Air pollution caused devastating impacts on children's health in urban area of Sri Lanka

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Abstract : Indoor and outdoor air pollution have become a public health challenge in Sri Lanka, majorly with the introduction of open economic policy in 1978. The emissions from motor vehicles (55%), industries (25%) and domestic sources (20%) collectively contributed to air pollution (Ministry of Environment, 2012). Sri Lanka produced over 90% of power demand from hydroelectricity two decades before and it was gradually reduced to 40-50% approx. as of now, due to the usage of thermal and coal power plants to produce electricity. Over 50% of the vehicles, 70% of industries and many thermal power plants are located in the urban area of Sri Lanka (Ileperuma, 2019). Open dumping and burning of solid waste in the urban areas by both households and local authorities-at the waste dumpsites, and continue decomposition process of waste emit dust particles, methane, toxic and other greenhouse gases to the atmosphere (Ruzaik, 2015). The culmination of all the above factors subsidized for air pollution and it subsequently impacted for health of the general public, including children of the nation. The children are highly exposed to polluted air in the home and school environment. However, the policymakers does not provide more priority; although it is a dangerous and silent hazard, which is positively correlated with communicable and non-communicable diseases. Hence, this analytical study is carried out with the objective of identifying causes and potential health impacts and to provide possible remedial measures to mitigate and manage this issue at a minimum risk rate. Predominantly, the data and information from published and unpublished secondary sources were used. MS-Office was used to analyze the data, following both quantitative and qualitative approaches. Analysis reveals that World Health Organization(WHO) estimated the number of deaths attributed by air pollution in Sri Lanka is approx.. 5,200 (Nandasena, et al. 2012) and 60% of the children visit to the Lady Ridgeway-Children hospital for medical treatments on respiratory diseases (Ruzaik, 2015). Dharshana and Coowanitong,(2008) showed that PM_{10} has the strongest association to bronchitis, emphysema and other chronic obstructive pulmonary diseases among children with a correlation coefficient of 0.717 at 99% confidence. Approximately 20% of asthma patients at the Lady Ridgeway children's hospital could be due to exposure to high PM_{10} levels. This study majorly recommends to promote habits of wearing facemasks in outdoor, especially for children and suggested the Government of Sri Lanka to prepare a national level policy strategy to provide "Clean Air to all in 2030".

Keywords: Air pollution, atmosphere, emission, hazard and health impacts.

1. Introduction

Air Pollution is an acute and growing environmental problem in Sri Lanka, due to the continuous process of changing the economic structure from agriculture to industrial-based status by introducing frequent manufacturing and industrialization policies by changing Governments since 1978 with the introduction of open economic policy in Sri Lanka. The increasing trend of importation of various types of vehicles, absence of well-planned road network, ample traffic congestions during peak hours and incineration of solid waste-especially in the urban areas, fuelwood combustion for cooking, use of mosquito coils, industrial emission *etc*. have collectively caused for polluting air in the atmosphere. This has resulted for high significance of human health hazards, as the various toxic gases and fine particles emitted to the air, beyond its natural capacity of the environment. The

gaseous air pollutants, such as sulphur dioxide, nitrogen dioxide and carbon monoxide are directly dilute with the air; as a result of combustion of fossil fuel of automobiles, and power plants, industries and biomass burning. In 1992, the whole of Sri Lanka was considered as one free trade zone to promote manufacturing, industry-based exports and allow foreign investors. This has become a major cause for emissions of toxic gases together with vehicular emissions and crates toxicological, respiratory and cardiovascular diseases to the human while generating more impacts on children.

2. Objectives

The objectives of this study are as follows,

- To assess the causes and potential health effects of air pollutions in Sri Lanka.
- To analyze the existing status of health impacts together with children in urban Sri Lanka.
- To provide possible remedial measures to mitigate and manage health impacts.

3. Methodology

This analysis was carried out, following the qualitative approach and predominantly extracted data from secondary sources, using PubMed and MEDLINE resources guide (https://pubmed.ncbi.nlm.). A few literatures have been identified on air pollution and health impacts in Sri Lanka. Manual search to identify relevant studies and conference proceedings published in the journals have provided a few articles and research papers on this title. All citations and due references are given in the TEXT and reference list below MS-Office was used to analyze the data.

