

Presidential address

Physical and chemical pollutants and their impact on health

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Introduction

In delivering the Presidential Address of our College in the Year 2000, at the end of the millennium, it may have been appropriate for me to delve into the past and consider the challenges of the future. Both these I have done on two similar occasions in the past— as the President of the Association of Community Medicine in 1996 ('A Quarter Century of Public Health') and as the President of the College of Medical Administrators in 1997 ('Beyond 2000 A.D.- Health Issues and Options').¹ Today, I hope to deal with a topic that has interested me for many years, and would gain more importance in the new millennium— physical and chemical pollutants and their impact on human health.

Improvements in medical and public health practices, which have reduced infant mortality and increased life expectancy, have led to a rapid increase in the population in the present century. This has caused increased pressures on agriculture to meet the nutritional needs of the population and pressures on industry to meet the demands for energy and the material goods of civilization. Pollution of the environment is caused by the waste products from these activities, which may sometimes have adverse effects on human health.

Early environment health programmes were directed almost exclusively to the control of communicable diseases caused by biological agents that were transmitted through identifiable features in the environment. New environmental health problems, notably those arising from pollution of the environment by

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rapid agricultural development and the use of modern methods in agriculture, industrialization, and developments in transportation utilising fossil fuels have now emerged, and require urgent attention. Today's community physicians will have to equip themselves with the knowledge and skills required to face these new challenges.

Effects of pollutants on health

Environmental pollutants can affect human health in two distinct ways:

1. by the transfer of pollutants from the environment to man through consumption of polluted food or water, or the inhalation of contaminated air resulting in acute or chronic ill effects; and
2. by causing secondary consequences on human health from damage to the external environment, such as by causing damage to food crops and destruction of fish life in polluted rivers, which would exert their effects through a reduction in food supplies.

Acute effects

Episodes of acute poisoning have done more than anything else to draw public attention to the potential hazards of chemicals: air pollution was the cause of the large number of deaths and illness caused by respiratory disease in Meuse River Valley in Belgium in 1930 in Donora, Pennsylvania in 1948 and the London Fog in 1952; leaking methyl isocyanate from a pesticide plant in Bhopal in India killed 2500 people and blinded and injured more than 200,000; and in 1986, the Chernobyl nuclear plant accident killed 300 people in the then Soviet Union, and 2 million people had to be moved out of areas affected by radiation.^{2,3,4,5}

Chronic Effects

Unlike acute effects, which occur from exposure to massive doses of pollutants for short periods of time, chronic effects resulting from exposure to smaller doses for long periods of time are very difficult to quantify. These effects may be characterised by a long period of latency and may not even be expressed in an individual's lifetime.

The damaging effects from chronic exposure are essentially two fold:

- 1) *Somatic effects* - affecting body tissues of the individual exposed to the agent; and
- 2) *Genetic (hereditary) effects* - affecting the gonads, sparing the individual but affecting the health of descendants through several generations.

The *somatic effects* of pollutants are many and varied, they include:

- a) *damage to specific organs in the body*, e.g. liver, kidneys, lungs, and nervous system;
- b) *carcinogenesis* - the induction of cancer in a wide range of tissues;
- c) *teratogenesis* - damage to the rapidly growing foetus resulting in gross physical abnormalities, e.g. thalidomide;
- d) *enzyme interactions* causing stimulation or inhibition of enzyme systems in the liver affecting its detoxification function; and
- e) *Immunotoxicity* - damage to the body's immune mechanism.

Genetic effects are limited to damage to germ cells. The damage is manifested in future generations as physical or mental abnormalities. They may cause chromosomal aberrations or gene (point) mutations. Mutations involving chromosomes are quite drastic and are expressed in the very next generation, but gene mutations are normally recessive and may remain hidden for several generations.

Sources of pollution

The principal sources of environmental pollutants are: agricultural activity; industrial activity; and emissions from vehicular traffic. Domestic waste also makes an appreciable contribution to environmental pollution.

Agriculture

Traditional agriculture has, in recent times, been subjected to radical changes from greater pressure on the land to improve the quality and quantity of food. The traditional crop rotation system is being replaced by an intensive system of cultivation where an identical crop is grown regularly on the same land. This single cropping provides greater opportunities for the

establishment of a variety of pests, which attack the crop. In addition the development of new high yield varieties of crops provides further opportunities for establishment of pests. These varieties have a relatively high nutritional requirement, requiring the application of artificial fertiliser.

