Editorial

M. Asoka T. De Silva

National Policies and Plans for Mitigation of Air Pollution

The various ramifications concerning the occurrence, impact, and abatement of air pollution and ambient air quality are discussed in this number of Vidurava. There is no doubt, that despite emission control measures, air quality has been deteriorating at an unprecedented pace in recent times mainly due to increasing vehicular traffic. The impacts of air pollution on the health of the people, and in consequence, the well being of the nation as shown by the contributors to this edition of the Science Magazine are astonishingly revealing.

It is however, significant to note that unorthodox mechanism for mitigation of air pollution through the use of ecosystem sciences have now drawn the attention of scientists and environmentalists. This approach though may be seen as a novelty must be recognized, was a tradition that our ancestors had consciously and conscientiously resorted to in order to ensure a cleaner living environment.

In the year 2002, in response to the concerns aired by all segments of society, the then Ministry of Forestry and Environment established under its purview the Air Quality Management Centre, in order to co-ordinate air pollution mitigation activities. Among the early measures initiated by this Centre included the formulation of a National Policy on Air Quality Management. It also gazetted mobile air emission standards, fuel quality specifications, and vehicular specification standards for importation of vehicles, and finalized the so-called "Clean Air 2007 Action Plan".

In addition, regulation needed for gas emission tests and clearance for all motor vehicles before the issue of revenue licenses which came into effect from November 2008, were indeed positive steps towards curtailing noxious emissions.

The Ministry of Environment also took the decisive step to ratify international conventions relating to these issues. Under these conventions, the use of leaded petrol was banned in 2002, while regulations for reduction of sulphur contents of auto diesel from 1.0g per litre to 0.5g per litre were also implemented.

It is thus clear that the relevant state agencies have already taken the correct initiatives to mitigate air pollution, but more needs to be done, and hopefully their efforts to ensure a healthy living environment for the people, will become a reality in the near future.

Air Pollution: An Overview

Prof. O.A. Illeperuma

The atmosphere is so essential to sustain life on earth that we take it for granted that it can survive to maintain life in spite of the many ways in which we disturb its equilibrium. We think about the quality of water we drink and most people boil water to kill any microorganisms in it before drinking. However, did you ever think about how pure is the air you breathe? People in cities and along main highways are especially vulnerable to breathing polluted air. We are all familiar with the sneezing bouts caused by inhaling air containing dust particles. In addition, people living in congested areas breathe air polluted not only with dust and soot but also with toxic gases generated by automobiles and factories. In this paper we present, some of the major air pollutants which we encounter in our daily lives.

Air pollution is the introduction of chemicals, particulate matter, or biological materials to air that cause harm or discomfort to humans or other living organisms, or damages the natural vegetation and structures. An air pollutant can be defined as a substance present in a sufficient concentration in air to produce a harmful effect on humans and other animals, vegetation or other materials. These air pollutants contribute to changing the composition of the atmosphere. **Table 1** gives the major air pollutants normally encountered in our daily lives.

Most of these pollutants are produced by human activities such as transport, power generation, industrial processes, forest and agricultural fires and incineration of solid wastes.

There are two types of air pollutants. A primary air pollutant is a substance that has been added directly to the air from a given source. It can even be carbon dioxide which is already present in air which rises above a certain level or else it could be something like the oxides of nitrogen or sulphur which are added from the exhaust fumes of motor vehicles. A Secondary air pollutant is one formed in the atmosphere through a chemical reaction involving normal or added components of air.

Oxides of carbon

Carbon monoxide is perhaps the most abundant air pollutant in a

Table 1 Major classes of air pollutants and examples

Class of pollutant	Examples
Oxides of carbon	carbon dioxide, carbon monoxide
Oxides of sulphur	sulphur dioxide, sulphur trioxide
Oxides of nitrogen	nitric oxide, nitrogen dioxide
Hydrocarbons	methane, butane, benzene
Photochemical oxidants	ozone, peroxyacylnitrates (PAN)
Particulates	soot, dust, asbestos, salt spray
Other Inorganic compounds	hydrogen sulphide, sulphuric acid

city such as Colombo. This is produced along with oxides of nitrogen and sulphur during the combustion of petrol or diesel in all types of motor vehicles. During the combustion of hydrocarbons such as petrol or diesel, if the combustion is complete and if adequate oxygen is present then the product should be carbon dioxide. However, in practice, these conditions are not achieved. Instead partial combustion takes place producing carbon monoxide and carbon (soot). A simple example to illustrate this is the gas cooker you have at home. Normally we can see two zones in such a flame: an inner blue zone and an outer pale blue or almost colourless outer zone. The blue colour is due to carbon monoxide and the outer colourless flame is where full combustion takes place giving carbon dioxide. Sometimes, if the nozzle holes are blocked, we see a yellow flame and this is due to the presence of carbon.

Carbon dioxide is essential for plants to make carbohydrates through the process of photosynthesis. However, the carbon dioxide concentration in the atmosphere has been steadily increasing and has now reached 0.386 ppm (or 0.0386%) and this is a serious issue because of its contribution to global warming which in turn produces adverse climatic changes. Increased burning of fossil fuel (coal, natural gas, oil, petrol) and destruction of forests are responsible for this effect.

The other oxide of carbon, viz. carbon monoxide is extremely toxic. When inhaled it reacts with the oxygen carrying component in our blood producing carboxy haemoglobin which reduces the amount of oxygen carried to the brain and other parts of the body. This results in dizziness, headaches, chest pains and a general deterioration of health. Headaches and nausea that people get when travelling in air conditioned buses is mainly due to carbon monoxide generated in the closed environment of the bus. People also get headaches if exposed to polluted air in a busy section of the city over a long time. This is particularly harmful to people with heart problems.

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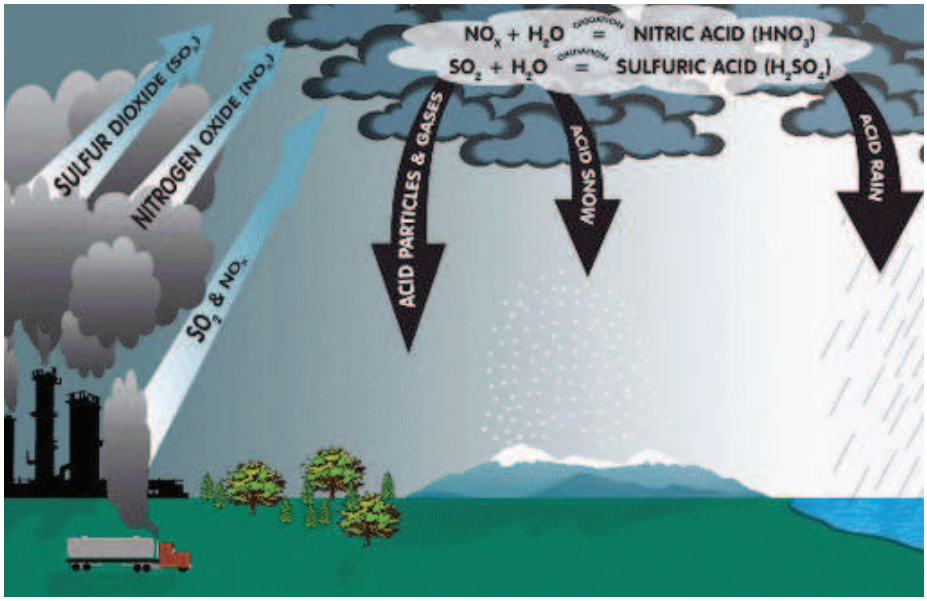
Oxides of nitrogen

Nitric oxide is formed when oxygen reacts with nitrogen in air at the high temperatures inside an automobile engine. This is called thermal nitric oxide as opposed to fuel nitric oxide which is formed during the combustion of organic nitrogen compounds in petrol or diesel. Nitric oxide reacts with more oxygen from the atmosphere forming reddish brown nitrogen dioxide which has a characteristic sharp, biting odour. It is extremely irritating particularly to eyes and lungs.



Cities such as Los Angeles in the USA are sometimes referred to as brown cities due to the presence of this oxide of nitrogen. The nitrogen dioxide produced eventually reacts with water and forms nitric acid which comes down as acid rain.

Sulphur oxides

Some cities in the West such as London, New York and Chicago use coal or oil for domestic heating and electricity generation. These power plants produce particulates such as dust and soot and also sulphur dioxide, a dangerous pollutant. It is also produced in the combustion of petrol and diesel in motor vehicles. Thus, it is a problem even in a country like Sri Lanka where the number of automobiles has been increasing year after year. Furthermore, with increasing industrialisation, the newly constructed factories contribute significantly to increased sulphur dioxide levels in the atmosphere. It is also produced during incineration of solid wastes, forest fires and during the eruption of volcanoes where large quantities sulphur dioxide are emitted to the atmosphere.