4. Overview of air pollution and health impacts

Air pollutants can be defined as a substance present, in a sufficient concentration to produce a harmful effect on human, animals and other living organisms of nature; resulted from the seepage of chemicals, particulate matters (referred to as PM), criteria pollutants (ground-level ozone (O^3), carbon monoxide (CO_2), sulfur oxides (SOx), nitrogen oxides (NOx), and lead (Pb)), or biological materials into the atmosphere, which could affect the health of humans, as well as the health of plants and animals (United States Environmental Protection Agency, year 2018). According to the World Health Organization (WHO, 2018), the highest portion of harmful pollutants are emitted by industries and vehicles. Greenpeace Southeast Asia and the Centre for Research on Energy and Clean Air, (2018) stated that the burning gas, coal and oil results in three times as many deaths as road traffic accidents worldwide and it is estimated that air pollution has a $2.9 trillion economic cost, equating to 3.3 percent of the world's GDP. It was linked to 4.5 million deaths with $PM_{2.5}$ pollution also responsible for 1.8 billion days of work absence, 4 million new cases of childhood asthma and 2 million preterm births. Further, the disability from chronic diseases cost the world's economy $200 billion in 2018, with sick leave and preterm births costing $100 billion and $90 billion respectively.

Above statistics clearly shows that air pollution and corresponding damages to the human health will have large impacts on the respective country’s economy in multiple ways, such as health and welfare cost to the government, inability to work and lower participation rates in the labour force. Children are the high significant group for health impacts (mostly respiratory diseases) and possibilities for not attending schools and subsequently adversely affect to their learning too. Their parents also devote more time on their health care activities and they are compelled to apply leave for their workplace. It will badly effect to country’s economy and to create a good future generation.

Air pollution accounts for 1 in 8 deaths worldwide, approximately 7 million (WHO,2012) deaths have been attributed annually by polluted air. Out of which, 4 million deaths were occurred, due to indoor air pollution and 3 million from outdoor air pollution (WHO, 2014). Air pollution impacts on human health by way of short and long-term basis, depending on the individuals' health conditions react to the pollutants. Children (300,000 deaths below 5 years) and elderly people are most vulnerable to air pollution, due to their weaker status of immunity strength and defensive ability of the body. Accordingly, the 24% (1.4 million) of deaths due to strokes, 25% (2.4 million) of deaths caused by heart diseases, and 43% (1.8 million) of deaths instigated by lung disease and lung cancer have occurred every year as a result of air pollution. This polluted air contains high levels of dangerous particulate matter, which are small enough to enter into the human bloodstream, through the lungs and contributes to premature deaths. The continuous process of such negative situation will ultimately lead to negative impacts on the global economy, especially for low-income countries (UN,2020).

In Sri Lanka, indoor air pollution is high especially in the rural area, as they use of firewood for cooking and use mosquito coils and outdoor air pollution is considerably more in the urban area of Sri Lanka, as result of emission from motor vehicles, traffic congestions, incineration of solid and plastic and industrial emission *etc*. The 80% households in the rural area use firewood for cooking with lack of adequate ventilation in the kitchen, which produces highly toxic air pollutants, affecting the health of people. This situation has become a cause for respiratory diseases; such as asthma, bronchitis, pneumonia and chronic obstructive pulmonary disease (COPD) and non-respiratory diseases. Further, the fossil fuel combustion yields fine particles, especially those with less than 10 µm in diameter, which can penetrate deep inside the lung and causing many undesirable health effects (Ileperuma, 2004; Ileperuma and Mubarek, 2019).

According to Ileperuma, (2018), Dr. Anoma Siribaddana, Consultant Chest Physician at the Kandy General hospital, the number of children with Chronic Obstructive Pulmonary Disease (COPD) is on the rise. This condition normally affects middle-aged and older adults and habitual smokers. There is no cure apart from controlling the symptoms of this serious health condition. Hospital statistics also show an increase in the number of asthma patients, who spend time in the city. In addition, the air pollution has economic impacts, due to increased mortality and illness, the degradation of crops and property and to tourism, since tourists avoiding or shortening visits to cities that are heavily polluted (Ileperuma, 2015).