The use of agrochemicals- both pesticides and artificial fertilisers- has thus become essential in agricultural practice. Inorganic pesticides such as arsenic, copper and mercury compounds, which were in use prior to the Second World War have been replaced by organic pesticides following the initial use of DDT as a hygienic insecticide to control lice in the prevention of typhus fever, and subsequently in malaria control.

Many varieties of herbicides, fungicides and insecticides are used in agriculture, today. Pollution of waterways from improper disposal of containers and pollution of food from application of pesticides are not uncommon.

Artificial fertilisers have been a major factor in increasing crop yields by as much as ten-fold. Higher concentrations of nitrates in the soil and water from use of fertiliser may lead to the accumulation of nitrates in plants.

Chemical transformation of nitrates to nitrites can occur in plants as well as in man. Increased nitrites in food cause methaemoglobinaemia in young children, which reduces the oxygen carrying capacity of red cells. Toxicity of nitrites may be further enhanced by reaction with certain amines present in food, with the formation of nitrosamines, which are carcinogenic.

Pollution from industries and vehicular emissions

Air pollution

Atmospheric pollution is caused by emissions by smoke, gas and grit from domestic and industrial chimneys, locomotives and ships; by gaseous pollutants from chemical works and industrial processes; and by exhaust gases from motor vehicles. Pollution from vehicular emissions is chiefly found in metropolitan areas where the number of vehicles is rapidly increasing. The complex of pollutants in air includes carbon monoxide, oxides of nitrogen,

polycyclic hydrocarbons, sulphur dioxide, suspended particulate matter, ozone and peroxyacyl nitrates formed by photochemical oxidation of oxides of nitrogen and hydrocarbons. Volatile solvents and suspended mineral dusts such as asbestos and silica may also be present.

I will now consider some of the known biological effects of the more important toxic chemical pollutants in air.

Sulphur dioxide and Particulate Matter

Domestic and industrial sources are the main sources of sulphur dioxide and particulates. Vehicular emissions contribute a relatively small proportion. But since these emissions occur close to ground level within the breathing zone, they contribute appreciably to the total amount inhaled. At points close to mixed traffic, smoke from diesel engines makes a substantial contribution to suspended particulate matter in the air- the contribution from petrol-powered vehicles is insignificant.

Sulphur dioxide is catalysed by certain other atmospheric pollutants to form sulphur trioxide, sulphuric acid and sulphates- all of which have varying irritant effects on the respiratory system.

Inhaled sulphur dioxide is highly soluble in the aqueous surfaces of the respiratory tract, and is, therefore, absorbed in the nose and the upper airways where it exerts its irritant effect; little of it reaches the lungs. Sulphuric acid mist and some sulphates are more powerful respiratory irritants than sulphur dioxide and produce similar but more severe effects.

Epidemiological studies have provided much of the information concerning the effects of exposure to realistic concentrations of sulphur dioxide and suspended particulate matter. The most dramatic effects on mortality have been the sudden increases in the number of deaths that have occurred during episodes of exposure to high concentrations, notably in the Meuse Valley in 1930, in Donora in 1948, and in London in 1952. People with pre-existing heart disease and lung disease, and the elderly were the most affected. In the London episode, which lasted five days, about three times more than the expected number of deaths occurred during and immediately after the event. The levels of sulphur dioxide and smoke were noted to have reached high levels. Subsequent studies carried

out to assess the mortality from moderate daily variations have revealed a relative increase in mortality with increases in concentration of sulphur dioxide and smoke.

In the general population, increased respiratory symptoms and decreased respiratory function, as well as an increased incidence of respiratory illness in children have been observed.⁶

The possibility of air pollution being a causal factor in the increased incidence of cancer of the lung has been studied due to the excessive occurrence of lung cancer in urban populations where carcinogenic substances such as polycyclic hydrocarbons are present in suspended particulate matter. Although some studies indicate a probable association, the Royal College of Physicians reviewed this issue some time ago and concluded that the upward trend in the incidence of lung cancer is best explained by the causal role of cigarette smoking rather than by the presence of carcinogens in ambient air.⁷

Oxides of Nitrogen

The major source of man-made emissions of oxides of nitrogen is the burning of fossil fuels. Transportation sources, especially petrol-powered vehicles, contribute as much as 50 percent to the total emissions in some countries.

