Management of Air Pollution in Sri Lanka

R.N.R. Jayaratne

Senior Environmental Officer, Central Environmental Authority.

Introduction

Clean air is an essential basic need of all living beings. Purity of air we breathe is an important factor for human health. People in the past did not pay much attention to air as a resource like land and water, because air is abundantly available in the atmosphere. Atmospheric pollution was often not considered critical since nature and extent of atmospheric pollution cannot be easily seen or felt. The earliest pollutants noted in the atmosphere were probably of natural origin. Smokes, fumes, ash and gases from volcanoes and forest fires, sand and dust from windstorms in arid regions, fog in humid low lying areas, and natural terpene haze from pine trees in mountainous regions were part of our environment long before human-induced, or anthropogenic factors which damaged the environment. Except in such extreme cases as volcanic eruptions, pollution from natural sources does not usually, by itself, pose problems severe enough to endanger lives and properties. Destructive human activities are responsible for pollution problems for making earth's atmosphere an inhospitable environment.

Air pollution began with the discovery of fire. The origin of modern air pollution problems can be traced back to eighteenth century with the birth of the industrial revolution. The predominant agricultural activities were replaced with the industrial activities and people started to shift from countryside to cities. The power required for factories were generated by burning fossil fuels such as coal and petroleum. The smoke and ash produced by burning coal in power plants were identified as the major cause of air pollution problem during the late nineteenth and early twentieth centuries. Atmospheric pollution became worse with the emissions from increased use of automobiles with the industrial revolution.

What is Air Pollution?

Air pollution can be defined as natural or artificial introduction of chemicals, particulates, or biological materials into the atmosphere that cause harm or discomfort to humans or other living organisms, or damage the environment, i.e natural or human-induced emissions that degrade the quality of the atmosphere.

Air pollution occurs when air contains substances in quantities that could harm the comfort or health of humans and animals, or could damage plants or materials. These substances are called air pollutants and can be either particles, liquid or gaseous in nature. Air pollutants may be described as primary pollutants, i.e. those emitted directly to the atmosphere or secondary pollutants, i.e those formed by chemical reactions between substances already in the air. The primary air pollutants of the greatest concern are suspended particulate matter, oxides of nitrogen, sulfur dioxid, carbon monoxide, hydrocarbons (volatile organic compounds), and lead. Ozone is the most important secondary air pollutant. The following section describes the most important air pollutants.

Major air pollutants

The following eight pollutants have been identified as the most widespread and serious air pollutants:

1. Suspended particulate matter (SPM) (Air-borne particulate matter)

SPM is a complex mixture of solid particles and aerosols (liquid particles) suspended in the air .We can see these particles as dust, smoke, and haze. Air-borne particulate matter is produced through natural processes and as a result of human activities. In urban and industrial areas, 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. In coastal areas, the atmosphere may also contain a significant level of sea-salt particles. Apart from the particles directly emitted, processes taking place in the atmosphere can lead to the formation of 'secondary' particles such as photochemical aerosols and condensed acids.

The levels of the air-born particulates are measured in terms of their sizes,

The term PM_{10} is used to describe air-borne particles of less than 10μm in aerodynamic diameter. These small particles pose a great hazard to human health because they are small enough to pass through the filtration mechanisms in the upper respiratory tract and penetrate to the lower airways.

$PM_{2.5}$ is the term used to describe air-borne particles of less than 2.5μm in aerodynamic diameter. These small particles pose the greatest hazard to human health because they are small enough to penetrate to the lungs and attack lymphocytes and phagocytes in the lungs. Exposure to such particles, both short-term and long-term, has linked to increased death rates from heart and lung diseases, as well as pneumonia, loss of lung function, asthma and other respiratory problems.