5. Causes of air pollution in Sri Lanka

Air pollution, both indoors and outdoors, is a major environmental health problem affecting people in both developed and developing countries. Although air pollutants are many, the most important are particle pollution (often referred to as particulate matter (PM)), ground-level ozone (O^3), carbon monoxide (CO), sulfur oxides (SOx), nitrogen oxides (NOx), and lead (Pb) which are found in the ambient air (also known as "criteria pollutants"); PM, CO, SOx, NOx, environmental tobacco smoke (ETS), formaldehyde and polycyclic organic matter are found indoors (WHO, 2018).

The causes of air pollution can be categorized into three basic groups: transport, industry (including power generation) and domestic source. The below figure-1 depicts the emissions from power generation (15%), motor vehicles (34%), industries (5%), waste incineration (11%) and burning/domestic source (35%) collectively contributed for air pollution (Ministry of Environment, 2019). Sri Lanka produced over 90% of power demand from hydroelectricity two decades before and it was gradually reduced into 40-50% approx. as of now, due to the usage of thermal and coal power plants to produce electricity. Over 50% of the vehicles, 70% of industries and many thermal power plants are located in the urban area of Sri Lanka (Ileperuma, 2019). The vehicular emissions could be observed in the urban areas, due to the ever-increasing number of vehicles, insufficient road network and traffic congestions.

In 2017 Sri Lanka's motor vehicle population grew by 7% to 7.2 million. The consumer goods imports volume index was increased by 9.6% in 2018 and decreased by 20.7%in 2019 mainly due to the significant decline in vehicle imports (Ceylon Chamber of Commerce, 2018). The vehicle imports and registration will further decrease in the year 2020 too, due to the import restrictions imposed by the Central bank of Sri Lanka, during the second quarter of this year. Although it is a good sign in terms of air pollution, we have excess vehicles in the urban areas, which resulted in more pollution, traffic jams in the peak hours and loss of productivity due to more time consumptions for traveling. The average speeds under urban driving is varied from 40-50 km/hr, but unable to travel with uniform speed as the over traffic, which will emit soot, carbon monoxide and unburnt hydrocarbons to the atmosphere.

Another major factor for air pollution is use of fossil fuels for coal and oil petroleum, gas products in thermal power generation plants. According to the National Energy policy and strategies of Sri Lanka, increased demand will necessitate power generation using more and more fossil fuel. The fossil fuel combustion in Sri Lanka is more than 50%, CO_2 emission from manufacturing industries account for 6% (www.indexmundi.com, date 27.11.2020). In the domestic source, the fuelwood use for cooking, especially in rural areas (90% of households) is also contributed for air pollution in a large scale.

Similarly, the air pollution occurs largely through inefficient haphazard open dumping and burning of waste (11%), which produces CO_2, hydrogen, nitrogen, organic compounds, dust and another form of toxic gases being generated during the waste degradation process, which also contributed for emission of greenhouse gases at 45% approx. (Ruzaik, 2015).

The below diagram shows the major contributors to air pollution in Sri Lanka.

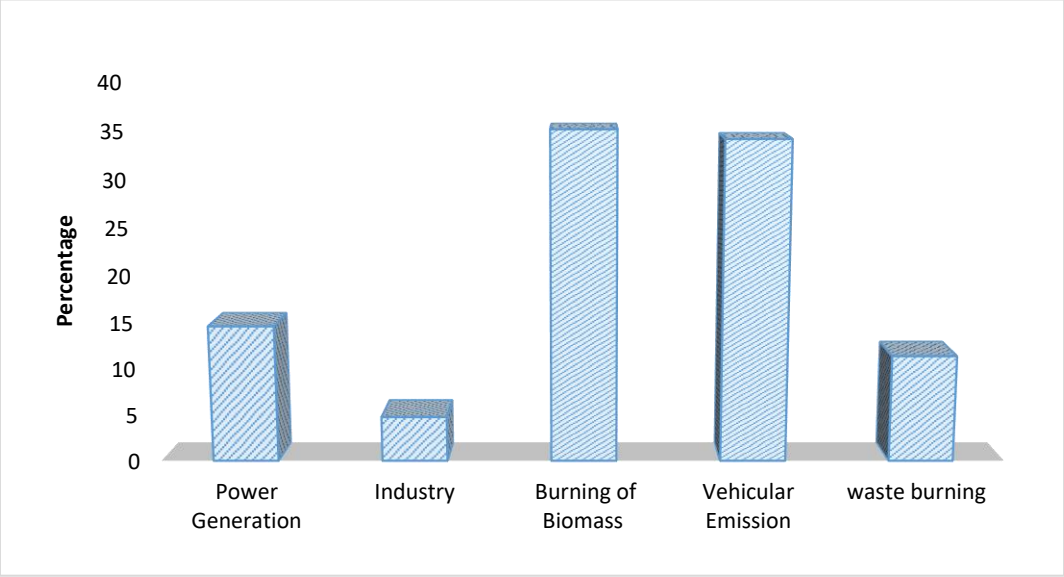

Figure-1: Causes of air pollution in sri lanka

Source: Prepared, based on the statistics of NBRO report, (2018/2019)