Oxides of nitrogen are irritant gases, which are less soluble in aqueous surfaces than sulphur dioxide. The effects on the respiratory system are, therefore, seen in the lower airways and the lungs as the aqueous surfaces of the upper airways retain only small amounts of the inhaled oxides of nitrogen.

Studies have shown that concentrations of oxides of nitrogen exceeding 1300 micrograms/m³ caused functional changes in healthy subjects- particularly an increase in airways resistance. Inadvertent exposure to high concentrations has been reported in occupational exposures; in these situations were acute as well as delayed effects causing pneumonia, bronchiolitis and pulmonary oedema have been described.^{8,9}

Carbon Monoxide

Exhaust emissions from petrol-powered motor vehicles constitute the most important source of carbon monoxide (CO) in the atmosphere at breathing level. The rate of emission of CO

from this source depends on such variables as the type of vehicles, its mode of operation and its speed. Concentrations in urban areas closely relate to the density of traffic and show peaks during "rush hours". Concentrations fall sharply with increasing distance away from the street.

It is well known that carbon monoxide forms strong bonds with the iron atom of the protohaem complex of haemoglobin forming carboxyhaemoglobin (HbCO) thus impairing the oxygen carrying capacity of blood; the dissociation of oxyhaemoglobin is also altered due to the presence of HbCO in the blood, thereby further impairing the oxygen supply to the tissues (the affinity of haemoglobin for CO is about 250 times that for oxygen).

The effects on health of high concentrations of CO are widely known. Much attention has been given in recent times to the possible effects of exposure to low concentrations of CO which result in blood HbCO levels of 10 percent or less.

Studies done on the effects on psychomotor functions by assessing the impairment of vigilance, perception, and the performance of fine tasks following exposure to concentrations of CO too low to produce clinical signs and symptoms, suggests that CO contributes to impairment of psychomotor function.¹⁰

In patients suffering from angina pectoris, a reduction in the time of onset of angina on exercise has been demonstrated when the HbCO levels exceeded 2.5 percent. Similar effects have been demonstrated in patients with intermittent claudication from peripheral vascular disease.¹¹ It is likely that others such as the anaemic, those with cerebrovascular disease, and the elderly may be similarly affected.

Studies have also shown that limitation of working capacity in healthy subjects appeared at HbCO levels as low as 4 percent with incapacity increasing with exposure to higher HbCO levels.

Lead

The contribution of alkyl lead additives in motor fuel accounts for the major part of all inorganic lead emissions. Over 70 percent of the lead is likely to enter the environment immediately after combustion; the rest is trapped in the crankcase oil in the exhaust system. The degree

of pollution from lead depends on the car density and the lead content of petrol.

A major component of the lead absorbed accumulates in bones and teeth, the amount increasing throughout life. A smaller component is distributed in the soft tissues, including the blood.

The biological effects of lead have been characterised in some detail; several organs and systems are known to be affected.¹²

The haemopoietic system shows effects at much lower blood lead levels than any other system. Lead interferes with the synthesis of haemoglobin at several enzymatic steps in the biosynthesis of haem causing anaemia.

The effect of lead on the central nervous system causing lead encephalopathy is associated more with childhood lead poisoning than with poisoning in adults. The reason may be due to the ease with which lead crosses the blood-brain barrier in children. The clinical features of lead encephalopathy range from symptoms of restlessness, headaches and irritability to more severe signs and symptoms of delirium, mania, paralysis and coma. Death is not uncommon in severe cases, and those who survive may show residual neurological damage. Many cases of lead encephalopathy have been reported in Sri Lanka from pollution of the environment with lead fume during the extraction of gold and silver from jeweller's waste, an industry carried out in the some parts of Colombo and its suburbs.

There has been concern about the occurrence of subtle neurological damage in young children resulting in behavioural disorders without the appearance of lead encephalopathy; but several psychometric studies have failed to provide conclusive evidence.¹³

Indirect effects from Air Pollution

Depletion of the ozone layer and global warming

The release of gases containing chlorine and bromine through human activity, particularly the use of chlorofluorocarbons in aerosols, has caused the gradual depletion of the ozone layer over North America, a large part of South America and Asia, nearly the whole of Europe, Australia and New Zealand. The ozone layer serves as a protective envelope in the

stratosphere protecting humans from the harmful effects of ultraviolet-B radiation.

