

# CHM 319: Environmental Chemistry Module 2



NATIONAL OPEN UNIVERSITY OF NIGERIA

# CHM 319 Environmental Chemistry Module 2

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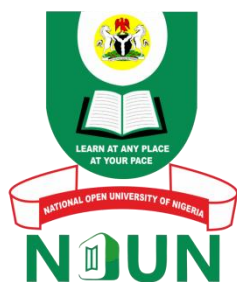
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# Module 2 Sources, Types and Effects of Environmental Pollution

## Unit I Water Pollution

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### 1.0 Introduction

In sciences “contamination” refers to a situation when a chemical substance is present in a given sample or matrix with no evidence of harm while “pollution” is used in cases where the presence of the chemical is causing harm. Pollutants therefore are chemicals causing environmental harm.

Broadly, our environment can be classified into water, air and soil environments. Hence, we talk of water pollution, air pollution and soil pollution. In many cases, the classification has no clear-cut boundary as a pollutant found in air may soon find its way into the soil or aquatic environment and vice versa.

### 2.0 Objectives

At the end of this unit, you should be able to:

- differentiate between a contaminant from a pollutant
- identify chemical substances that are fundamentally responsible for the contamination or pollution of an aquatic environment
- mention the sources of the named pollutants
- classify the sources into natural or anthropogenic, and also identify the sources or diffuse sources.

### 3.0 Main Content

#### 3.1 Pollutants in Aquatic Ecosystems

#### 3.2 Effects and Criteria of Pollutant Designation

Any chemical can become a pollutant in water if it is present at a high concentration. For example, serious pollution incident can result from spill of sugar and milk. When a water body becomes polluted, one or more of the following effects would be experienced:

- Aesthetic or visual nuisance including production of foul smell.
- Heightened temperature of the water body.
- Lack of oxygen or devaluation of dissolved oxygen.
- Acute or chronic toxicity causing damage to aquatic or human life.

- Disturbance of the pH regime.
- Eutrophication i.e. much availability of nutrients giving rise to excessive growth of some organisms in water.

Although any chemical can be a pollutant, certain chemicals have been identified by international agreement as being “**priority pollutants**”. These priority pollutant chemicals have been selected based on the following criteria: (i) they are toxic at low concentrations; (ii) they bioaccumulate; (iii) they are persistent; and (iv) they are carcinogens (Substances that can cause cancer).

It is true that priority pollutants can be very dangerous or hazardous even at low concentrations, but then; different chemicals can constitute priority pollutants in different contexts. For example, effluents containing biodegradable organic chemicals generally act as pollutants not because they contain chemicals at concentrations that are toxic, but because they contain chemicals that provide abundant food for microorganisms. The microorganisms thus multiply rapidly as a result of the increased food input. The microorganisms, in the process of growing and oxidising the organic chemical foodstuff, use up the dissolved oxygen rapidly leading to the death of higher organisms like fish.

### 3.3 Modes of Chemical Pollutant Release

There are two broad types of chemical release into an environment, namely: **point source discharge** or **direct discharge** and **non-point source discharge** or **diffuse discharge**. Point source or direct discharge is the release of environmental pollutants from a specific place such as industrial sites, sewage works or agricultural land. Pollution from point source discharges are easier to monitor, control, and their environmental impacts is relatively easier to determine. On the other hand, the non-point discharge of pollution refers to pollution from diffuse or even diverse places e.g. heavy metal pollution arising from harmattan loesses deposition. Such pollution sources are usually difficult to determine, and very often, statistical weapons such as factor analysis are resorted to in order to reliably predict their sources.

Currently, emphasis on priority pollutant control has shifted from control of point sources towards control of diffuse sources. This is because new technology enabling priority pollutant is now available and pollution control technology has improved tremendously. In some cases however, the availability of new technology only partially solves the existing problem, for example, hydrochlorofluorocarbons (HCFCs) are preferred to the chlorofluorocarbons (CFCs) because HCFCs are expected to break down in the atmosphere fairly rapidly. However, the trifluoroacetic acid, which some HCFCs are expected to produce, is very stable and will wash out from the atmosphere whenever rain falls. In areas like seasonal wetlands which have high evapotranspiration rates, the trifluoroacetic acid may concentrate to levels which may damage plants.