Above statistical information reveal that seriousness of air pollution in Sri Lanka. The pollutants and fine particles discharge from exhaust gases from motor vehicles, burning of biomass and burning of solid was are filtered through the nose and the upper respiratory tract, even it is lesser than PM_{10} (10 microns fraction) in diameter will have hazardous impact on human health. The children are more vulnerable, since their undeveloped body conditions.

6. Analysis and discussion

This paper attempt to discuss the health impacts of air pollution, providing a special reference to children's health issues, since the children, who are living within the urban area are more vulnerable and at high risk. According to the Global Climate Risk Index-2020, Sri Lanka has been ranked 6th most affected country by environment-related hazards; such as floods, heatwaves, storms, landslides that occurred in the recent past. The Central Environmental Authority (CEA) has issued 17 Environmental Impact Assessment (EIA) and 266 Initial Environmental Evaluation (IEE) certificates in 2019. In order to regulate environmental pollution, the CEA granted Environmental Protection Licenses (EPL) to the companies of potentially polluting industries. In November 2019, we observed that the air pollution level in Colombo City increased remarkably, which was more likely due to transboundary air pollution emanating from India (CBSL, 2019). However, the urban population are at risk, in terms of inhaling bad air.

6.1. Air pollutants and its consequences

The following table-1 depicts the sources of air pollutants, its nature, sources and impacts in summarized form.

Table-1: Air pollutants and its consequences

Pollutant	Description	Sources	Effects
Carbon Monoxide (CO)	CO is an odorless, colourless, and poisonous gas produced by the incomplete burning of fossil fuels (gasoline, oil and natural gas).	Vehicles, such as cars, trucks, buses and small engines and some industrial processes are major sources of CO. In urban areas; motor vehicles discharge nearly 90% of CO. Wood stoves, cigarette smoke and forest fires are also contributed for CO emissions.	CO interferes with the blood's ability to carry oxygen, slowing reflexes and causing drowsiness. In high concentrations, CO can cause death. Headaches and stress on the heart can result from exposure to CO.
Nitrogen Oxides (NOx)	Nitrogen and oxygen combine during combustion (burning) forms NOx. Many NOx are colorless and odorless gases.	NOx come from burning fuels in motor vehicles, power plants, industrial boilers and other industrial, commercial and residential sources that burn fuels.	NOx can make the body vulnerable to respiratory infections, lung disease, and possibly cancer. NOx contributes to the brownish haze seen over congested areas and to acid rain. NOx easily dissolves in water and forms acids which can cause metal corrosion and fading/deterioration of fabrics.
Sulfur Dioxide (SO_2)	SO_2 is a gas produced by chemical interactions between sulfur and	SO_2 comes largely from burning fossil fuels (gasoline, oil and natural	SO_2 easily dissolves in water and forms an acid which contributes to acid rain.

	oxygen.	gas). It is released from petroleum refineries, paper mills, chemical and coal burning power plants.	Lakes, forests, metals, and stone can be damaged by acid rain.
Volatile Organic Compounds (VOCs)	VOCs are organic (contain carbon) compounds that vaporize easily. Gasoline, benzene, toluene and xylene are examples of VOCs.	VOCs are emitted as gases (fumes). Sources of VOCs are burning of fuels, solvents, cleaning supplies, paints and glues. Cars are a major source of VOCs	VOCs contribute to smog formation and can cause serious health problems such as cancer. They may also harm plants.
Suspended particulate matter (SPM)/(Air-borne particulate matter)	SPM and aerosols (liquid particles) suspended in the air, as dust, smoke and haze.	Air-borne particulate matters are produced due to the natural processes and as a result of human activities. Combustion of fossil fuels (e.g. from power stations and motor vehicles), industrial operations, incinerators and earth-moving activities contribute to generate air-borne particulate matter.	Exposure to such particles can affect both your lungs and your heart. Numerous scientific studies have linked particle pollution exposure to a variety of problems, including: premature death in people with heart or lung disease. Non-fatal heart attacks.
Lead (Pb) and other heavy metals	Metals smelters are the main source of airborne heavy metals and battery manufacturing plants, and leaded gasoline are the leading sources of air-borne lead	Motor vehicle emissions are a included with air -borne contaminants including arsenic, cadmium, cobalt, nickel, lead, antimony, vanadium, zinc, platinum, palladium and rhodium.	Lead affects the central nervous system of human and children neurological. Also it effects the intellectual development of children, causing learning disabilities. Pb create high blood pressure (in higher concentrations), kidney diseases or anemia.