2. Oxides of Nitrogen (NO_x)

Nitric oxide (NO) and nitrogen dioxide (NO_2) are collectively called oxides of nitrogen (NO_x). Nitrogen dioxide is a brownish gas with a strong odour and is a respiratory irritant. While nitric oxide does not significantly affect human health, nitrogen dioxide can cause damage to the mechanisms that protect the human respiratory tract, increasing a person's susceptibility to, and severity of, respiratory infections and asthma. Sustained exposure to high level of nitrogen dioxide can lead to more serious chronic lung damage, particularly in the presence of other pollutants such as ozone and sulfur dioxide. Nitrogen oxides are produced by both natural and man-made processes. The most common sources of nitrogen oxides in the nature are bacterial breakdown of organic nitrates, forest fires and volcanic activity. The major source of manmade NO_x emission source is internal combustion engines. Nitrogen oxides are products of combustion processes, where atmospheric nitrogen, and any nitrogen in the fuel are converted into its oxides, mainly to nitric oxide (NO) and nitrogen dioxide (NO_2). The nitric oxide slowly oxidizes to form nitrogen dioxide in the atmosphere, but this reaction proceeds more rapidly in the presence of ozone. Nitrogen oxides in the atmosphere reduce visibility, help to form acid aerosols, contribute to global warming and act as catalysts in the decomposition ozone in the upper atmosphere. Nitrogen oxides also can form ozone and peroxy acetyl nitrates (PAN) through interaction with hydrocarbons in presence of sunlight.

3. Sulfur dioxide (SO_2)

Sulfur dioxide is a colourless gas with a sharp, irritating odour and a primary pollutant. It is formed in combustion processes involving burning fossil fuels containing sulfur (particularly coal and oil), in the refining of petroleum, and in other industrial processes. Sulfur dioxide may also oxidize in the atmosphere to form sulfuric acid, contributing to acid deposition, or acid rains.

Sulfur dioxide affects human health by causing respiratory irritation and increasing susceptibility to respiratory tract infections. Sulfur dioxide reacts with the mucous layer lining of the airways to produce an irritant acidic solution that stimulates the nerve endings, leading to coughing and wheezing. Individuals who suffer from pre-existing respiratory conditions such as asthma and bronchitis are the most sensitive to sulfur dioxide exposure. The simultaneous presence of air-borne particulate matter can exacerbate these effects. Sulfur dioxide and its aerosols (water droplets containing dissolved sulfur dioxide) also damage vegetation and some materials.

4. Carbon Monoxide (CO)

Carbon monoxide is a colourless, odourless gas produced by the incomplete combustion of fuels containing carbon such as oil, gas, coal and wood. Carbon monoxide forms a stable complex with hemoglobin (Hb) in red blood cells, called carboxyhemoglobin (COHb) which reduces the ability of the blood transporting oxygen from the lungs throughout the body. The resulting oxygen deficiency can impair or damage organs such as brain, nerves and heart muscle, which require large amounts of oxygen to function normally. In urban areas, motor vehicles account for up to 90 % of carbon monoxide emissions. Industrial processes, wood and waste burning are the other sources of carbon monoxide.

5. Volatile organic compounds (VOCs)

Organic compounds that evaporate easily are basically called volatile organic compounds (VOCs). These include materials such as gasoline, paint solvents, pesticides, and organic cleaning solutions. They evaporate into the air in a vapor state, as well as in the form of fragments of molecules resulting from the incomplete oxidation of fuel and wastes. VOCs are responsible for smog formation. Some VOCs cause minor irritation of skin, eyes, nose and throat, and have a general narcotic effect. Some have been identified as carcinogenic. Some health effects from overexposure to VOCs are dizziness, headaches, and nausea. Long-term exposure to certain VOCs, such as benzene, has also been shown to cause cancer, and eventually death.

6. Lead (Pb) and other heavy metals

Metals smelters are the main source of air-borne heavy metals and battery manufacturing plants, and leaded gasoline are the leading sources of air-borne lead. The three systems in the body most sensitive to lead are the blood-forming system, the nervous system, and the renal system. Reproductive endocrine, hepatic, cardiovascular, immunological and gastrointestinal functions may also be affected by air-borne lead. Lead affects the human central nervous system, and in young children neurological and intellectual development can be impaired causing learning disabilities. In older people, lead can cause high blood pressure and (in higher concentrations) kidney diseases or anemia. However, since leaded fuel has not been sold in Sri Lanka from June, 2002, health effects of lead will be minimal in the future.