### 3.4 Pollution Control: Regulation and Control of Priority Pollutants

The growing internationalisation of priority pollutants control is mostly driven by the recognition that pollution does not recognise environmental compartmental or national boundaries. For example, a pollutant can cross from soil to aquatic environment. Likewise, pollution caused in London may soon find expression within the geographical boundary of

Nigeria. It has been recognised also that protection of aquatic environments (marine water particularly) can only be accomplished by international action.

Government, regulatory agencies and industrial initiatives have recognised the following hierarchy of approaches to priority pollutant control: **Replace** – use another, more environmentally friendly chemical; **Reduce** – use as little of the priority pollutants as possible; and **Manage** – use in a way to eliminate or minimise accidental or adventitious loss and waste.

The regulation and control of priority pollutants is an international issue and is not just a case of tightening up on discharge consents as diffuse sources can be important and even dominate in some cases. It also requires a portfolio of complementary activities based on a hierarchy of **replace – reduce – manage**.

### Self-Assessment Exercise

1. Differentiate between contamination and pollution.
2. List six observable effects resulting from a given water body pollution.
3. What are the criteria used to designate a chemical substance as a “priority pollutant”?
4. (a) Explain what is meant by (i) point source discharge and (ii) non-point source discharge of pollutants into an environment.  
(b) Give two reasons why there is greater emphasis on non-point Source discharge than on point source discharge of pollutants.
5. State and briefly discuss the hierarchy of approaches to priority pollutant control.

### 3.5 Individual Aquatic Environment Pollutants: Their Sources and Effects

A wide range of pollutants can enter the aquatic, or more specifically, the marine environments in a number of ways. These pollutants or classes of pollutants are:

#### 3.5.1 Crude Oil

Because crude oil is a very complex mixture of many different chemicals, the effects of an oil spill on the aquatic environment depend on the exact nature and quantity of the oil spilled. The effects are also determined by such other factors as the prevailing weather conditions and the ecological characteristics of the affected region.

Crude oil gets into water bodies through transportation (tanker operations and accidents, dry docking and non-tanker accidents), fixed installations (coastal refineries and offshore production) and other sources (municipal wastes, industrial wastes, urban run-off, atmospheric fallout and ocean dumping). Some of the damages caused to aquatic organisms by oil spills are growth inhibition of phytoplankton, large scale mortality in littoral communities through acute toxicity and smothering, fish kill, death of seabirds through

drowning, hypothermia or toxic effects of ingested oil and vulnerability of coastal populations of marine mammals e.g. seal colonies.

### 3.5.2 Sewage

Domestic sewage, with or without the presence of industrial wastes, probably represents the commonest and most widespread contaminant of inshore and nearshore waters. Sewage may reach the water bodies in different forms: untreated raw sewage discharges, partially or properly treated discharge and outright dumping of associated sewage sludge at marine sites. Sewage poses aesthetic and health risks to human populations and also acts as a vector whereby a considerable variety of other contaminants reach the aquatic environment.

### 3.5.3 Persistent Organic Chemicals

Persistent organic chemicals which have proved to be of concern in the aquatic environments are essentially chlorinated pesticides such as DDT, dieldrin, aldrin, endrin, lindane, hexachlorobenzene and toxaphene. Others include polychlorinated dibenzo-p-dioxins (PCDD) and polychlorinated dibenzofurans (PCDF); pesticides like 2, 4 – dichlorophenoxyacetic acid (2,4-D), 2,4,5 – trichlorophenoxyacetic acid (2,4,5-T) and 2-methyl-4,6-dichlorophenoxyacetic acid (MCPA). There are other chemicals which are sufficiently common, toxic and persistent to represent potential threats e.g. polycyclic aromatic hydrocarbons (PAHs), plasticizers (e.g. phthalate esters), detergent residues, organic solvents, and so on.

These chemicals contaminate the aquatic systems through aerosol drift, surface runoff, aerial spray and direct application on water hyacinth or mulluscs. Amongst the top predators, the main deleterious effects have been eggshell thinning in birds (by DDE) and interference with the reproductive and immune system in mammals (by PCBs). A considerable number of top predator birds showed major declines in abundance during the peak period of DDT usage. Apparently responsible for the abnormalities in male sex development in wildlife and humans including members of the DDT family of compounds, chlordecone (Kepone), various sterols and possibly nonylphenol. Of these, p,p– DDE is the most potent.