Source: Prepared, based on the WHO database, 2018/2019.

Above table was compiled with the information extracted from WHO database (2018/2019) to elaborate the combination of pollutants, assorted in the polluted air and its health impacts. According to the automated air quality monitoring stations (Colombo and Kandy) statistical information (2019), the pollutants available in the air are below the average standards, except the fine particles (PM_{10} and $PM_{2.5}$), which are always above the national standard in Sri Lanka. Air quality in Kandy is comparatively polluted than the Colombo, due to its geographical location, over capacity of vehicles and traffic congestion. Topographical features of the Kandy City surrounded by hilly areas is lacking its natural air purification process, resulted from more Sulphur dioxide (41%), nitrogen dioxide (14%) and ozone levels (28%) in the air during the period 2001-2005 (Ileperuma, 2020).

6.2. Health effects of air pollution in Sri Lanka

Air pollution is a major cause of diseases and subsequent death, which accounts estimation of 7 million premature deaths/annum (WHO,2019). Approximately, 91% (i.e. 9 out of 10) of the world's population lives in places, where air quality levels exceed WHO standards (<10 µg/m^3) of pollutants. Pollutants such as particulate matter (PM_{10} and $PM_{2.5}$), SO_2, CO_2, NO_2 and O_3 cause of lung cancer (WHO, 2005).

This study identified that there are no comprehensive research on "air pollution and health impacts" have been carried out in Sri Lanka, except a few research in brief (eg. Nandasena et al. (2013), Chandrasiri, (2006) and Ileperuma (2020); selecting prominent urban areas for the case study. Hence, it is required to extend a comprehensive study for the island very soon on air pollution and related issues. According to WHO guidelines, the air quality in Sri Lanka is considered moderately unsafe-the most recent data indicates the country's annual mean concentration of $PM_{2.5}$ is 11 µg/m^3, exceeding the recommended maximum of 10 µg/m^3 (www.who.int/.accessed on 27.11.2020).

While analyzing collected literature, it was revealed that the concentration level of particulate matter (PM) in the air is used for measuring quality of the air, such particles that could impact the human health. The size of the particulate matters are measured at two concentration level with its diameter- less than 2.5 µm or $PM_{2.5}$ and less than 10 µm or PM_{10}. The WHO's air quality guidelines recommend that the annual mean concentrations of $PM_{2.5}$ should not exceed <10 µg/m^3 and <20 µg/m^3 for PM_{10}. Continuous process of inhaling fine particles lesser than $PM_{2.5}$ too will create repertory issues in the human body, because it will travel deeper into the cardiopulmonary system and caused for long-term health issues.

According to this analysis, the outdoor air pollution is a mix of particulate matters, chemicals and other materials will form tiny hazardous particles and mix in the air; which will contribute for breathing problems, chronic diseases, increased hospitalization, and premature mortality. The expose to the polluted air will have short term and long term symptoms and diseases. The eyes irritation, running nose, throat pain, wheezing, coughing, shortness of breath, chest pain, headaches, nausea, and upper respiratory infections are short-term symptoms, which could be ended-up with asthma, tubercular and emphysema *etc*. In long term, it will lead to lung cancer, cardiovascular disease, chronic respiratory illness, developing allergies, heart attacks and strokes *etc*.