UV radiation in sunlight plays an important role in the causation of dryness and wrinkling of the skin. But more importantly, UV-B exposure is expected to increase the incidence of all types of skin cancers among white populations. It is unlikely that the majority of Sri Lankans would be affected by exposure to UV-B.

It is likely, however, that cataracts would be a more widespread health effect of exposure to UV-B radiation than skin cancers as all exposed persons are likely to be equally affected. Wearing glasses or sunglasses can block much of the UV radiation from entering the eye. Plastic lenses, whether tinted or not, reduce exposure by 90 percent and glass lenses afford about 80 percent protection. Use of hats as well as protective eyewear provides further protection.

Exposure to sunlight alters subsets of T-cells and induces suppressor T-cell activity in normal subjects. Under conditions expected to prevail with global environmental changes, this suppression of the immune system is likely to promote the proliferation of cancer cells and increase the incidence of infectious diseases and make them more lethal.

The growth of phytoplanktons, which form the beginning of the food chain on which all marine species depend, is impaired by UV-B radiation. This will adversely affect marine food production. The increase in tropospheric oxygen, which is an indirect consequence of depletion of stratospheric ozone, is likely to cause toxic effects on plants, thereby adversely affecting food production.¹⁴

Increase in atmospheric levels of carbon dioxide over the years is feared to cause *global warming* with melting of polar ice caps with submersion of land; other climatic changes caused by global warming are likely to affect food supplies.

Pollution of soil and water

Many toxic industrial chemicals find their way into the soil and to waterways. Uncontrolled waste disposal from industrial establishments introduce a variety of chemical pollutants into waterways. In addition thermal energy released into waterways will destroy aquatic life with a consequent impact on human health.

The earth's crust and oceans are found to contain about ninety naturally occurring elements of which about seventy are metallic elements. In general non-metallic elements are found to be less hazardous to man and include the vital elements of living matter- carbon, hydrogen, oxygen, nitrogen and phosphorus. Many metallic elements are found to be hazardous to man although very many of these elements are essential in low concentrations for healthy growth. Some metallic elements such as lead, cadmium and mercury accumulate in the body over a period of time before their effects are manifested.

Some chemical pollutants gain entry into the food chain where they are preferentially concentrated at various levels. Examples of the dramatic consequences of entry of toxic pollutants into the food chain have been well documented in Japan. The well-known 'Minimata disaster' in the 1950s was caused by the consumption of fish, which was contaminated with methyl mercury from effluents from a chemical plant that processed vinyl chloride. Methyl mercury whilst causing adverse effects on those who consumed the fish is believed to have caused congenital abnormalities in children of exposed mothers some of whom did not themselves suffer any ill effects. In another instance of chronic poisoning in Japan, which occurred in the 1960s, symptoms of chronic cadmium poisoning were observed in the population in the Jintsu river basin. Those affected complained of severe bone pain caused by osteomalacia. The disease was called 'itai itai' disease- 'itai itai' being the manner of expression of pain by the Japanese. Investigation revealed that the rice consumed by those affected was from fields irrigated with water from the Jintsu river which was contaminated with cadmium during the Second World War by effluent from a chemical industry. The symptoms appeared many years after the war from accumulation of cadmium in the body over the years.¹⁵

Toxic organic chemicals in pesticides, dyestuffs, detergents, solvents found in industrial, agricultural and consumer waste is a serious hazard particularly when these substances contaminate water and food.

In order to ensure the safety of drinking water and food WHO and other international and

national organisations have established quality guidelines indicating the levels below which harmful effects are unlikely to occur.

Radioactive contamination

Radioactive contamination of the environment resulting from human activities became a serious source of pollution after the Second World War. Application of nuclear fission in the development of atomic weapons and the subsequent use in nuclear power reactors are the main artificial sources of pollution.

The testing of atomic weapons, especially the series of massive testing programmes in the 1960s, has resulted in the major part of artificial radioactivity. Much smaller quantities of artificial radioactivity enter the environment continuously as wastes discharged from nuclear installations. Accidental leakages from these installations are also contributory.