7. Hazardous Air pollutants

Toxic chemicals in the air including carcinogenic chemicals, radioactive materials and other chemicals such as asbestos, vinyl chloride, benzene, dioxins and, etc are considered as hazardous air pollutants. According to the United State Environmental Protection Agency, there are 188 of hazardous air pollutants and many of them are human carcinogens.

8. Ozone (and other photochemical oxidants) (O_3)

Photochemical oxidants or photochemical "smog" are terms used to describe a complex mixture of chemicals produced in the atmosphere by the action of sunlight. The principal component is ozone and its concentration is commonly used as a surrogate for these photochemical oxidants.

Ozone is a secondary pollutant, that is, it is not emitted directly, but is formed in the atmosphere by the reaction of various precursor compounds. Ozone is a colourless, highly reactive gas with a distinctive sharp odour. It is formed naturally by electrical discharges in the upper atmosphere and exists naturally in the stratosphere where it protects the Earth from the harmful ultraviolet radiation of the sun. However, at ground level, elevated concentrations of ozone irritate mucus membranes in the eyes, nose and throat and decrease lung function in healthy people, especially during exercising. It also affects the growth of vegetation, and damages materials such as rubber, masonry, and paints. The production of ozone depends on the intensity of sunlight and temperature, and the reaction takes place over several hours. The highest concentrations of ozone normally occur at noontime in tropical countries and during summer afternoons due to downwind of major sources of ozone precursors such as nitrogen oxides and reactive organic compounds (hydrocarbons).

Effects of Air Pollution

Deterioration of the human health by poor air quality indirectly affects the productivity of people and hence the national economic growth. The adverse health effects of various air pollutants have been documented in numerous studies [1]. Exposure to air pollution can cause both **acute** (short term) and **chronic** (long term) health effects. Acute effects are usually immediate and are often reversible when exposure to the pollutant ends. Common acute health effects include eye irritation, headaches, and nausea. Chronic effects sometimes take a while to become apparent, last indefinitely and tend not to be reversible. Chronic health effects include decreased lung capacity and lung cancer resulting from long-term exposure to toxic air pollutants such as asbestos and beryllium.

Air pollutants affect primarily the respiratory system, and may affect skin, eyes, and other body systems. Both gaseous and particulate air pollutants can have negative effects on the lungs. Solid particles can settle on the walls of the trachea bronchi and bronchioles. Gaseous air pollutants may also affect the functions of the lungs by slowing the action of cilia.

The lungs are the organs responsible for absorbing oxygen from the air and removing carbon dioxide from the bloodstream. Continuous breathing of polluted air can slow down the normal cleansing action of the lungs, and result in more particles reaching the lower portions of lung. Damage to the lungs from air pollution can inhibit this process and contribute to the occurrence of respiratory diseases such as bronchitis, emphysema and cancer. This can also put an additional burden on the heart

and circulatory system. High concentrations of air pollutants in many developing countries lead to increased illnesses, particularly among individuals suffering from respiratory problems, and cause premature death.

Apart from health effects, there are many effects of air pollution. These include the effects on vegetations, soil, water, man-made materials, climate and visibility (formation of smog).

Acid rain is formed when air pollutants such as sulfur dioxide (SO_2) and nitrogen oxides (NO_x) are transformed into acids in the atmosphere, and it destroys or damages wild life, forests (plants and vegetations), aquatic life in lakes and streams, and many man-made structures such as buildings and outdoor art. The ancient statues located in Greece and Italy and marble decorations on Taj Mahal in India are being noticeably damaged by acid rains.

Climate change, destruction of bio diversity and rise of mean sea level are the major environmental problems caused by increasing green house gases in atmosphere as a result of air pollution and deforestation. There is also evidence that increased ultraviolet radiation caused by the depletion of ozone layer is affecting the normal growth cycles of plants.