### 3.5.4 Heavy Metals

Metals and metalloids with an atomic density (greater than  $6\text{g/cm}^3$ ) which are associated with pollution and toxicity problems are generally referred to as **heavy metals**. Examples are As, Cd, Cr, Cu, Hg, Ni, Pb and Zn. Unlike most organic pollutants, heavy metals occur naturally in rock-forming and ore minerals. So, there is a range of normal background concentrations of these elements in soils, sediments, waters and living organisms. Thus, the presence of the metal is an insufficient evidence of pollution (we only talk of pollution when there is high concentration of the metals relative to the normal background levels).

Heavy metals find wide applications in electronics, machines and the artifacts of everyday life as well as “high-tech” applications. Hence, they tend to reach the environment from a vast array of anthropogenic sources as well as natural geochemical processes. Depending on their speciation (as well as on the condition of the organism), heavy metals like Hg, Pb and Sn in the aquatic environments are potentially harmful.



### 3.5.5 Eutrophication

The addition of excess nutrients to a water body is known as **eutrophication**. Important sources of these nutrients include breakdown of organic matter, phosphorus-containing detergents, agricultural runoff and leaching of artificial fertilizers and manures from intensive farming units, the burning of fossil fuels which increases the nitrogen content of rain, and so on and so forth. Nitrogen and phosphorus are the two nutrients most implicated in eutrophication. This is because growth of organism in water bodies is usually limited by phosphorus rather than nitrogen; it is the increase in phosphorus which stimulates excessive plant production in freshwaters.

One of the serious effects of eutrophication which result in huge financial loss, is the stimulation of algal growth especially in water supply reservoirs; this is the main cause of water treatment problems. Large populations of algae may result in the blocking of filters in the treatment works.

Drinking water with high nitrate contents presents potential health problems. In particular, babies under six months of age who are fed with such water may develop methaemoglobinaemia (blue baby syndrome), in which the nitrate in their feeds is reduced to nitrite in their acid stomachs. The nitrite then oxidises ferrous ions in their blood haemoglobin, thereby lowering its blood carrying capacity.

### 3.5.6 Acidification

Generally, there are three categories of water with respect to their acidity differences; (i) those which are permanently acidic with a  $\text{pH} < 5.6$ ; (ii) those which are occasionally acidic, where  $\text{pH}$  is normally above 5.6, but may drop below 5.6 periodically; and (iii) those which are never acidic, the  $\text{pH}$  never dropping below 5.6. The acids either fall directly into water bodies in form of precipitation or are washed in from vegetation and soils within the catchments. Sometimes, acids can be generated indirectly from mining activities. For example, exposed iron pyrites can undergo chemosynthetic bacterial oxidation to yield sulphuric acid, making water flowing from the area to have a  $\text{pH}$  of 3.5 or below.

When there is acidification of a water body, among the animals to first disappear are the shrimps, minnows, trout and crayfish. Normally, no species of fish reproduces at values of  $\text{pH}$  below 5.4.

### 3.5.7 Thermal Pollution

Water used for cooling discharge from electricity generating stations is the main source of pollution by heat. An increase in temperature alters the physical environment in terms of a reduction in both the density of the water and its oxygen concentration, while the metabolism of organisms increases.

Cold water species (of fish especially) are very sensitive to changes in temperature and tend to disappear if heated effluents are discharged to the headwaters of streams. As the temperature increases, a conflict arises; the rate of heart-beat of a fish increases to obtain oxygen for increased metabolic processes, but at the same time, the oxygen concentration of the water is decreasing.

### 3.5.8 Radioactivity

Sea water and marine sediments are naturally radioactive because of the natural presence of radioactive potassium 40, uranium and thorium decay series, and the creation of lighter radioisotopes through the interaction of cosmic rays and atmospheric gases, with the products subsequently transferred to the water surface. Chemically, radionuclides behave almost identically to their stable counterparts. They are, therefore, partitioned between water, sediments and biota according to their behavioural properties e.g. C<sub>5</sub>-137 is largely water soluble, Pu-239 and Pu-240 form strong associations with fine-grained sediments.