Analysis of ambient air quality data monitored at Colombo Fort monitoring unit clearly revealed that PM_{10} is the dominant air pollutant in the Colombo atmosphere. Further investigation showed that PM_{10} has strong associations with three types of respiratory illnesses, especially among children. Among these associations, the disease category which includes bronchitis, emphysema and other chronic obstructive pulmonary diseases showed a prominent association with a correlation coefficient of 0.717 at 99% confidence. In addition, an application of health impact assessment software developed by WHO revealed that nearly 20% of Asthma patients recorded at LRH (the Lady Ridgeway Hospital for Children) in 2005 could be attributed to exposure to PM_{10} in Colombo. It was observed that nearly 60% of the respiratory cases occurred at reasonably lower concentrations (below 80 µ gm^{-3}) thus, future management plans aiming toward positive health impacts should focus on shifting the entire PM_{10} pollution distribution towards lower ends (Thishan D. & Nowarat Coowanitwong, 2007).

$PM_{2.5}$ was measured in the primary living area in a sub-sample of households (n = 198). Indoor $PM_{2.5}$ measurements from 132 urban homes showed a mean of 84.4 µg/m^3 and a range of 25.2 µg/m^3 to 620.6 µg/m^3. The 66 rural homes had a mean of 94.4 µg/m^3 and a range of 5.9 µg/m^3 to 755.0 µg/ m^3. The highest indoor $PM_{2.5}$ measurements were reported from homes that burned biomass for cooking in the urban setting (mean of 243.2 µg/m^3 and a range of 40.7 µg/m^3 to 620.6 µg/m^3) (Nandasena et al. (2012). According to the Senanayake et al., (2011), Venous and umbilical cord blood samples of 24 mother-baby combinations from Colombo have been analyzed and only one mother-baby combination had no lead in their blood. Measurements of blood

lead levels in children living in a traffic congested area of Colombo showed that 6% of the children had blood lead levels above 10 µg/dL and not a single child had a blood lead level >10 µg/dl. Further, the children in the urban area had a significantly higher prevalence of wheezing when compared to those in the semi-urban area.

According to Perera et al. (2007), the drivers, three-wheeler drivers, street vendors and shopkeepers in the urban area are at high risk by exposing with polluted air-bus drivers were affected by NO_2 (57.36 µg/m^3) and SO_2 (82.70 µg/m^3), three-wheeler drivers (NO_2 - 50.18 µg/ m^3; SO_2 - 78.36 µg/m^3), shop keepers (NO_2 - 54.91 µg/m^3; SO_2 - 63.29 µg/m^3) and outdoor vendors (NO2- 37.66 µg/ m^3; SO2 - 35.25 µg/m^3). Accordingly, they are high prevalence of respiratory diseases.

Siritunga et al. (2006) stated that effects of outdoor air pollution on the respiratory health of school children selected from a rural and an urban area in the Kandy district and correlated the results with the ambient air pollution levels. A total of 510 children from each area was the sample and their respiratory illnesses were recorded using the diary method. Average pollutant concentrations of SO_2, NO_2 and O_3 were three to five times higher in the city school premises compared to the rural area and these can be readily correlated to the respiratory symptoms. Thus, in the city school, occurrence of cough was 1.8 times higher, nasal discharges were 1.4 times higher and throat irritation was 1.8 times higher.

This analysis shows that air pollution and subsequent health impacts in the urban area are high, due to the emissions from motor vehicles, industries and domestic sources. High prevalence of reparatory diseases are common among the people, those who have highly exposed to the polluted air. The urban children are victimized as the polluted air in the atmosphere. The children are happened to expose to the polluted air in the home and school environment, especially in the urban areas; while long waiting for school buses, travelling with opened windows, lack of space in the residential environment *etc*. The positive correlation with air pollution and human health impacts will lead to unhealthy population and future generations. The government has spent approximately LKR 21.6 billion in 2018 and LKR 28.4 million in 2019 for healthcare sector (CBSL Report, 2019. Pg 124). This is approximately 1.6% of GDP.

6.3. Impacts of air pollution on children's health in Sri Lanka

Air pollution is a major environmental health hazard to children as stated above. The health of children living in urban areas more vulnerable, due to the air pollution. Globally, 93% of children (630 million children below 5 years) are exposed to air pollution. Approximately average 550,000 children, lesser than 5 years, infected with respiratory tract infections, which led to deaths. The major reason behind this is children's immune systems and lungs are not fully developed to resist such impacts. Further, just like the arms and legs, the largest portion of a child's lungs will grow long after he or she is born, eg. 80% of their tiny air sacs develop after birth. Those sacs, called the alveoli, are where the life-sustaining transfer of oxygen to the blood takes place. The lungs and their alveoli are not fully grown until children become adults (Friedrich, 2018).