Air Pollution in Sri Lanka

Unlike in many of its Asian neighbours, Sri Lanka is fortunate that it has not yet experienced acute air quality problems as a result of industrial expansion, increasing vehicular traffic and thermal power generation and rapid urbanization. Emissions from motor vehicles are the most significant contributor to air pollution in Sri-Lanka like in most newly-industrialized countries. Road and rail are the main transport systems in Sri Lanka. Air transport and water transport are insignificant compared to road and rail transport systems within the country. The transport sector accounts for about 60% total fuel consumption in Sri Lanka.

In Sri Lanka, air pollution problem in the transport sector arises due to the following factors together with sharp increase of vehicle population.

- Poor maintenance of vehicles increases the air pollution by air-borne particles from diesel vehicles and carbon monoxide & volatile organic compounds from petrol vehicles.
- High traffic congestion because of not having a proper road network, traffic control system and poor maintenance of roads (especially in urban areas).
- Absence of a proper and well-planned public transport system (Normally engines of most of the passenger transport buses are kept started and idling at the bus halts polluting the environment).

Emissions from thermal power generation are the recent significant contributor of air pollution in Sri Lanka. Furnace oil is used mostly in industrial boilers and some thermal power stations. High concentration of sulfur (maximum3.5%, average 2.3%) in furnace oil is responsible for high sulfur dioxide levels in industrial areas and thermal power generating areas in Sri Lanka. Within the last decade, industrial activities in Sri Lanka have grown at a relatively rapid pace. Air pollution due to industrial sources has increased in proportion to industrial expansion. Air pollution problem due to industrial activities in Sri-Lanka has arised absence of air pollution control measures and neglect of environmental problems at the planning stage. Most industries which were established prior to 1980 use outdated technology without incorporating proper pollution control measures. Many of these cannot adopt new technology or pollution control equipment and lack physical space for installation of pollution control devices.

In Sri Lanka, in addition to the above-mentioned air pollution sources, emissions from burning of firewood for domestic cooking and , of chena for clearing and forest fires also contribute to air pollution to some extent. The western province in Sri Lanka (area including the districts of Colombo, Kaluthara and Gampaha) commonly known as Colombo Metropolitan Region (CMR) was identified as the most vulnerable area of air pollution. Kandy town area, Galle, Kurunegala, and Puttalam have also been identified as other air pollution hot spots in Sri Lanka.

Air quality monitoring in Sri Lanka has focused mainly on the Colombo City where economic activities and urbanization mainly takeplace. Air quality monitoring in other cities such as Kandy, Anuradhapura, Puttalam, Kurunegala, etc. is very limited.

In Sri Lanka, indoor air quality monitoring is very limited as compared to the urban air quality monitoring. Even though the Lead has been eliminated from gasoline in 2003, presence of Lead in paints is still a cause for indoor air pollution other than poor ventilation, use of biomass, etc.

Status of Air Pollution in Sri Lanka

Dust/Soot is the major source of air pollution in Sri Lanka. As identified by the Central Environmental Authority (CEA), major cause of dust pollution is mobile sources. In addition, resuspension of dust particles due to poor maintenance of roads has aggravated the dust pollution, especially in urban areas.

Annual averages of ambient PM_{10} level in Colombo over the years have remained relatively within the 72 to 82 µg/m³ range with a slight decreasing trend from 1998 to 2006. The peak was recorded in 2001(Figure 1).These values, however, consistently exceeded WHO latest guideline value of 20 µg/m³ for PM-10 Thus Colombo city is very unhealthy in terms of its particulate pollution.. However, there is a slight decreasing trend of PM-10 from 1998 to 2006 (Figure 1).

