of Kelaniya
15. Mr. Nalaka Gunawardena – TVE Asia Pacific
16. Ms. Nileshika Wijenaike – Unilever Sri Lanka
17. Prof. Nimal Gunawardena – University of Peradeniya
18. Mr. Ranjith Ratnayake – Sri Lanka Water Partnership
19. Mr. S.B. Niyangoda - Sri Lanka Water Partnership
20. Mr. Thakshila Dilhan Premaratne - Sri Lanka Water Partnership
21. Prof. SHanthi De Silva – The Open University
22. Ms. Thushari Perera – Irrigation Department
23. Ms. Udayangani Basnayake – Mahaweli Authority of Sri Lanka
24. Mr. Udith Perera – Unilever Sri Lanka
25. Ms. Sharon De Silva – NDB Bank
26. Prof. Champa Navaratne – University of Ruhuna
27. Ms. Badra Kamaladasa – Irrigation Department
28. Dr. D.N.K. Dayawansa – University of Peradeniya
29. Mr. D.S.D. Jayasiriwardena – National Water Supply and Drainage Board
30. Dr. Herath Manthrithilake – International Water Management Institute
31. Dr. Kaushalya Wijeweera - Mahaweli Authority of Sri Lanka
32. Mr. Lal Muthuwatta - International Water Management Institute
33. Prof. Niranjani Ratnayake – University of Moratuwa
34. Ms. Renuka Jeya Raj - International Water Management Institute
35. Mr. W.B.G. Fernando - National Water Supply and Drainage Board
36. Dr. Badrani Thoradeniya – University of Moratuwa
37. Mr. Paramith Ruwan Pathirana – Sri Lanka Water Partnership
38. Ms. Asangi Karunaratne - National Water Supply and Drainage Board
39. Ms. Champa K Dissanayake – Atomic Energy Authority