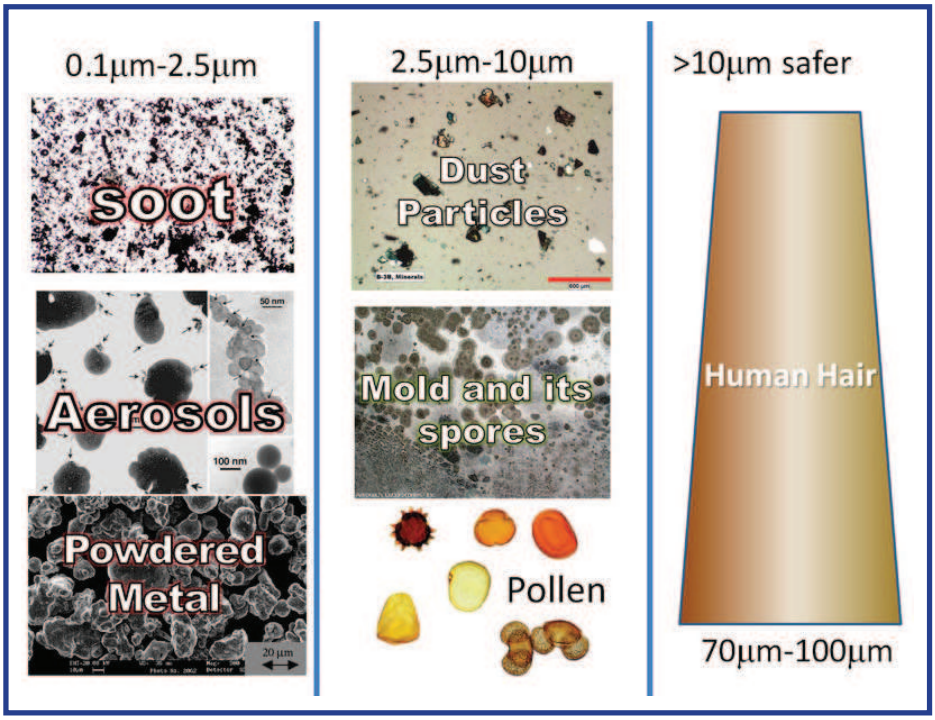
Coal, oil and other petroleum products contain varying amounts of sulphur in the form of organic sulphur compounds which get oxidised during the combustion process. In addition, coal also has iron sulphide as an impurity and the sulphur percentage of some of the cheaper coals can be as high as 4%. Both organic sulphur compounds and inorganic sulphur compounds in coal generate sulphur dioxide upon combustion. Generally in a coal powered electricity generation plant, scrubbers are installed to remove sulphur dioxide from leaving to the atmosphere. A scrubber is a type of filter mechanism lined with lime which reacts with sulphur dioxide. Another way to remove sulphur is by employing fluidised bed reactors where coal is mixed with limestone and then fired. Here, limestone decomposes giving calcium oxide which then reacts with sulphur dioxide.

Sulphur dioxide is also produced as a byproduct in various metallurgical processes where the metal sulphides are roasted to the corresponding oxide. Sulphur dioxide can damage plants, dissolve marble and concrete and even eat away iron and steel. The effects it has on the delicate lung tissues are all too obvious. Even at extremely small concentrations, sulphur dioxide poses a potential health hazard. Sulphur dioxide also reacts with oxygen in the air under the influence of sunlight producing sulphur trioxide which could then react with rain water producing sulphuric acid contributing to acid rain.

Hydrocarbons and other volatile organic compounds

The primary source of hydrocarbons present in the atmosphere is the release of unburnt fuel from automobiles. Some minor components escaping to the atmosphere without combustion such as 3,4-benzopyrene are well known carcinogens. There are other volatile compounds which are divided into the separate categories of methane (CH_4)

and non-methane volatile compounds (NMVOCs). Methane is produced during the decomposition of organic matter under anaerobic conditions such as those found under the water logged conditions in a paddy field. It is an efficient greenhouse gas which contributes to enhanced global warming. In the category of NMVOCs, are the aromatic compounds benzene, toluene and xylene which escape to the atmosphere as unburnt fuel, are suspected carcinogens and may lead to leukemia and other cancers through prolonged exposure. 1,3-butadiene is another dangerous compound which is given out in industrial processes.



Other types of volatile organic compounds present in the atmosphere include pesticides used in agriculture. In addition, chlorofluorocarbons used as aerosols and refrigerants also contribute significantly to Greenhouse effect.

Fine particles

These refer to all those solid and liquid particles commonly referred to as aerosols, and includes dust, soot, ash, asbestos, lead compounds, sulphuric acid droplets, ammonium sulphate, as well as aerosols (formed by the reaction of atmospheric ammonia with sulphuric acid), oils etc. In addition to creating visibility problems for motorists and airplanes, these are some of the most toxic of all air pollutants. Most of these are produced due to activities of man such as land clearing, forest burning, and due to combustion of fossil fuels in vehicles and industries.

Particles are classified according to their sizes and the widely used unit is the micron (1 micron = 10^{-6} metres). Particles > 10 microns are filtered by the nose and hence do not reach the lungs while those smaller penetrate into the lung. Fine particles are those with diameters < 2.5 microns and coarse particles are those with sizes > 2.5 microns. They are commonly referred to as the PM 10 and the PM 2.5 fractions. Particles are generated into the atmosphere from the following sources;

Automobile exhaust fumes
Forest and domestic fires
Volcanoes
Indoor cooking using firewood
Soil and rock debris
Sea salt spray
Industry

The adverse health effects of particulates are well established. What is startling is that an

increase in 10 μg/$m^{-3}$of the PM 2.5 fraction causes a 1.5% increase in total daily mortality and a 2.1% increase in ischemic heart disease.

Photochemical smog

Photochemical smog is a type of air pollution produced when sunlight acts upon motor vehicle exhaust gases to form harmful substances such as ozone (O_3), aldehydes and peroxy acyl nitrates (PAN).

Nitrogen dioxide given out during fossil fuel combustion and other industrial activities dissociates as a result of the UV radiation from the sunlight giving nitric oxide and oxygen atoms. These reactive oxygen atoms combine with atmospheric oxygen to give ozone.

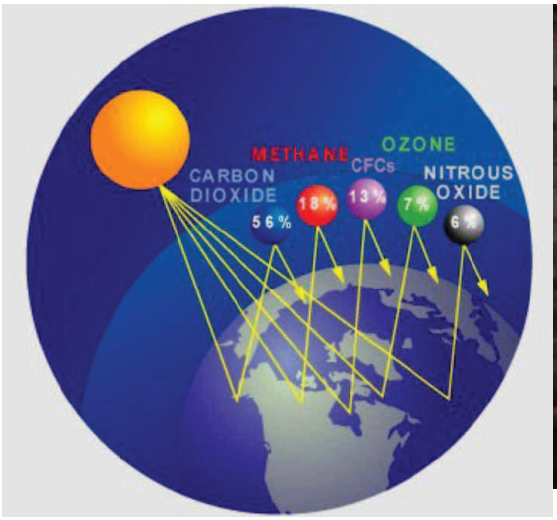
Ozone is considered as a photochemical oxidant with strong oxidising properties and affects humans as well as vegetation. Ozone is also produced during the operation of photocopiers and laser printers and hence they should be operated in well ventilated areas. It has been shown that this gas causes reduced lung function and exacerbates asthma. It also causes yellowing of leaves of some sensitive plants such as spinach and tobacco.

Ozone so formed reacts with unburnt hydrocarbons from motor vehicles and nitrogen dioxide to yield a class of compounds known as peroxyacylnitrates (PAN). These have tear like properties and are oxidising agents causing numerous health problems.

Persistent organic pollutants (POPs) are organic compounds that are resistant to environmental degradation through chemical, biological, and photolytic processes. Because of this, they have been observed to persist in the environment, and being capable of long-range transport, bioaccumulate in human and animal tissue, biomagnify in food chains, and have potential significant impacts on human health and the environment.

Indoor air pollution

The commonest form of indoor air pollution is the kitchen smoke coming from indoor cooking using firewood. Most rural households carry out cooking in congested kitchens and is quite unhealthy. This is again due to particles in the smoke and in addition, there are a large number of carcinogenic polyaromatic hydrocarbons, peroxyacyl nitrates and carbon monoxide. Carbon monoxide causes headaches and the peroxyacyl nitrates



cause eye irritation. Both of these are common symptoms experienced by people during firewood cooking. Through years of exposure our mothers who spend a lot of time in indoor kitchens may develop lung cancer due to the toxic aromatic hydrocarbons. What is needed is that people should be educated to cook in an outdoor open kitchen which helps to disperse the pollutants instead of an enclosed indoor kitchen. Children too are affected since they spend more time with mothers rather than fathers who normally spend their time outside the kitchen. Diseases like pneumonia, bronchitis, asthma and other pulmonary diseases are common among these two categories.

Radon coming from granite is another source of indoor air pollution where radioactive minerals included in the granitic rocks disintegrate giving radon gas which is radioactive and inhalable. Inside the lungs this gas decays into solid radioactive elements which keep on emitting harmful radiations over a long period of time. Exposure to such radiations cause cancer and if granite is used as floor tiles, then the area should be well ventilated by keeping the windows open. The danger lies in enclosed spaces such as air conditioned rooms where the air is internally cooled and no fresh air is drawn in by the air conditioners.

Modern furniture where urea-formaldehyde resins are used for binding pieces of wood together emit fomaldehyde with time. It is a known carcinogen and hence should be avoided. This problem is severe in western countries where the rooms are either air conditioned during summer and heated in winter with the windows closed. Household pesticides always leak and give pesticides into indoor air. Cigarette smoking too is a serious indoor air pollution problem since other non-smokers are affected due to passive smoking.

Biological sources of air pollution are also found indoors, as gases and airborne particulates. Hairs from pets, dust mites in bedding, fungi producing fungal spores, house plants, soil and pollen from surrounding gardens are some examples of biological air pollutants.