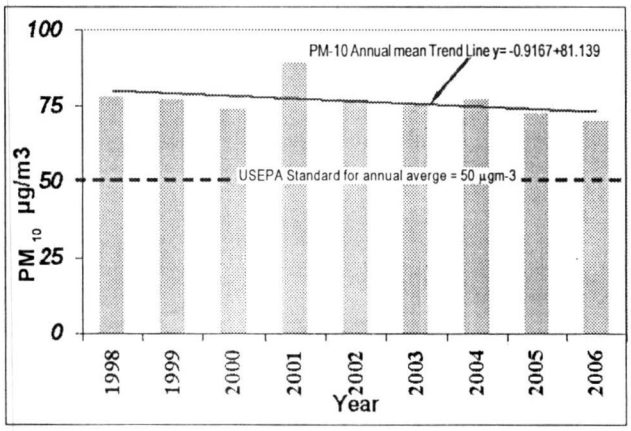

Figure 1: Annual averages of PM-10 at Colombo Fort ambient air quality monitoring Station (1998-2006)

Source : Central Environmental Authority (Year 2007)

Despite high SO_2 emissions from industrial activities, especially thermal power plants within CMR and emissions from diesel vehicles, one-hour averages of SO_2 has exceeded from time to time but fell within the annual United States Environmental Protection Agency (USEPA) limit of 80 µg/m³. (Sri Lanka does not have an annual standard for SO_2). Unlike PM-10, which was fairly stable within a small range of values, SO_2 levels in the Colombo City have shown an increasing trend from 1997 to 2001 and from May 2003 to end of the year 2006 (Figure 2).

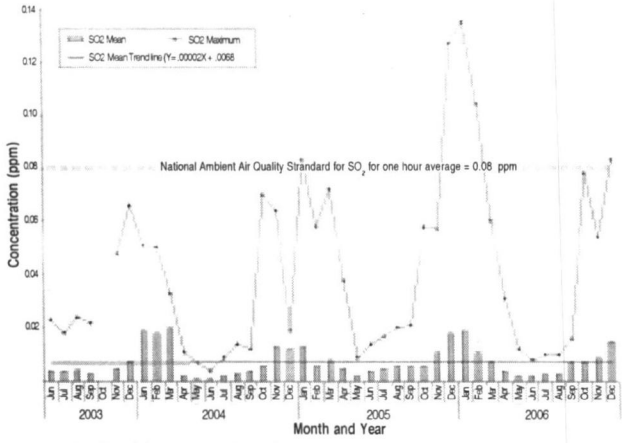

Figure 2 : Monthly mean and maximum of one-hour averages of sulfur dioxide concentration at Colombo Fort (June 2003 - December 2006)

Source: Central Environmental Authority (Year 2007)

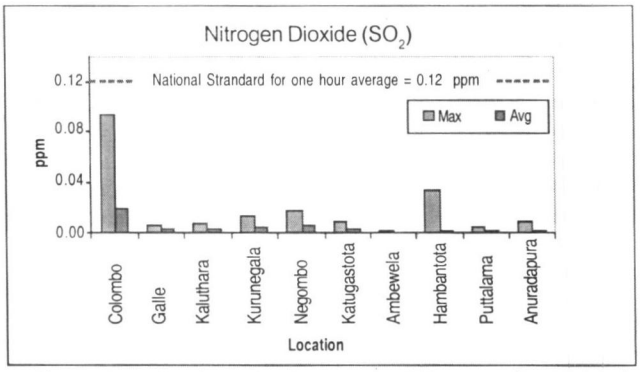

Figure 4: Mean and maximum of one-hour averages of NO_2 concentrations at selected locations in Sri Lanka

Source: Central Environmental Authority (Year 2000)

NO_2 concentration levels in the Colombo City over the past years have also shown the same trend as with SO_2. (ie. Increasing from 1997 to 2001 and from May2003 to December 2006. (Sri Lanka does not have an annual standard for NO_2) (Figure 3).