The immediate aftermath of the 1986, Chernobyl nuclear power plant accident in the Soviet Union included: 300 deaths (New York Times, April 27, 1990); twice the normal rate of birth defects among those living in the vicinity of the plant (Los Angeles Times, March 27, 1989); thyroid glands of more than 150,000 people were "seriously affected" by doses of radioactive iodine; rates of thyroid cancer were 5 to 10 times higher for the 1.5 million people living in the affected areas; leukaemia rates among children increased; one-fifth of the republic of Byelorussia's more than 10 million people had to be moved from areas contaminated by radiation (Los Angeles Times, June 20, 1990); and it will take up to 200 years to "totally wipe out" the effects of the accident in the affected areas.

Due to their long half-life, two nuclear fission products, Strontium-90 and Caesium-137 are of special interest, particularly after massive leakages from nuclear installations. These contaminants enter the food chains and contaminate all principal foods such as meats, milk and milk products and to a lesser extent cereal grain. Their presence in milk is of special concern to young children. Exports of these products from countries affected by massive leaks of radioactive material demands vigilance from countries importing such products. Food imports from such countries, particularly milk

products, are tested in Sri Lanka before releasing them into the market. Radioactive Iodine, although present among pollutants during accidental leakages does not have long-term effects due to its short half-life but can affect those in the vicinity of leakages from nuclear installations.⁵

Control measures

Much can be done to prevent the introduction of harmful pollutants into the environment. Many countries have adopted quality standards for industrial and agricultural pollutants and also restricted the use of highly toxic substances. Many possible solutions have been advanced for the reduction of harmful pollutants in the environment. In Sri Lanka the National Environmental Act requires 'that no person shall discharge, deposit or emit waste into the environment which will cause pollution except:

- a) Under the authority of a licence by the Authority; and
- b) In accordance with such standards and other criteria as may be prescribed under the Act.'

Enforcement of the provisions of the Act has, however, been hampered by lack of trained personnel.

Industrial pollution control could be achieved only by an increased expenditure on the treatment of industrial waste. Technical processes for achieving this are already available. But the use of this technology would increase the cost of production, which would eventually be borne by the consumer. The damage from environmental pollution is, in the long term, likely to cost the community more than it would have to spend to prevent the damage from occurring at all.

Various improvements in vehicle design have been effected for better engine performance to control the effects of pollution from vehicle fumes. The reduction in the lead and sulphur content of petrol, which would reduce atmospheric pollution from their combustion products, would, however, increase cost. Several recommendation made by a committee appointed to study the problem of vehicular emissions in the late 1980s are yet to be implemented.

The problems associated with indiscriminate use of highly toxic pesticides as well as persistent pesticides is now better appreciated and many countries, including our own, have restricted or banned the use of these chemicals.

An effective alternative for the use of pesticide chemicals is not yet available. One interesting alternative suggests reverting to traditional methods of agriculture by making available more land for agriculture. Proponents of this solution argue that the huge demand for animal feedstuff is one reason for the enormous pressure on land. Animals have a low protein conversion efficiency- usually less than 10 percent. It is known that varieties of bean and cereal can be converted to acceptable analogues of meat and milk. If the conversion of crops to acceptable protein foods is made more efficient the pressure on the land is likely to be relieved and would enable the resumption of the more traditional methods of agriculture thereby reducing the need for pesticides.

Recent advances in genetic engineering have made it possible to produce genetically modified foods with a variety of beneficial characteristics. Agricultural scientists have already produced genetically modified crops with:

- Insect resistance- to control insect pests feeding on crops while leaving non-pest insects alone;
- Disease resistance- to limit crop losses from epidemics;
- Herbicide resistance- allowing farmers to use fewer chemicals and obtain weed free crops;

Other modifications, which are not directly applicable to environmental control, have enabled:

- Delayed ripening of fruits that maintain their freshness; and
- Production of healthier vegetable oils with lower saturated fat content.

However, public concerns over genetically modified foods remain an issue of debate. Sri Lanka has already banned the import of genetically modified foods. But reputed scientists and medical journals now favour the use of genetically modified foods. If the proof is in the eating, 300 million North American

consumers have been eating several dozens genetically modified foods grown on hundreds of million acres since 1994 with no documented adverse effects.¹⁶

Conclusion

I have outlined the health impacts of some of the more common pollutants that may be present in the environment as a consequence of man's activity. There are obviously no easy solutions to these problems particularly in developing countries like our own. The state has an obligation to provide adequate resources to protect the people from exposure to environmental risks. Community physicians who in the past have been involved mainly with problems arising from biological pollutant will, in the future, have to acquire the necessary competence to assist in finding solutions to health problems arising from physical and chemical pollutants as well.

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