Air pollution also causes major global environmental problems such as global warming and the depletion of the ozone layer. It is a major health problem in big cities of Sri Lanka and the health costs of treating respiratory diseases is escalating owing to increased vehicle numbers and urbanisation. Implementing long term solutions such as rapid mass transport systems such as electric trains, and improvement of the public transport systems is an urgent necessity.

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Air We Breathe: An Investigation into Air Quality

Prof. K.R. Ranjith Mahanama

Air is a mixture of gasses consisting of nitrogen, oxygen, water vapor, carbon dioxide, and inert gasses and several other minor constituents. This mixture creates a protective envelope around the earth surface which is known as the atmosphere. Atmosphere is not uniform. The density of gasses present at the earth surface is highest at lower levels, but gets thinner with elevation or altitude. You may have experienced this phenomenon when you are climbing a mountain. At higher elevations breathing is difficult due lack of oxygen. At the sea level;

- nitrogen and oxygen are the two most abundant gasses in air contributing to 99.0% of atmospheric constituents.
- water vapor composition varies from place to place and from time-to-time, and it accounts for rain and weather.
- abundance of carbon dioxide and other emissions have elevated significantly with the industrialization.
- inert gasses and other atmospheric constituents are in minute quantities.

As a composite, air introduces a blend of stability and reactivity to the atmosphere which is essential to maintain life on earth. However, the atmosphere undergoes dynamic changes due to the inputs from natural processes and human activities.

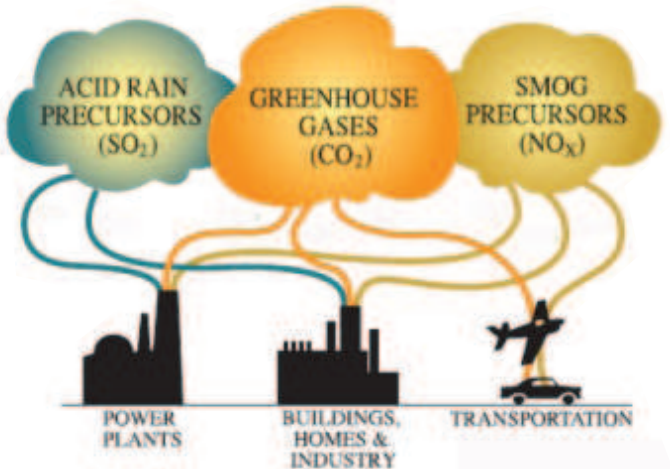
- *Inputs from natural processes:* Volcanic eruptions as well as wild forest fires and wind introduce gasses and particles to the atmosphere. Since the quantities are relatively low, atmosphere can cope up with the inputs and the overall impact is often negligible. In some cases, massive inputs can make significant impacts locally but they gradually diminish with the dispersion of inputs.
- *Inputs from human activities:* The human activities often release chemicals perturbing the atmospheric composition. The consequences are significant creating local problems as well as global problems. The gravity of the problem depends not only on how much is in the air, but also on the chemical nature of the released materials.

Air, without any of these inputs or emissions, is considered to be quality air. Air becomes polluted or its quality gets degraded when the amount of unwanted substances present in air increases beyond threshold values.

Atmospheric Inputs

Let's understand the processes which deteriorate the air quality.

- *Industrial emissions:* Though Sri Lanka is not an industrialized country, use of relatively out dated technologies, poor maintenance of the industrial equipments and impurities of the fuels contribute to significant releases of greenhouse gasses and hazardous chemicals to the atmosphere.



- *Motor vehicle emissions:* Significant number of our vehicles are used-vehicles and they are operating on poorly maintained roads. Most of the vehicles do not have facilities to control the emissions. Tampering the combustion mechanisms, impurities in the fuel and poor vehicle maintenance, continuously deteriorate the air quality. The five senses in you enable you to recognize the level of emissions from the motor vehicles especially diesel emissions. Go to a busy road in a city and you can smell the diesel fumes, taste the diesel, feel the carbon from diesel fumes deposited onto your body, see the smoke in air and hear the noise from the vehicles.
- *Household activities:* Perhaps you may have thought that the home is the safest place to live. In fact, it is the best place if you can control the air quality in your home. Unfortunately, we neglect the air quality without understanding that we are spending 80-90% of the time indoors. The issue of air pollution due to household activities will be discussed separately.

- *Agricultural practices:* We often introduce chemical pesticides and fertilizers in excessive quantities to get better yields. In most of the cases, these added chemicals get into air and ground water polluting them.

Through all these processes the air quality is degraded and people are compelled to breathe the polluted air or they are exposed to poor air quality conditions. These exposures not only degrade the health of the people but they damage the materials that belong to the people.

Current atmospheric problems due to degradation of air quality are,

- *Global warming:* This is the elevation of ambient temperature due to the excess of greenhouse gasses.
- *Acid rain:* Precipitation of acidic components released to the atmosphere.
- *Ozone Layer Depletion:* Thinning the ozone layer that protects us from hazardous ultra-violet solar radiations
- *Smog:* Smoke and fog that are released from industries and from motor vehicles which deteriorate the visibility and health.
- *Health issues:* Aggravation of existing health problems and causing new health problems.
- *Material Damage:* Corrosion of metallic and limestone structures.

Indicators of outdoor air pollution

Even without air quality measurements, one can sense the poor quality of air. Following are some of the indicators.

- One can sense the airborne pollutants (smell, taste, feel etc.)
- Haze formation and reduced visibility due to particles
- Reddish sunset (airborne

particles scatter the light)
- Heat stress and sunburns
- Health problems including asthma, breathing difficulties, headache, burning sensation in nose, eye and throat

Indoor air quality

So far the focus was on outdoor air quality but the problem in indoors is severe than in outdoors. To understand the exposure to pollutants or chemicals in outdoors and indoors one can do a simple test. Release a drop of perfume in your house (indoors) and find out the duration of smell. Do the same at a location outside the house which is open (outdoors). It will be noticed that the odors lasts longer indoors than outdoors. This is because mixing of air in the indoor is poor, and the chemical vapour stays longer, causing a higher exposure. But, in outdoors such chemical vapour get dispersed and diluted quickly resulting in a low exposure.

In many peoples minds air pollution is associated with contamination of urban air from automobile exhausts and industrial emissions. The following evidences will show how greater is the problem in indoor situations where we spend 80-90% of our time. Here, the term indoors refers to all the locations which have limited or restricted air circulation than where a free movement of air exists as in the outdoors. Most of the houses, schools, offices and vehicles belong to this category. Based on World Health Organization studies it is known that

- A pollutant released indoors is one thousand times more likely to reach people's lung than a pollutant released outdoors.
- Health problems due to air quality have direct correlations with indoor pollutants than outdoor pollutants
- Five hundred million people, mostly women and children in developing nations are exposed to levels of indoor air pollution that are above the safe levels.
- Three million of women and children die each year from indoor air pollution in developing nations primarily due to exposure to the smoke from cooking activities.
- As far as health is concerned, indoor air pollution is second in importance to sanitation for developing countries.
- It is estimated that indoor air pollution accounts for 4-6 % of the burden of disease, placing it above exposure to tobacco smoke, sexually transmitted diseases, alcohol and homicides as a leading causes of ill health and death.
- It has been estimated that unprocessed solid biomass fuels release at least 50 times more noxious pollutants than gaseous fuels.
- Poor air circulation in indoors elevates infection disease transmissions.
- 95% of low birth weight infants are born in developing nations. Both malnutrition and indoor pollutants account for the low birth weights.

In Sri Lanka, respiratory diseases are the second most leading cause of hospitalization over the last two decades. This is due to high exposures to the pollutants both at indoors and outdoors. Yet, only few attempts have been made to correct the problem. The current research findings of the few investigations carried out so far have established that indoor air pollution has contributed to aggravate the asthmatic conditions, to the development of chronic obstructive pulmonary diseases, to cataract formation, and to the low birth weights of the infants.

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Vulnerable groups

- *Infants:* Since the immune systems of infants are not fully developed, their small airways are more susceptible to the effects of inflammation.
- *Young children:* Young children with developing lungs breathe faster than adults, elevating the intake of pollutants. Children breathe a greater volume of air relative to their body weight making them more susceptible.
- *Infirm and elderly people:* They are also more susceptible to chronic conditions resulting from frequent and long periods of exposure.
- *Expectant women:* Poverty and indoor air quality which goes hand in hand worsens the growth of the babies.

Knowingly or unknowingly we are engaging in large number of indoor activities which result in releasing the pollutants. When these pollutants are confined to lower air volumes in indoors, airborne concentrations elevate, damaging health and materials kept in indoors. In addition to the indoor sources, some of the pollutants infiltrate to indoors and get entrapped in the air volume worsening the condition. This is more significant for the people who are living in industrialized areas and who are living closer to busy roads.

Indoor sources

Let's try to identify some of the indoor sources which can elevate indoor pollution levels.

- *Combustion processes including cooking, smoking, candle burning, oil lamps, mosquito coils:* All these combustion processes release various chemicals to indoors. The level of risk depends on various factors including the combustion process, ventilation and the nature of the chemicals. You may recognize that the control of combustion (some of these combustion processes can be completely avoided indoors) is the best way to improve air quality.

- *Off gassing from building materials:* Most of the building materials including paints, furniture and linen release chemicals. Not only that they can collect the pollutants onto those surfaces when the airborne concentration is high. You may have noticed the smell from these building materials. But people often ignore them assuming they do not contribute to health.

- *Bio effluents:* Dust mites (small animals in dust as well as on animals), fungi, bacteria, viruses, human and animal dander's are abundant indoors. Most of them are abundant in indoors due to our negligence. Most of these bio effluents are respirable and they can be transported to the lungs aggravating the health problems.