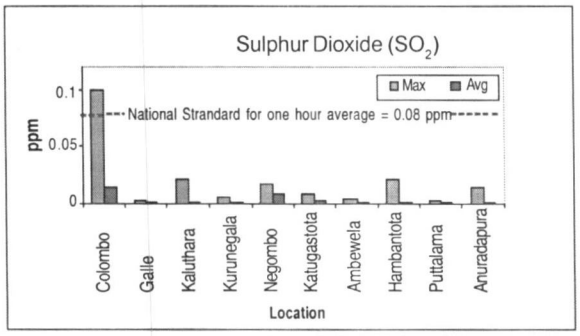

Figure 5: Mean and maximum of one-hour averages of SO_2 concentrations at selected locations in Sri Lanka

Source: Central Environmental Authority (Year 2000)

Environmental (Protection and Quality) Regulations of 1990. Under the section 32 of National Environmental Act, then Minister of Transport, Highways, Environment and Women's Affaires gazetted the National Ambient Air Quality Standards for Sri Lanka in the extraordinary gazette No 850/4 dated 20th December 1994. These regulations did not directly deal with vehicular air pollution.

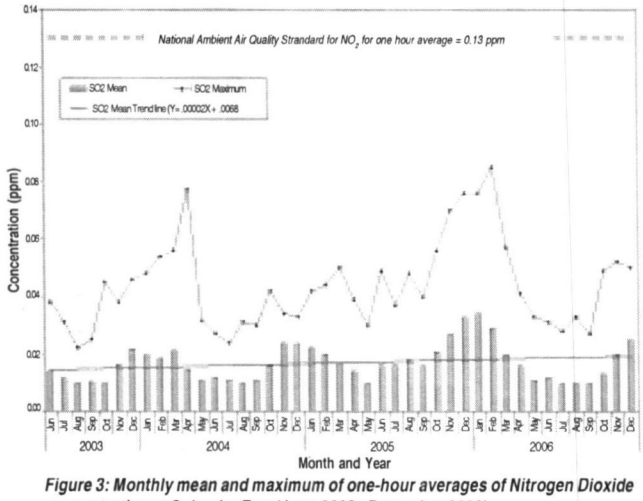

Figure 3: Monthly mean and maximum of one-hour averages of Nitrogen Dioxide concentration at Colombo Fort (June 2003 - December 2006)

Source: Central Environmental Authority (Year 2007)

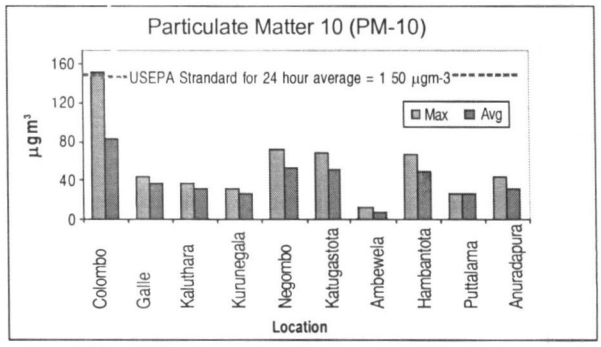

Figure 6: Mean and maximum of one-hour averages of PM_{10} concentrations at selected locations in Sri Lanka

Source: Central Environmental Authority (Year 2000)

Ambient air quality levels of NO_2, SO_2 and PM_{10}) were monitored in Galle, Kalutara,Kurunegala, Negombo, Katugastota, Ambewela, Hambantota,Puttalam and Anuradhapura for a period of one week at each location in 1999.The maximum value of hourly averages for each parameter was reported, and the average of each parameter for the monitoring period at each monitoring location are presented in figures 4, 5 and 6 respectively.

According to these figures, the highest air pollutants concentrations were recorded in Colombo Fort monitoring station. 24-hour average concentrations of PM_{10} in Negambo, Katugasthota and Hambanthota exceeded, the WHO guideline value of 50 μgm^{-3}

Air Pollution Control Regulations in Sri Lanka

The National Environmental Act (NEA) No 47 of 1980 (amended 1988 & 2000) was enacted primarily focusing on environmental protection and management. The emission of pollutants into the atmosphere is prohibited under section 23 of the National Environmental Act and the National

Although little monitoring data was available at that time, and taking into consideration World Health Organization (WHO) Guidelines and standards prevailing in other countries, the standards adopted here were more stringent than the WHO guideline values. The USEPA standard for PM_{10} (particulate matter diameter of 10 microns or less) is used as an interim standard in Sri Lanka as there is no standard for PM_{10} in Sri Lanka, Monitoring of PM_{10} is more meaningful to the human health aspects rather than total suspended particulate matter(SPM).