Releases of radioactivity by anthropogenic activities into the aquatic/marine environment include: (i) radiation from Weapons Testing Programmes; (ii) routine releases from Nuclear Power Plants e.g. tritium, sulphure-35, zinc-65 and cobalt-60; (iii) releases from Nuclear Fuel Reprocessing Plants e.g. tritium, C-14, C0-60, Sr-90, Te-99, Ru-106, I-129, Cs-134 and 137, Ce-144, Pu-241 and Am-241; (iv) reactor accidents on land e.g. Chernobyl in the Ukraine (April, 1986) nuclear reactor accident; (v) dumping of low level waste e.g. radioactive material dumped at Koko village in Nigeria; and (vi) naval sources e.g. nuclear warheads and reactors from accidents to submarines.

Humans are the most sensitive of all living organisms to the effects of radiation, therefore all radiological population measures are designed to protect humans on the understanding that all other species will therefore automatically receive adequate protection. Radiation effects on humans are either **somatic** or **genetic**. Somatic effects are those that cause (noticeable) damage to the individual e.g anemia, fatigue, loss of hair; cataracts, skin rash and cancer. Genetic effects include inheritable changes resulting from mutations in reproductive cells. It is widely held that even small dosages of radiation can have some adverse effects, genetic effects being of greatest concern.

### Self-Assessment Exercise

In a tabular form similar to the one below, list five pollutants of an aquatic ecosystem, their sources and effects.

Pollutant	Source(s)	Effect(s)
(1)		
(2)		
(3)		
(4)		
(5)		

## 4.0 Conclusion

Despite the vast amount of scientific information available with respect to water pollution over the past five decades, many of our fresh waters still suffer from poor water quality, with severe consequences for the flora and fauna they support. Scientific know-how is subverted by economic and political constraints, and in many instances, by careless accidents within the catchment.

Newly synthesized materials are constantly being added to our waterways as traces or in effluents and the long-term effects of these are largely unknown. A continuing programme of surveillance is required to protect our water resources from further effects of environmental degradation that threatens our collective co-existence.

## 5.0 Summary

In this unit, you have learnt that:

- contamination is the presence of a chemical substance at a level causing no harm;
- pollution is the presence of a chemical substance at a level causing harm; a pollutant can enter an environmental compartment through a point-source or diffuse source discharge;
- substances (or situations) that can cause water pollution include crude oil, sewage, persistent organic chemicals, heavy metals, eutrophication, acidification and radioactivity.

## 6.0 Self-Assessment Exercise

Explain how (a) Sewage, (b) Eutrophication and (c) Acidification, can lead to water pollution.

## 7.0 References/Further Reading

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## Unit 2 Air Pollution

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### 1.0 Introduction

Most people tend to associate air pollution problems with the advent of the industrial revolution whereas, such problems have somehow plagued the human race for centuries. The earliest pollutants noted in the atmosphere were probably of natural origin. Smoke, fumes, ash and gases from volcanoes and forest fires; sand and dust from windstorms in arid regions; fog in humid low-lying areas; and natural terpene hazes from pine trees in mountainous regions were part of our environment long before anthropogenic (human-induced) problems came on the scene.

It is true however, that anthropogenic inputs have tremendously increased the levels of each pollutant in the atmosphere. Pollution of the atmosphere increases in almost direct proportion to the population density and is largely related to the products of combustion from heating plants, incinerators and automobiles plus gases, fumes and smokes arising from industrial processes. Air pollution of quite another type is of major concern nowadays. This results from radioactive materials that gain entrance into the atmosphere through nuclear explosions.

Except in such extreme cases as volcanic eruptions, pollution from natural processes does not usually pose problems severe enough to seriously endanger life; ultimately, human activities are to blame for pollution problems that threaten human's expectation of long and healthy life.

### 2.0 Objectives

At the end of this unit, you should be able to:

- name major air pollutants and their sources
- state the health effects of each air pollutant and
- describe the mechanism of action of some of the pollutants in human body.