- *Cleaning activities:* It is good to live in a clean house but the cleaning itself can pose a risk. For example, all the cleaning activities including sweeping, dusting, and vacuuming release the settled particles onto air subjecting them to inhalation. Hence, cleaning should be done with covered breathing zone under proper ventilation in the absence of people around.

Poor ventilation

When a house or building is constructed, local authorities inspects the premises to assess the ventilation requirements, which include a minimum window area for each room. Once people occupy the building, the windows and doors are kept closed to prevent intrusion of insects, dust particles and other nuisances from the outdoor. Thus the restrictions to the natural ventilation make the air to be stagnant, and concentrate the pollutants indoors. This is a common mistake in most households and even in public places. In the night we further restricts the ventilation, and in addition introduce new pollutant sources such as smoke emanating from mosquito coils, joss sticks, oil lamps etc. The pollutants generated from these sources have lesser chance of escaping from the indoors.

Cooking

From cooking we expect to preserve the food, to enhance the nutritional value, to improve the appetite (taste, smell and appearance) and to destroy pathogens (bacteria and fungi). Inadvertently, during cooking we release pollutants indoors, and through negligence worsens the quality of indoor air. In early days, the kitchen was a separate entity from the main house. People cooked food in the kitchen and brought the cooked food to the table leaving the smoke outside. Now in modern middle-income houses, the kitchen is near the living room. Inhabitants are compelled to inhale the smoke during cooking (may be as an appetizer for the food). After the meal, often a mosquito coil or a cigarette is lit emitting smoke (may be the desert). This situation is very much similar to low-income families as well. Their kitchen may be only a corner of the living area of the house. Perhaps you may not believe that cooking is the biggest contributor that deteriorates the indoor air quality. It is known that,

- Solid fuels such as wood and biomasses produce 10 to 100

times more pollutants than the gaseous and liquid fuels.
- About half of the households use unprocessed solid fuels (biomasses including cow dung and agricultural waste) for cooking in the world.
- In Sri Lanka, 85-90% of the people use unprocessed solid fuels for cooking
- Smoke emanating from stoves is released at the breathing level elevating the health risk.
- Most of the stoves are not properly vented.
- Most of cooking is done while people are present.

It is estimated that smoke from indoor fires kill one person every 20 seconds in the developing world. Further, it is noted that inefficient stove can be as bad for health as smoking two packs of cigarettes per day. These evidences are more than adequate for us to correct the problem rather than sacrificing our health.

Your role in improving the indoor air quality

All of us are spending longer hours indoors, and we need to maintain the air quality to safeguard our health. Following guidelines enable us to improve the indoor air quality.

- Educate people about air quality and related health issues
- Open the doors and windows to bring and circulate fresh air (do not stagnate the air)
- Minimize the indoor combustion activities
- Ensure combustion appliances are properly vented and receive enough air supply
- Avoid procedures and products that can deteriorate air
- Avoid bringing products into the building that could release harmful or bothersome odors or contaminants
- Integrate air quality into purchasing decisions
- Buy limited quantities and do not store volatiles
- Give away partially full containers or surplus chemicals
- Choose non chemical methods for pest control
- Do not smoke and discourage others to smoke in indoors
- Do not block air vents
- Do not cut, rip or sand asbestos containing material
- Do not remove lead paint
- Do not idle the vehicles inside the closed garage

Final thoughts

In a world full of real and apparent risks, we often assume that the air we breathe is safe. Unfortunately, there are instances when dramatic episodes of air pollution have been documented to impair health and increase mortality rates. The above narration is an attempt to discuss the issues pertaining to air quality and it paves the way to appraise the health concerns and environmental impacts. The continuous degradation of the air quality prompts us to take immediate action in controlling the air quality. If we ignore the facts or fail to comprehend the gravity of the problem we may have to pay the consequences in terms of our health and wealth.

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The Next Issue of the Vidurava Scioence Magazine

Volume 30 Special Issue
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Theme: Lifestyle & Health

Lifestyle and Health

Adolescent Food Habits

Sports Medicine

Stress and Health Life

Smoking and Alcohol

Child Obesity

The Impact of Air Pollution on our Health

Dr Bandu Gunasena

Through technological advancements man has developed ways to purify the water and food we consume, but there is still no easy way to purify the air that we breath.

Most of the time people who work in risky environments are asked to wear heavy cumbersome masks. Therefore, it becomes very important to be aware of the air pollutants, their sources and the health effects of air pollution to protect our atmosphere and our health.

Pollutants can remain in the atmosphere as a gas or as a suspension of very fine solid particles or liquid droplets. Well known examples are sulphur oxides formed in volcano eruptions and some industrial activities, nitrogen oxides produced in high temperature combustion and thunder storms, as well as carbon monoxide emitted from incomplete combustion of natural gas and fossil or bio fuel, methane, benzene etc.

Other than air pollution in general, indoor air pollution has a bigger impact on health because a person would breathe that air for longer periods of time. Radon emissions from certain parts of earth, formaldehyde from plywood and carpets, lead from wall paints, carbon monoxide from fire wood are some of the important indoor pollutants.

Important organic allergens lead to asthma, while catarrh and allergies are the result of excreta of house dust mite, pollen of house plants and indoor mold.

Children below 5 years of age are highly susceptible to lung damage by polluted air. WHO estimates that there are 2.4 million deaths occurring annually due to illnesses directly related to air pollution of which the commonest organ to be affected is the lung, which is followed by the cardiovascular system.

Common lung diseases due to air pollution are bronchial asthma, Chronic Obstructive Pulmonary Disease (COPD), bronchiectasis, and recurrent pneumonia. These chronic diseases will lead to loss of working days due to cough, shortness of breath, wheeze and sputum production. When the problem becomes severe it results in hospital visits, admissions, permanent disability and premature death.

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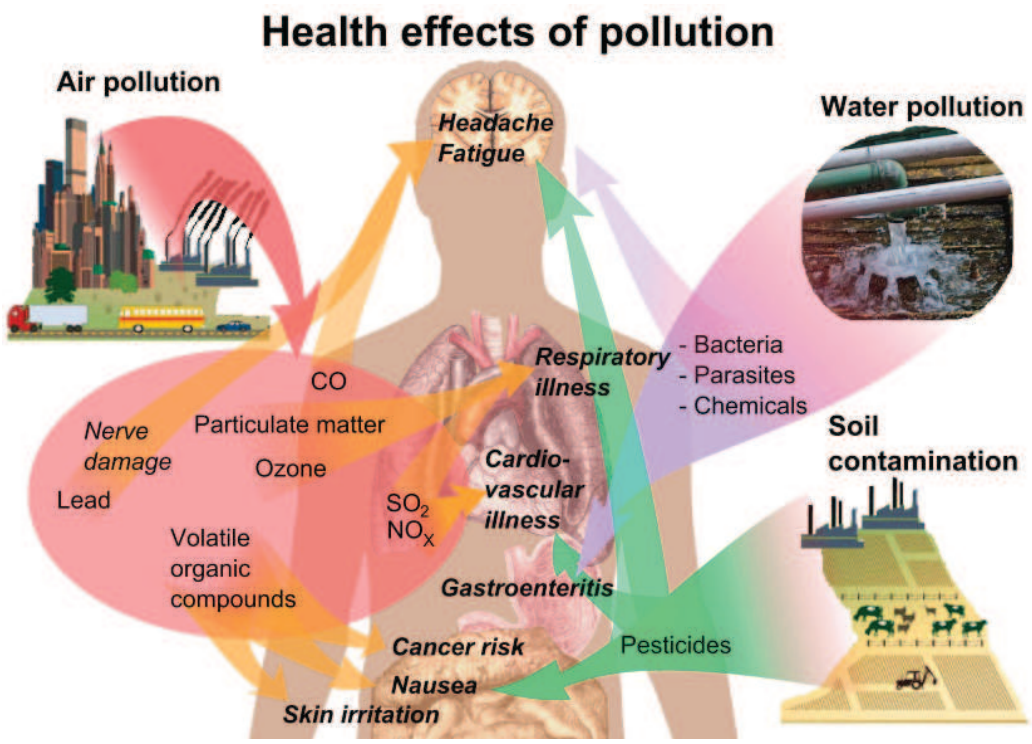
Asthma is a temporary obstruction to air ways occurring due to transient narrowing of bronchial lumen by constriction of the smooth muscles around



the air way . This can occur repeatedly in response to environmental pollutants but after some time the process can continue without the offending agent.

COPD is irreversible obstruction of air way due to chronic damage to air ways. Commonly this condition is due to cigarette smoking but at the same time fire wood fumes and diesel and petrol combustion fumes also can cause similar damage. Bronchiectasis is abnormal dilatation of bronchial tubes resulting in abnormal collections of mucus along the bronchial tree. This rich protein material can get infected easily with microorganisms resulting in recurrent chest infections and further lung damage.

Now there is conclusive evidence to prove that exposure to fine particulate matter shorten the life expectancy and increase the risk of lung cancer.

Exposure to asbestos dust cause chronic lung damage leading to permanent shortness of breath and lung cancer. Similarly dust generated in coal mines, silica from metal crushing sites and dust from graphite mines can cause chronic lung damage.

COPD is irreversible obstruction of air way due to chronic damage to air ways. Commonly this condition is due to cigarette smoking but at the same time fire wood fumes and diesel and petrol combustion fumes also can cause similar damage.