The standards for mobile emission control and management was published by extraordinary

gazette No 1137/35 dated 23rd June 2000 and amended by extraordinary gazette No 1295/11 dated 30th June 2003. It included the following:

- Vehicular exhaust emission standards
- Fuel quality standards
- Vehicle exhaust emission standards for importation of vehicles

The Environmental Impact Assessment (EIA) regulations of 1993 require that any new project undertaken under the prescribed list undergo a full EIA or an Initial Environmental Examination (IEE) before a license is issued. This process has brought public pressure to ensure compliance.

Though the National Environmental Act(NEA) gives Central Environmental Authority(CEA) the mandate to regulate and control air pollution, enforcement has been rather slow due to lack of specific emission standards and reliable data. While the Motor Traffic Act considers visible emissions as an offence, it is not rigorously enforced.

The industrial emission standards have also been prepared but yet to be gazetted as a regulation.

Air Quality Management in Sri Lanka

While the present levels of air pollution in Colombo City appear to be manageable the projected rates of economic and vehicular growth could result in air quality becoming worse in the near future. To identify the potential threat of air pollution in Colombo metropolitan region (CMR), in 1993, the government of Sri Lanka developed and published the Clean Air 2000 Action Plan (CA2AP) for air quality management in the Colombo metropolitan area through Metropolitan Environmental Improvement Program (MEIP). Due to various reasons, majority of the fifty proposed actions on air quality management could not be implemented.

However, the Air Resource Management Centre (AirMAC) was established in 2001 jointly by the Environmental Economic and Global Affairs Division of the then Ministry of Forestry and Environment and the Central Environmental Authority in partnership with all stakeholders of air resource management to develop, co-ordinate and integrate programs and mechanisms to mitigate air pollution. It also included strengthening institutions, capacity building, developing of air resource research programmes and establishing air resource information centre for dissemination of air resource information.

The Central Environmental Authority and Ministry of Environment and Natural Resources have taken many steps to control air pollution through AirMAC. Some of them are as follows:

✧ **Enforcement of Vehicle Emission Standards**
- *Vehicle Emission Standards, Fuel Standards, and Emission Standards for Importation of vehicles has been gazetted in 2003 (GE. No 1295/11 dated 30/06/2003)*

✧ **Implementation of Vehicle Emission Standards through Vehicle Emission Testing (VET) Programme to control air pollution from vehicles.**
- This is scheduled to be implemented by the Commissioner of Motor Traffic and
- Vehicle emission testing centres will be established soon in Sri Lanka.

✧ **Improvement of Fuel Standards**
- Introduced unleaded gasoline from 2003 to stop emission of particulate lead into the atmosphere from gasoline powered vehicles.
- Reduction of Sulfur content in diesel from 15000 PPM to 3000 PPM through Ceylon Petroleum Cooperation and planned to further reduce sulfur content in diesel up to 500 PPM by the end of year 2008 to minimize the SO_2 emission to atmosphere from diesel vehicles, diesel power plants and industries using auto diesel.

✧ **Ongoing activities**
- Steps are being taken to legalize source emission standards to control emission of air pollutants from stationary sources.
- Steps are being taken to review the existing ambient air quality standards incorporating PM_{10}, and $PM_{2.5}$
- The government has banned the import of two stroke three wheelers with effect from January 2008.

Concluding Remarks

We must pay more attention to manage air quality because poor air quality deteriorates human health which in turn adversely affects the productivity of people and national economic growth. Unless timely action is taken to prevent or minimize air pollution, future generation will be deprived of a clean atmospheric environment for them to live. As custodians of the environment, we all have responsibility to take action to reduce air pollution and bequeath it in perfect condition to ensure posterity of the present as well as future generations. ■