Above statements reveals that defensive mechanism in the children's body to react against the sickness (antibody) are very lesser that the adults. We observe in our vicinity that the Children have more respiratory infections than adults. The reasons behind this are, they like to play outside the home environment and expose to polluted air continuously; although their immunity system weaker than the adults. This behavior resulted various health impacts, such as asthma, bronchitis and other respiratory infections and other diseases, because growing lungs may be most vulnerable to permanent adverse effects. According to Dr. Anoma Siribaddana (Consultant Chest Physician at the Kandy General hospital), the number of children with Chronic Obstructive Pulmonary Disease (COPD) is on the rise (Ileperuma, 2015).This statistics clearly revealed that the trend of airborne diseases are serious and create unhealthy future generation.

It was sound that approximately over 10,000 children in Sri Lanka has some sort of respiratory systems until they reach their 10th year of age. This may be running noose, frequent fever, cough, bronchitis, common cold and similar other symptoms. The major causes behind this are genetic issues and expose with air pollution. Out of 4.2 million premature deaths in the world, almost 300,000-350,000 are children under the age of 5 years (WHO, 2014). In Sri Lanka too over 45% of the admissions of children to the hospitals are due to air pollution (Dharshana and Coowanitong, 2008)

Below table-3 explains that the children have faster respiratorymrates than adults and the "normal" respiratory rate can vary significantly by age, which is depicted below.

Table-3: Average respiratory rates of children

Age	Rates (number of breaths/minute)
Newborn	30-60
Infant (1-12 months)	30 - 60
Toddler (1-2 years)	24 - 40
Preschooler ((3-5 years)	22 - 34
School age (6-12 years)	18 - 30
Adolescent (13-18 years)	12 - 16

Source:https://www.verywellhealth.com/what-is-a-normal-respiratory-rate-2248932 accessed on 03.08.2020

Belo table was prepared based on the information extracted from literatures on age wise children health impacts of a few urban areas, which provides evidences for vulnerability of children of air pollution.

Table-4: Age wise children health impacts of air pollution in Sri Lanka

Location	Children Age groups	Air pollutants	Health impact	Reasons
Colombo North teaching hospital	1-10 years	SO_2 NO_2 PM_{10}	Asthma	Dusty home enviroment is a significant risk factor for Asthma
Colombo Urban area	9 – 15 years	SO_2 NO_2 PM_{10}	Respiratory symptoms	Respiratory symptoms were higher in Colombo as compared to the rural area due to household risk factors.
Lady Ridgeway . Children's Hospital, Colombo	Below 12 years	SO_2 NO_2 $PM_{2.5}$	Wheezing and breathing difficulties	Episodes of nebulization positively correlated with most polluted days as children are exposed to outdoor dusty environment.
Kotte Medical	5-11 years	Dust pollutants	Respiratory symptoms	Respiratory symptoms were significantly higher

Officer of Health area				in houses as use of firewood
Kandy urban area	2-16 years	PM_{10}	Respiratory Health issues- running nose, cough & cold	32% of children from village school and 8% from the city school had health issues as inhaling particular matters with air.
Galle urban area	3-14 years	Not identified the pollutants type	Wheezing	Occurrences of wheezing was higher in Galle due to polluted urban air pollution.
Gampaha urban area	5-11 years	Not identified the pollutants type	Asthma	Prevalence of asthma was significantly higher in the presence of firewood smoke
Gampaha urban area	1-12 years	Not identified the pollutants type	Respiratory symptoms & peak flow rate	Higher rate of respiratory symptoms identified in the Industrialized area.
Ampara urban area	9 –15 years	SO_2 NO_2 PM_{10}	Respiratory symptoms	Respiratory symptoms were higher due PM.

Source: Nandasena, et al. , 2012.

Intact, the schoolchildren, below 12 years are more exposed to high levels of pollutants, especially in the urban areas of Sri Lanka, due to its overcrowding and vehicular congestions. The impacts of air pollution are significantly high, among the schoolchildren. The elements of NO_2, SO_2, and TSP levels are significantly higher in the school premises of the urban area, compared to the rural school. The respiratory health issues of schoolchildren (12 to 16 years), residing around Colombo and Kandy city is significantly reached to PM_{10} level. Similarly, the children are exposed to the bad air in the home environment too, due to the cooking and burning of multiple materials in the home environment (Nandasena, et al. 2012).