Other than the effects related to the lung, air pollution is also a risk factor for coronary artery disease and stroke.

Air pollution can lead to cancers in other parts of the body like uterine cervix and brain.

In order to achieve targets of clean air, industrial work needs to be done with modern instruments designed to reduce pollution. Particulate control devises would prevent the workers from getting over exposed to hazardous fumes.

Exposure to asbestos dust cause chronic lung damage leading to permanent shortness of breath and lung cancer.

Public awareness about types of air pollution and the methods to avoid or minimize the risks, along with a proper and effective legal system is mandatory in controlling air pollution.

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Monitoring and Regulation on Air Quality

Dr Thusitha Sugathapala

Introduction

Ambient air quality degradation is becoming a severe environment problem, especially in urban sectors in Sri Lanka. Air pollution is experienced in both indoor and outdoor environments, as a result of a mix of thousands of sources ranging from individual cook stoves to motor vehicles, industrial processes and power plants. There are various categories of air pollutants too, leading to numerous adverse effects and impacts, ranging from human health, effects on plants and animals, agriculture and food production, damage and soiling of buildings and structures, stratospheric ozone depletion, acidification, global warming and climate change. The complex nature of air pollution requires the development of a comprehensive air quality management (AQM) plan to maintain the quality of the air at acceptable levels. Under an AQM plan, appropriate policies, strategies and actions should be developed and implemented to control emissions of air pollutants (i.e. source emission standards), ensuring that pollution concentrations in the ambient air do not exceed defined target levels (i.e. air quality standards - AQS). As such, monitoring and regulation on air quality become essential elements of an AQM plan in any country (see **Figure 1**). The capacity for monitoring in Sri Lanka is weak due to the inadequacy of measuring stations and equipment. However, commendable progress has been achieved in standards and regulations for air pollution control. Presently, ambient AQS (outdoor) are in place and emission standards for mobile sources are being implemented under Sri Lanka Vehicle Emission Testing (SLVET) programme. The emission standards for stationary sources have been already developed and regularized, and are about to be fully enforced. However indoor air quality issues of built environments are yet to be addressed by regularity interventions in the country.

Air Pollution

Air pollution refers to emission of any substance to the atmosphere, altering the air's natural composition and exceeds the capacity of natural processes to convert or disperse it, thus endangering human health and environment. These emissions may result from primary air

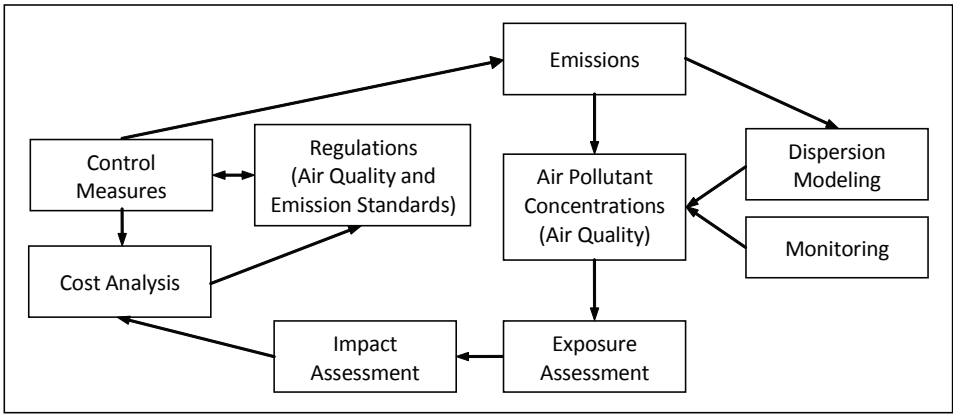

Figure 1 Monitoring and regulations inair quality management (AQM) plan

pollutants emitted to air directly from a source or from the secondary air pollutants produced in the air by the interaction of primary pollutants or by reaction with natural atmospheric constituents. Examples of common primary air pollutants include particulate matter (PM), sulphur oxides, nitrogen oxides, carbon monoxide and volatile organic compounds (VOC) while secondary air pollutants include ozone, formaldehyde, peroxy acetyl nitrate, smog and acid mist. Emissions can be identified on the basis of their sources as point sources such as major industrial sites; area sources such as domestic emissions and emissions from light industry and commercial areas; mobile sources such as motor vehicles; and biogenic (or natural) sources such as dust storms, forest fires, and volcanic eruptions.

Emitted pollutants could also be categorized as criteria pollutants and air toxics, as defined by the United State Environmental Protection Agency (USEPA). Criteria air pollutants are those for which an ambient AQS or guideline has been established to protect human health and welfare. These usually include carbon monoxide, nitrogen oxides, sulfur dioxides, PM (less than 10 micrometer diameter - PM_{10} and less than 2.5 micrometer diameter - $PM_{2.5}$), hydrocarbons and lead. Air toxics consist of chemical, physical and biological agents of different types, which are known or suspected to cause serious health problems. These pollutants include a range of hydrocarbons such as benzene, toluene, polycyclic aromatic hydrocarbons, pesticides, asbestos, chlorine, formaldehyde and other numerous less common substances. Many urban air pollutants can also contribute directly or indirectly to global climate change, but the main greenhouse gases (GHGs) which contribute to climate change are carbon dioxide, methane, nitrous oxide. In AQM, GHGs are often not considered because they do not lead to direct health and environmental impacts.

Examples of common primary air pollutants include particulate matter (PM), sulphur oxides, nitrogen oxides, carbon monoxide and volatile organic compounds (VOC) while secondary air pollutants include ozone, formaldehyde, peroxy acetyl nitrate, smog and acid mist.

Monitoring of Air Pollution

Monitoring of air pollution is of two types: air quality monitoring and source emission monitoring. Each of these monitoring schemes is a key component of an AQM programme. Air quality monitoring refers to the periodic or continuous sampling and analysis of air pollutant concentrations in space and time in ambient air. This provides the data required to assess compliance with the existing ambient air quality (AAQ) guidelines or standards and to assess trends in air pollutant concentrations. In order to obtain accurate and reliable estimates of AAQ in a given local region or city, a network of carefully located air quality monitoring stations capable of measuring and recording real-time concentrations of different pollutants is required. Presently, Sri Lanka does not

have a fully operational air quality monitoring station, but initiatives have been taken by relevant authorities to acquire few stations with government funding.

Table 1: Comparison of AQS of Sri Lanka with international standards (in$\mu g/m^3$)

Pollutant	Sri Lanka NAAQS		EU AQLVs		USEPA NAAQS		WHO AQG	
	Standard	Average	Standard	Average	Standard	Average	Standard	Average
Carbon monoxide	58,000 30,000 10,000	Any time 1 hr 8 hr	10	8 hr	10 40	8 hr 1 hr	10 30	8 hr 1 hr
Sulfur dioxide	200 120 80	1 hr 8 hr 24 hr	350 125 20	1 hr 24 hr Annual	385 80	24 hr Annual	500 20	10 min. 24 hr
Nitrogen dioxide	250 150 100	1 hr 8 hr 24 hr	200 40	1 hr Annual	100	Annual	200 40	1 hr Annual
Ozone	200	1 hr	120	8 hr	160	8 hr	100	8 hr
PM_{10}	100 50	24 hr Annual	50 40	24 hr Annual	150	24 hr	50 20	24 hr Annual
$PM_{2.5}$	50 25	24 hr Annual	-	-	35 15	24 hr Annual	25 10	24 hr Annual

Source emission monitoring refers to the determination of pollutant concentrations in individual pollution sources, and this is used to assess the compliance of each source with relevant source emission standards. The monitored pollutant concentrations could be used in dispersion model, together with information on meteorological and geophysical conditions, to estimate ambient air pollutant concentrations at costs much lower than those for AAQ monitoring stations. Another important modeling tool is source apportionment, which starts from observed concentrations and their chemical composition and estimates the relative contribution of various source types by comparing the composition of sources with the observed composition at the receptors.

Air Quality Standards

AQS are ambient air quality levels for the acceptable presence of selected pollutants in the atmosphere, which are derived from expert evaluation of current scientific evidence of the impacts on human health and the environment. There are two types of standards: primary and secondary. Primary standards define air pollutant concentration limits intended to protect the public health, including sensitive populations such as asthmatics, children and elderly, while secondary standards define limits to protect the environment, including damage to animals, crops, vegetation and buildings.

In each country, AQS are established and published through national legislative and regulatory processes, and will vary according to country-specific approaches towards balancing risks to health and environment, technological feasibility, economic considerations, and other socio-political factors. This variability will depend on the country's level of development, capability in AQM and other factors. In many instances, the national and local government authorities in Asia have adopted a range of AQS either based on World Health Organization (WHO) air quality guideline (AQG) values, or the relevant standards of developed economies such as National Ambient Air Quality Standards (NAAQS) of USEPA or Air Quality Limit Values (AQLVs) of European Union (EU).