### 3.0 Main Content

#### 3.1 Air Pollution – Past, Present and Future

The smoke from isolated wood-burning fires of early cave dwellers went to the air almost unnoticed. But when the smoke from coal-burning furnaces in heavily populated cities started, the effects of pollution became severe enough to alarm some of the inhabitants of modern cities.

In A.D. 61, the philosopher Seneca described “the heavy air of Rome” and “the stink of the smoky chimneys thereof”. In 1273, King Edward I was bothered enough by the smoke and fog mixture that brooded over London to prohibit the burning of “sea coal”. By the time Queen Elizabeth I ascended the throne, the city's notorious pea-soup fogs had become smog. Because of her allergy and aversion to coal smoke, the Queen moved out of the city

into the cleaner air of Nottingham. Toward the end of Elizabeth's reign, a law was passed prohibiting the burning of coal.

By late 1880s, there were some corresponding evidences of interest in overcoming air pollution, including the enactment of smoke-control laws in Chicago and Cincinnati. In 1930, an inversion trapped smog in Meuse Valley, Belgium. Sixty three persons died and several thousand others became ill. The London smog disaster of 1952 made it impossible to ignore any longer the serious consequences of air pollution. Between 4<sup>th</sup> and 9<sup>th</sup> December, 1952, 4000 deaths attributed to air pollution had been recorded, enough to move Britons to pass the Clean Air Act in 1956.

From that time till now, Clean Air Acts have been passed in places like the USA, Australia, Canada, and so on and so forth. There had been Clean Air Act Amendments as well. Though it is likely that future changes will be made, it is probable that the move toward air pollution control has gathered enough momentum and public support to maintain a course which ensures a cleaner, healthier atmosphere for us now and generations to come.

### 3.2 Major Air Pollutants and their sources

Air pollutants are substances in the air that are responsible for pollution e.g. dust, fumes, gas, mist, odour, smoke, vapour, etc. Air pollution is the presence in the outdoor atmosphere of one or more air pollutants in sufficient quantities, characteristics and of such duration to reasonably interfere with the comfortable enjoyment of life or property.

#### 3.2.1 Particulates

Particulates can either be natural e.g. pollen, spores, bacteria, viruses, protozoa, plant fibres, rusts and volcanic dust, or anthropogenic e.g. fly ash, smoke, soot particles, metallic oxides and salts, oily or tarry droplets, acid droplets, silicates and other inorganic dusts and metallic fumes.

At high concentrations, suspended particulate matter poses health hazards to humans, particularly those susceptible to respiratory illness. The nature and extent of the ill effects that may be linked to suspended particulates depend upon the concentration of particulates, the presence of other atmospheric contaminants (notably sulphure oxides) and the length of exposure.

Airborne substances such as pollens and spores causing allergies in sensitive persons are called **aeroallergens**. Ragweed pollen is one of the worst allergens. Hay fever or asthma sufferers coming into the vicinity where ragweed pollen exists may suffer allergic reactions. Other aeroallergens of biological origin include yeast, molds and animal fur, feathers or hair. Finely powdered industrial materials can also cause allergic reactions in sensitive persons.

The most serious situations of particulate air pollution develop where local conditions favour atmospheric temperature inversions and the products of combustion and of industrial processing are contained within a confined air mass. A notable example is the situation in Los Angeles, where inversions occur frequently; they also occur, though less often, in several other metropolitan areas e.g. Lagos, Nigeria.

### 3.2.2 Volatile Organic Compounds (VOCs)

Volatile organic compounds are a wide range of compounds with boiling points between approximately 50 and 250°C and which, at room temperature, produce vapours. In the indoor environments particularly, VOCs originate from a number of sources: furnishings, furniture and carpet adhesives, glues, building materials, cosmetics, cleaning agents, fungi, tobacco smoke and fuel combustion.

By far, the greatest peak exposure to VOCs occurs during home decorating using solvent-based paints. Some of the compounds that may occur in a typical non-industrial indoor environment are aliphatic and aromatic hydrocarbons, halogenated compounds and aldehydes. Because of the diverse range of chemical substances defined as VOCs, determination of health effects is problematic. At the levels typically found indoors however, the major effects are likely to be sensory.