The air pollutant levels measured at the Colombo Fort monitoring station show that the hospitalizing rates of children for indoor treatment to the Lady Ridgeway Hospital is approx.. 31,000 children/annum; anticipating nebulizer therapy in the emergency treatment unit. The highest number of cases recorded for nebulization, during the most polluted day. According to the above monitoring center, the prevalence of bronchitis, emphysema, and other chronic obstructive pulmonary diseases had a strong association with PM_{10} levels of air, which shows such air is polluted and availability of particles. Nearly 20% of children affected with asthma have been admitted to the Lady Ridgeway Hospital due to exposure to PM_{10} level air (Dharshana and Coowanitong, 2008).

Accordingly, it was found that the children, those who are exposed to indoor or outdoor air pollution, are high prevalence of contracting with communicable and non-communicable diseases, especially school children and children in the shanties in the urban area. It is a timely requirement to find remedial measures to overcome these issues, especially for urban population.

7. Conclusion and recommendations

7.1. Conclusion

Breathing clean and quality air directly influence to the health of every organs in the human body, especially the lungs. An increasing trend of importation of various types of vehicles, absence of well-planned road network, traffic congestions during peak hours and incineration of solid waste especially in the urban areas, fuel wood combustion for cooking and use of mosquito coils especially in the rural area, industrial emission etc. have collectively induced indoor and outdoor air pollutions, creating human health impacts such respiratory and chronic diseases. Although, the percentage of pollutants mixed in the air is below average standards of WHO, the harmful particles with PM_{10} level could be observed, according to the statistical information of automated air quality monitoring stations in Colombo and Kandy. Most vulnerable group in Sri Lanka is aged and children population, since their immune system and lungs are not fully developed or week for resistance. Hence, ambient air pollution causes multifarious human health hazards and become a national challenge in Sri Lanka, where all stakeholders together with the general public should be come to gather to mitigate and manage this issue at an acceptable level and reduces adverse health effects.

7.2. Recommendations

- Suggested to prepare a national level policy strategy to provide “Clean Air to all in 2030” should be launched by the Government of Sri Lanka.
- It is suggested to establish an effective integrated mechanism with the participation of all stakeholders (including private sectors), based on a holistic policy and well-defined strategies with regard to the air quality and related issues to achieve proposed 2030 targets.
- Current habits/practice of wearing facemasks (legalized) should be promoted and continued after the current COVID pandemic situation too. This practice should be mandatory, while travelling, public places and especially in urban area.
- 09 automated air quality monitoring stations to monitor SO_2 and NO_2 in the air are available in Sri Lanka; however 41 urban councils and 24 Municipal councils are existed in Sri Lanka. Establishing more number of automated air quality monitoring stations at least to cover
- This study recommends to carry out a Health Impact Risk Assessment (HIRA) for every projects that are subjected to EIA, under the provision of National Environmental (Ambient Air Quality) Regulations of 1994. The Central Environmental Authority (CEA) has issued 17 Environmental Impact Assessment (EIA) and 266 Initial Environmental Evaluation (IEE) certificates in 2019. In order to regulate the environmental pollution, the CEA granted Environmental Protection Licenses (EPL) to the companies of potentially polluting industries. It is suggested implement a separate process to issue HIRA with EIA and EPL with support of Ministry of health.
- Transport plan is suggested to reduce the traffic congestion in the peak hours in the urban Sri Lanka and to improve the public transport system is the most efficient method to control vehicular pollution.
- Existing vehicle emission testing program should be re-evaluated and should be provided with productive guidelines to prevent vehicular smoke mixing-up with the environment.
- The citizens of Sri Lanka must be used fuel wood for their cooking outsides the residents with more ventilations or use any other alternative option affordable to them with less smoke and must be avoided children expose to smoke.

- The citizens of Sri Lanka must be encouraged to use mosquito nets instead of coils.
- It is suggested to have more researches on air pollution and related health issues in Sri Lanka, merging social-science and scientific research methodologies and to have a digitalize data base with quantitative and qualitative data, enabling everyone to access.
- It is recommended to introduce more courses or curriculums in University level to produce experts on air quality management and air quality measurements techniques *etc*.
- Medias contributions to educate and aware the public with regard to the dangers of both indoor and outdoor air pollutions.

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