The National Environmental (Ambient Air Quality) Regulation of 1994, published under the National Environmental Act No. 47 of 1980 by the Ministry of Environment and Natural Resources, sets NAAQS to protect human health and environment in Sri Lanka. This regulation, amended in 2008, specifies the concentration limits for six air pollutants namely PM_{10}, $PM_{2.5}$, carbon monoxide, sulfur dioxide, nitrogen dioxide and ozone. **Table 1** presents a comparison of NAAQS of Sri Lanka with AQS of USEPA and EU, and AQG of WHO. The data shows that NAAQS of Sri Lanka are in comparable with that of the developed economies. Sri Lanka is among the few countries in the

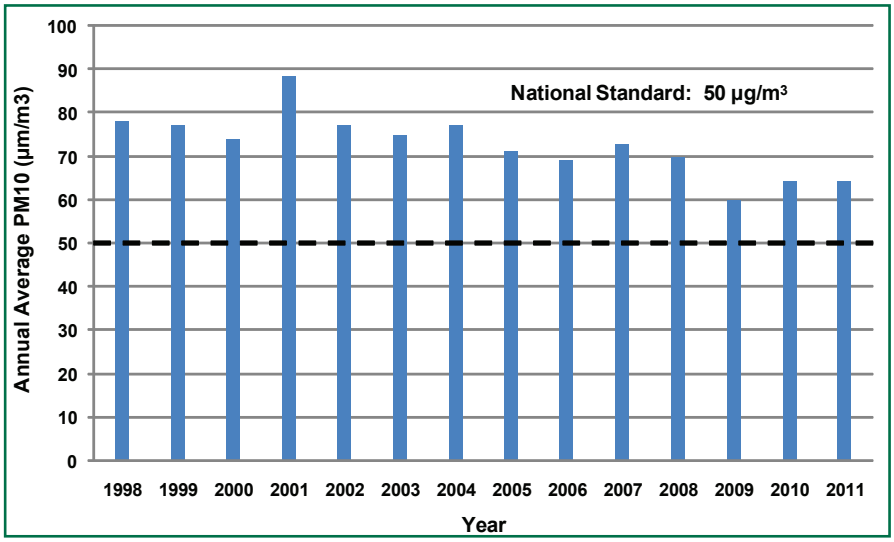

Figure 2 Annual average PM10 concentrations at Colombo Fort Monitoring Station

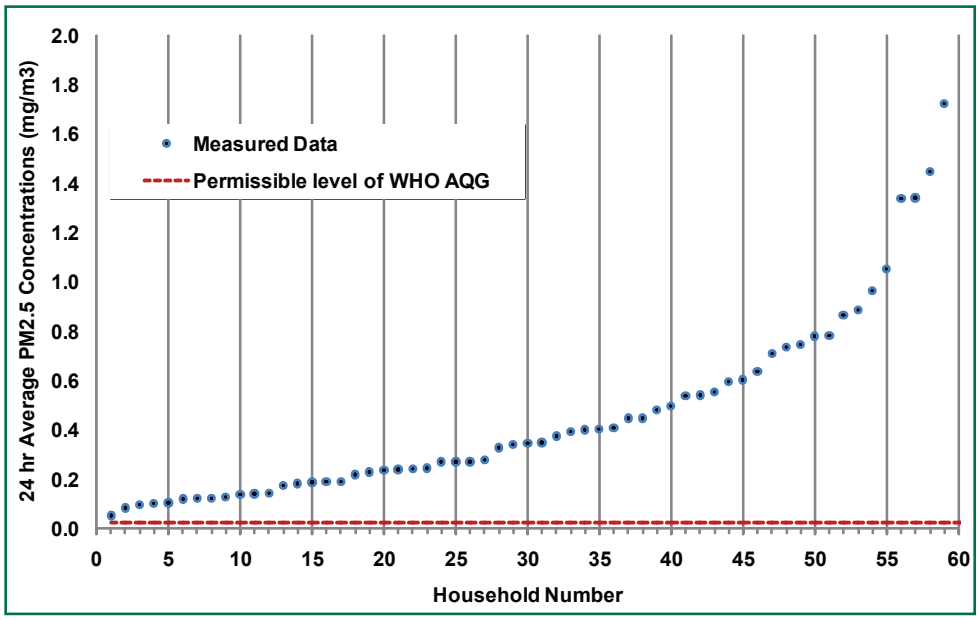

Figure 3 PM2.5 concentrations in estate sector households - arranged in ascending order

region having AQS for $PM_{2.5}$.

The annual average PM10 concentrations in Colombo, as recorded at the Colombo Fort Monitoring Station, exceeds the national standard of 50 µg/m^3, though there is a decreasing trend since 2002 from about 88 µg/m^3 to 64 µg/m^3 (**see Figure 2**). The lowest concentrations have been experienced since 2008, which could be attributed to the implementation of SLVET programme. Yet, these levels far exceed 20 µg/m^3 sets in AQG of WHO, emphasizing the issues of urban air quality degradation. The indoor air pollutions in households show much more severe situations. A study carried out on indoor air pollution in the estate sector households shows that the concentrations of $PM_{2.5}$ in the kitchen (which vary from 50 µg/m^3 to over 4000 µg/m^3) far exceed the limit 25 µg/m^3 set in AQG of WHO, as illustrated in **Figure 3**. This situation is attributed to the solid biomass cooking in conventional cook stoves in poorly ventilated enclosed spaces. Another study under taken in urban road side households revealed that the indoor air quality is affected by infiltration of vehicle pollutions into the indoor environment and both indoor and outdoor air quality levels exceeds the limits in the standards.

Source Emission Standards

The main intervention of controlling air pollution is achieved through enforcement of emission standards at the source itself. There are two categories – mobile and stationary sources emission standards. In order to control emissions from mobile sources, SLVET programme was developed and implemented as a nationwide programme. This was made effective from November 2008, and presently covers eight provinces. This was formulated as a centralized, test-only system with on-line information transfer to a database. The test procedures employed are no-load idle and fast idle test for gasoline vehicles and snap acceleration test for diesel vehicles. There are about 175 centers available island-wide. In year 2011, 2.38 million vehicles

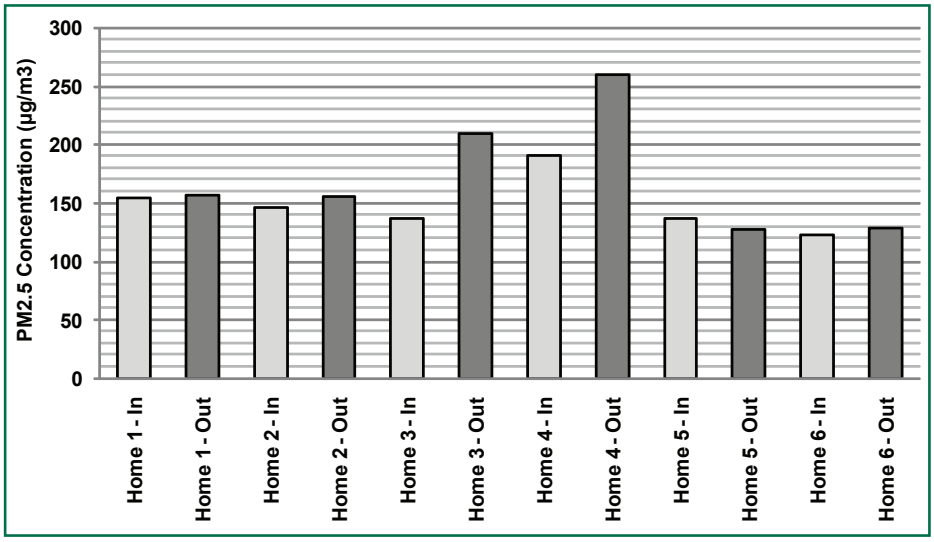

Figure 4 PM2.5 concentrations in indoor and outdoor of households

Another study under taken in urban road side households revealed that the indoor air quality is affected by infiltration of vehicle pollutions into the indoor environment and both indoor and outdoor air quality levels exceeds the limits in the standards.

have been tested, which is about 82% of the active vehicle fleet. Test results show about 17% failure in the first test and 13% failure in the re-test, indicating a 2% final failure rate.

Emission standards for stationary sources have also been developed. Once gazetted, the proposed standards will be mandatory and legally enforceable. In order to cover all the types of stationary sources, the standards adopt a two-tier approach. Tier 1 - equipment based standards is the primary one and covers stack emissions from commonly used equipment in industry including thermal power plants, boilers, thermic-fluid heaters, incinerators, crematorium, cupola, furnaces, ovens and cement kiln. In tier 2 – pollutant based standards, more than twenty pollutants, both combustion and non-combustion sources, are covered. Further, separate schedules for fugitive emissions are also included, covering PM, VOC, acid mists and asbestos fiber. Implementation of these standards would be a very important step towards mitigating air pollution in the country, but would be a challenging task due to the diversity and complexity of the emission processes and pollutants to be covered.

It could be concluded that both monitoring and regulation on air quality are important aspects of air quality management plan of the country, which need comprehensive planning and support for implementation from all relevant agencies and stakeholders.

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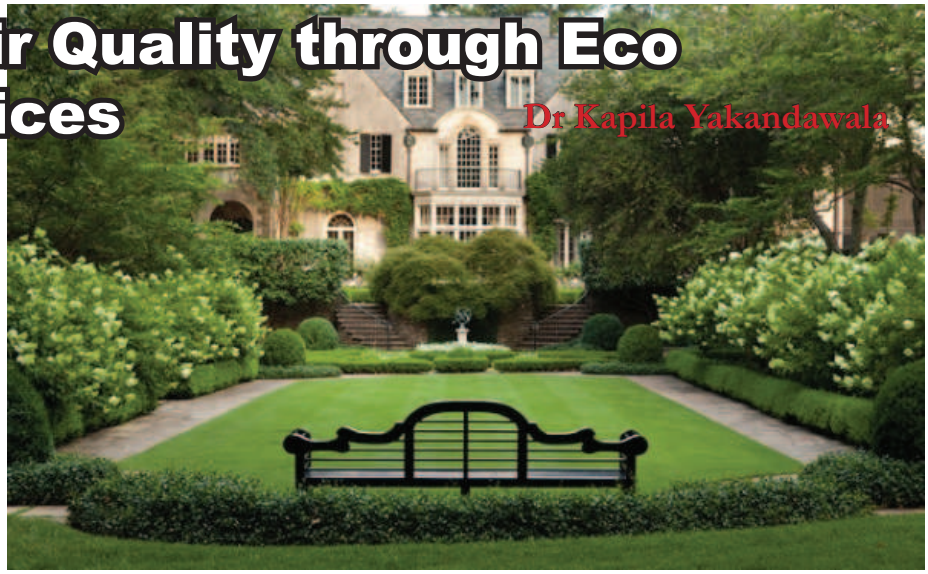
Enhancing Air Quality through Eco System Services



Dr Kapila Yakandawala

Human health and wellbeing depends upon the services provided by ecosystems and their components: air, water, soil, nutrients and organisms. Ecosystem services are the processes by which the environment produced resources are utilized by humans such as clean air, water, food and other materials. The continued delivery of these resources remains essential to our economic prosperity and other aspects of our welfare. Ecosystem services provide large scale benefits at several levels (local, regional and global) and to different groups (individuals, commercial firms and public bodies). Despite this, ecosystem services tend to be significantly undervalued by the society. Reasons being lack of adequate information and knowledge about ecosystem functions and the benefits they generate for the society. As no formal market for ecosystem services exists, these services are not allocated a price that would give some indication of their economic value to the society.

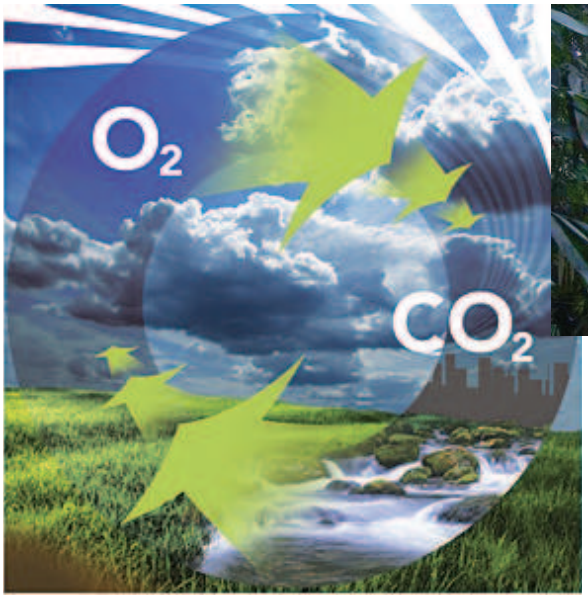
Although the most obvious threats to biodiversity, and in consequence to ecosystems services, come from direct human action including land use change and agriculture, there are also indirect threats from environmental pollution. Air pollution alone plays a part in this and this article will provides a review of current understanding of the interactions between air quality and plants and explore the routes towards the wise use of plants in combating air pollution.

What is air quality?

The term air quality means the state of the air around us. Good air quality refers to clean, clear, unpolluted air. Clean air is essential to maintain the delicate balance of life on this planet not only for humans, but also for other animals, vegetation, water and soil. Poor air quality is the result of a number of factors, including emissions from various sources, both natural and human induced. Poor air quality occurs when pollutants reach concentrations high enough to endanger human health and the environment. Air quality improves with increased percent of vegetation cover.

Forests: huge 'oxygen factories'

Today the earth's atmosphere contains about 21 percent of oxygen. However, early in earth's history, the atmosphere contained no oxygen but was rich in water vapour and other



gases. That situation began to change about three billion years ago when the first living organisms appeared. Among the first life forms were simple blue-green algae, which through the process of photosynthesis absorbed carbon dioxide from the atmosphere and chemically converted it into nutrients, releasing oxygen as a by-product. Over time the simple life forms developed into complex plants that also continued to produce oxygen. Most plants largely absorb carbon dioxide and produce oxygen during the day through photosynthesis and consume oxygen and produce carbon dioxide during the night through respiration. Between production and consumption, oxygen levels stay in balance today. The following statements give a clear idea about the importance of trees or forests in the production of clean air (Oxygen) and absorption of carbon dioxide.

"One acre of forest absorbs six tons of carbon dioxide and puts out four tons of oxygen. This is enough to meet the annual needs of 18 people." - *U.S. Department of Agriculture*

"On average, one tree produces nearly 260 pounds of oxygen each year. On this basis mature trees can provide enough oxygen for a family of four." - *Environment Canada, Canada's national environmental agency*

"One acre of trees annually consumes an amount of carbon dioxide equivalent to that produced by driving an average car for 26,000 miles. That same acre of trees also produces enough oxygen for 18 people to breathe for a year." - *New York Times*

Plants to intercept particulate matter

Particulate matter (PM) is an air pollutant consisting of a mixture of particles suspended in the air. These particles are emitted into the atmosphere through man-made processes including combustion from car engines; burning of solid-fuel; combustion in households; industrial activities (building, mining, manufacturing of cement, ceramic and bricks); erosion of the pavement by road traffic and abrasion of brakes and tyres; and work in caves and mines or natural processes. Among air pollutants, PM is of considerable concern for public health. According to the aerodynamic diameter, PM can be divided into fine ($PM_{2.5}$ /<2.5μm) and coarse particles (PM_{10} /<10μm). The fine particles are capable of penetrating into the lungs and are therefore an important matter of concern regarding human health.

Urban vegetation can be successfully used to reduce air pollution caused by PM. Research has shown that atmospheric dust over wooded areas can be 75% lower than over relatively non-vegetated, populated areas. Plants can remove PM pollution by intercepting airborne particles. Some particles can be absorbed into the plant, though most of the particles intercepted are retained on the plant surface. The intercepted particle often is resuspended to the atmosphere,

washed off by rain, or dropped to the ground with leaf and twig fall.

Recently there has been renewed interest in the use of vegetation to improve air quality, in particular pollution caused by PM. The ability of a vegetation to intercept PM depends on their morphological features such as leaf area, inter-nodal distance, petiole length, leaf orientation, leaf arrangement, presence of hairs, hair type etc. Most of these morphological characters collectively contribute to a dense canopy and others contribute to a coarse leaf texture where both as a whole play an important role in PM interception from air. These morphological characters vary from species to species and studies conducted have identified certain plants with greater potential to intercept PM. Such plants includes shrubs such as *Durantha repens*, *Helicteres isora* (Screw plant), *Bougainvillaea glabra* (Bougainvillaea), *Murraya paniculata* (Orange Jessamine), *Acalypha inferno* and trees such as *Terminalia arjuna* and *Mangifera indica* (Mango) are some examples.

Recently, there has been a renewed interest in Sri Lanka to beautify the urban environment. Therefore in landscaping activities such as road side planting, planting for screening purposes and other purposes in school premises, parks, and around office buildings with plants of desirable morphological characters, can be used to obtain health and environment benefits. Therefore, intelligent plant selection based not only on aesthetic aspects (beauty) but also on morphological aspects of plants should be promoted.

Removal of gaseous air pollutants

Plants are capable of sequestering many gaseous pollutants from the atmosphere, including nitrogen dioxide (NO_2), sulfur dioxide (SO_2), ozone (O_3) and carbon monoxide (CO). They are capable of removing gaseous air pollutants primarily by up taking via leaf stomata, though some gasses are removed by the plant surface. Once inside the leaf, gasses diffuse into intercellular spaces and may be absorbed by water films to form acids or react with inner-leaf surfaces. Studies conducted in USA revealed that air quality improvement in New York City due to pollution removal by trees during daytime averaged 0.45% for ozone, 0.43% for sulfur dioxide, 0.30% for nitrogen dioxide, and 0.002% for carbon monoxide. Therefore, plants in urban areas play a vital role in removing gaseous air pollutants.

Ornamental plants to clean indoor air

Many of us spend so much time indoors in enclosed spaces, such as the home, schools or at work places, and therefore maintaining a good indoor air quality is very important.


Bougainvillaea glabra (Bougainvillaea)


Terminalia arjuna

Air in these spaces can also be polluted from pollutants emitted from indoor sources. Poor ventilation systems, sealed buildings and the use of synthetic products in the home are the main causes of indoor air pollution. Newly constructed buildings are better insulated and sealed tightly to conserve air-conditioning. While it does save both money and energy, this new found efficiency has its downside in that pollutants may be trapped indoors and have less opportunity to dissipate to the outside. In fact, in certain instances, air pollution can be worse indoors than outdoors. Chemicals released from synthetic fabrics, furnishings, household products and in personal care products are among the contributors, which includes oxygenated volatile organic compounds (oVOCs) such as benzene, formaldehyde and trichloroethylene. In order to metabolize these chemicals, plants produce increasing levels of enzymes that transform these chemicals into less toxic substances. At the same time, as it turns out, the plant draws down more and more oVOCs, which can be metabolized by the enzymes. Not only oVOCs, some indoor plants are also capable of absorbing other pollutants such as sulfur dioxide, nitrogen dioxide and ammonia.

All ornamental plants are beneficial in this regard, at least to a certain degree, but some ornamental plants are better at removing these compounds. These plants actively consume certain types of air pollutants, which can have long-term positive health and environmental impacts. NASA has been researching on methods of cleansing the atmosphere in space stations to keep it fit for human habitation over extended periods of time, and they have also found that some ornamental plants help fight pollution indoors.

Some examples of plants commonly used in interior decorations in Sri Lanka which possess higher capabilities in removing indoor air pollutants are *Ficus benjamina* (weeping fig), *Sansevieria trifasciata* (snake plant), *Chlorophytum comosum* (spider plant), *Hedera helix* (English ivy), *Ficus elastica* (Rubber plant), *Dracaena fragans* 'Massangeana' (Cornstalk dracaena), *Dracaena marginata* (Red-edged dracaena) and *Epipremnum aureum* (Devil's ivy).

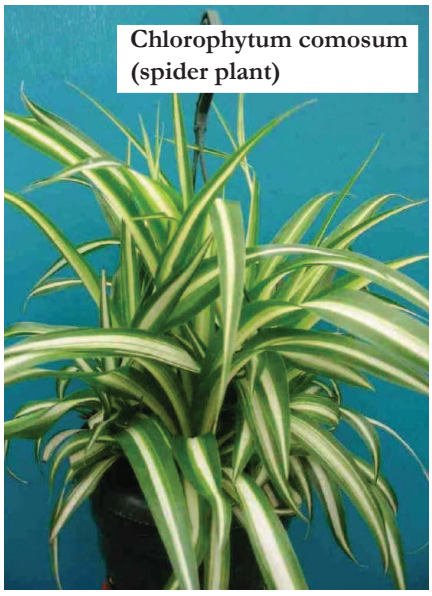
Therefore, we can promote using these plants in interior plant decorations over other ornamental plants not only to reap aesthetic benefits but also to purify the air indoors leading to a healthy life as people spend majority of their time indoors.

Lessening odour pollution of air

Although odour pollution of air is not directly harmful to


Dracaena fragans 'Massangeana'


Dracaena marginata (Red-edged dracaena)


Chlorophytum comosum (spider plant)

the human health, it can affect mental attitudes and enjoyment of the environment. Livestock facilities such as poultry and swine operations and industrial sources such as, meat, fish and other food processing plants, oil refineries, paint and plastic manufacturers and sewage and domestic refuse processing plants are often responsible for the emission of offensive odours. Emissions of ammonia and other gasses from these facilities/sources could have a negative impact on maintaining good neighbor-relations. Creating a barrier (windbreak) around the sources of these odours by using trees, shrubs, and other vegetation is a technology thought to help reduce odour emissions. The windbreak provides visual isolation and/or aesthetic enhancement, and also affects airflow near the site. These windbreaks are thought to reduce odour emissions by dilution and dispersion of gas concentrations of odour by a mixing effect created by windbreaks and through physical interception of odour particles and deposition of them on plants. In a wind break approximately 50 percent of the wind should be deflected up and over the wind break and 50 percent should pass through the canopy of the trees.

The effectiveness of ecosystem services provided by plants to enhance air quality depends on species composition, age, location with respect to habitation of people, and other elements in the landscape. Therefore, effective planning and management of ecosystems is vital to provide a pleasant, healthy and comfortable environment for all of us to live, study and work happily. Plants are on the job 24 hours every day working for all of us to improve our environment and quality of life. Therefore it is our duty to protect them for today and for tomorrow.

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Clean Air

What is clean air? When look at the composition of the clean air, it is found that there are 10 gases which make up clean air: In order of highest to lowest concentration they are **Nitrogen, Oxygen, Argon, Carbon dioxide, Neon, Helium, Methane (CH_4), Krypton, Hydrogen, and Xenon**.

Five of them travel alone, so we call them atoms. For example, a helium balloon contains atoms of helium (He), but an oxygen tank contains molecules of oxygen (O_2). When there's two or more atoms are bonded together, they are called molecules.

Nitrogen:
Eight (8) out of 10 atoms (or molecules) of air are made of nitrogen. Nitrogen gas can't be seen but when it is cooled to -320 °F (-195°C) it turns to a liquid, which you can see. Being this cold makes it handy for many things. It is being used to quickly freeze cream and sugar to make ice cream.

Liquid nitrogen is also used to cool certain metals to the point where they become superconductors. Superconductors conduct electricity (electrons) without any resistance. Oxygen reacts with many things including paint. Therefore, expensive works of art and other rare relics are stored in pure nitrogen. Nitrogen gas is fairly inert and doesn't react (combine) with most other substances, so it is used to protect items and keep oxygen away.

Under high temperatures, like in jet engine or car engine, nitrogen will combine with oxygen to form a class of toxic compounds called nitrogen oxides. The simplest having one nitrogen and one oxygen (NO). Others have two nitrogens and one oxygen (N_2O), one nitrogen and two oxygens (NO_2), and the fourth has two of each (N_2O_2). Their names (in order) are nitrogen oxide, dinitrogen oxide, nitrogen dioxide, and dinitrogen dioxide. Nitrogen dioxide has a brownish appearance, and it could often be seen in the polluted cities.

There are 10 gases which make up clean air: In order of highest to lowest concentration they are Nitrogen, Oxygen, Argon, Carbon dioxide, Neon, Helium, Methane (CH_4), Krypton, Hydrogen, and Xenon.

Oxygen:
Two (2) out of 10 atoms/ molecules of air are oxygen. Oxygen is produced by plants and is consumed by animals. Animals need oxygen to "burn" the food they eat in order to get the calories (energy) they need. The way animals use oxygen to burn food is different than a fire, but it produces the same products of carbon dioxide and water. Of all of the gases that make up air, oxygen is the most reactive.

Oxygen is everywhere. As a gas it makes up 21% of the air. Some oxygen gas is dissolved in water, and some oxygen gas is in the pores in the ground. Ninety per cent (90%) of the weight of the water in the rivers is oxygen atoms. Remember water is H_2O. The one oxygen in H_2O weighs 8 times as much as the two hydrogen atoms combined. The trees and grass are made out of carbon, oxygen, hydrogen, and nitrogen, with oxygen accounting for about half of a plant's weight. The rocks, the soil, and the mountains contain metals and silicon that is bound to oxygen, which makes up about 1/2 of their weight. Think about it; one half of a mountain's weight is from oxygen.

Argon:
Argon is 1 out of 100 atoms/ molecules of air. Argon is an inert gas that is used to pressurize light bulbs. Being inert it doesn't react with the tungsten metal, which makes

the filament. The argon gas also helps keeps the tungsten metal atoms on the surface of the filament from jumping off the filament. Argon gas is also used in welding to push away the air so that the oxygen in the air won't react (oxidize) the metal being welded.

Carbon dioxide:
Carbon dioxide only makes 3 out of 10,000 atoms/molecules of air; however, it supplies the carbon that plants use to make leaves, trunks, roots, etc. It's hard to believe that the weight of giant redwood trees came from the small amount of carbon dioxide gas in the air.

Neon:
Two (2) out 100,000 atoms/molecules of air are Neon. It is a clear inert gas; however, high voltage can strip electrons off neon atoms. As the electrons fall back into place, they give off ultraviolet light (black light), which you can't see. However, the glass tubes are coated with different phosphor powders, which glow when ultraviolet light hits them.

Helium:
Five (5) out of 1,000,000 atoms or molecules of air are helium. Helium is the second lightest gas (hydrogen is lightest). It is used to fill toy balloons and weather balloons. It is so inert that there is no danger of igniting nor will it combine with other elements. For this reason it is used in welding by having helium gas surround an electric arc that is melting a metal. The flow of helium gas keeps the oxygen away from the metal so that the oxygen won't oxidize (rust) the metals being welded.

Methane:
Two (2) out of 1,000,000 atoms/molecules of air are methane molecules. Bacteria is a big source of methane gas and this type of bacteria is found in termites, cattle (cow flatulence), rice paddies, swamps (called swamp or marsh gas), and in the sea bed. In the sea bed, methane can be found trapped in ice (see person holding ice that's on fire). Methane also comes from petroleum fields and is the natural gas you cook with. An embarrassing source of methane is from the eating of beans.

Krypton:
One (1) out of 1,000,000 atoms/molecules of air is krypton gas. You may remember krypton as the name of the planet that Superman came from. The pieces of the planet that fell as meteorites were called kryptonite. The element krypton is used in lamps in a similar way that argon is used (see above). The word krypton comes from "Krypto" meaning hidden. The gas krypton was in a way hidden because it took quite a while for scientists to discover it.

Hydrogen:
One (1) out of 2,000,000 atoms/molecules of air is hydrogen. Hydrogen is the lightest element, which is why it was the preferred gas to fill blimps and dirigibles. Unfortunately, hydrogen is very flammable, which led to the catastrophic tragedy of Germany's Hindenberg airship.

Xenon:
Eighty seven (87) atoms out of 1,000,000,000 (one billion) atoms/molecules of air are xenon. Like argon and krypton, xenon is used as the gas in lamps. This one is for a car's headlamp. These are probably the ones that look more blue.

One Last Look at Composition of Air:
Imagine the volume of air in a typical classroom that is 30 feet by 30 feet with a 10 foot high ceiling. Also assume, we separated all the gases. Oxygen would cover the room to about 2 feet deep. Nitrogen would fill almost to the ceiling (another 8 feet minus a couple of inches). Argon gas would fill a one inch layer over the whole room. The remaining gases fill the last one inch. Carbon dioxide has about the same volume of one student. Neon is 1.5 gallons. Helium would fill a one liter bottle. Methane gas would fill someone's 1/2 liter bottle. Krypton would fill a 12 oz soda can. Hydrogen would fill about half of a 12 oz soda can. And xenon gas would have the volume of a pencil's eraser.

Source:
http://www.chemistryland.com