### 3.2.3 Oxides of Sulphur

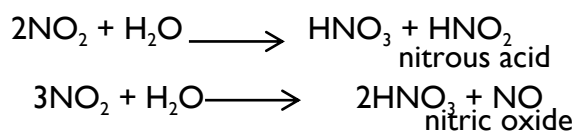
The oxides of sulphur ( $\text{SO}_x$ ) are probably the most widespread and the most intensely studied of all anthropogenic air pollutants. They include six different gaseous species: sulphur monoxide ( $\text{SO}$ ), sulphur dioxide ( $\text{SO}_2$ ), sulphur trioxide ( $\text{SO}_3$ ), sulphur tetroxide ( $\text{SO}_4$ ), sulphur sesquioxide ( $\text{S}_2\text{O}_3$ ) and sulphur heptoxide ( $\text{S}_2\text{O}_7$ ). However, only  $\text{SO}_2$  and  $\text{SO}_3$  are the oxides of sulphur of most interest in the study of air pollution.

The burning of solid and fossil fuel contributes more than 80 percent of anthropogenic  $\text{SO}_2$  emissions. It is estimated that  $\text{SO}_2$  remains airborne an average of two to four days, during which time it may be transported as far as 1000 kilometres. Thus, the problem of  $\text{SO}_2$  can become an international one. Relatively stable in the atmosphere,  $\text{SO}_2$  acts either as a reducing or an oxidising agent. Reacting photochemically or catalytically with other components in the atmosphere,  $\text{SO}_2$  can produce  $\text{SO}_3$ ,  $\text{H}_2\text{SO}_4$  droplets and salts of sulphuric acid. Sulphur dioxide can react with water to form sulphurous acid, a weak acid which can react directly with organic dyes.

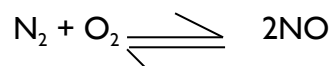
Sulphur dioxide, sulphuric acid and sulphate salts tend to irritate the mucous membranes of the respiratory tract and foster the development of chronic respiratory diseases such as bronchitis and pulmonary emphysema. In a dusty atmosphere,  $\text{SO}_2$  is particularly harmful because both  $\text{SO}_2$  and  $\text{H}_2\text{SO}_4$  molecules paralyze the hair-like cilia which line the respiratory tract. Without the regular sweeping action of the cilia, particulates are able to penetrate to the lungs and settle there. These particulates usually carry with them concentrated amounts of  $\text{SO}_2$ , thus bringing this irritant into direct, prolonged contact with delicate lung tissues. The  $\text{SO}_2$  – particulate combination has been cited as cause of death in several air pollution tragedies.

### 3.2.4 Oxides of Nitrogen

Oxides of Nitrogen ( $\text{NO}_x$ ) include six known gaseous compounds: nitric oxide ( $\text{NO}$ ), nitrogen dioxide ( $\text{NO}_2$ ), nitrous oxide ( $\text{N}_2\text{O}$ ), nitrogen sesquioxide ( $\text{N}_2\text{O}_3$ ), nitrogen tetroxide ( $\text{N}_2\text{O}_4$ ) and nitrogen pentoxide ( $\text{N}_2\text{O}_5$ ). The two important oxides of nitrogen in air pollution are  $\text{NO}$  and  $\text{NO}_2$ , being the only two oxides of nitrogen that are emitted in significant quantities to the atmosphere. Nitrogen dioxide is readily soluble in water, forming nitric acid and either nitrous acid ( $\text{HNO}_2$ ) or nitric oxide ( $\text{NO}$ ).

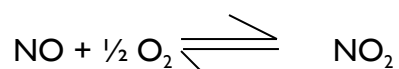


Both nitric and nitrous acid will fall out in the rain or combine with ammonia in the atmosphere to form ammonium nitrate ( $\text{NH}_4\text{NO}_3$ ). A good absorber of energy in the UV range,  $\text{NO}_2$  plays a major role in the production of secondary air contaminants such as ozone ( $\text{O}_3$ ). Nitric oxide is emitted to the atmosphere in much larger quantities than  $\text{NO}_2$ . It is formed in high-temperature combustion processes when atmospheric oxygen and nitrogen combine according to the reaction.



Small concentrations of the  $\text{NO}_x$  produced in the upper atmosphere by solar radiation reach the lower atmosphere through downward diffusion. Small amounts of  $\text{NO}_x$  are produced by lightning and forest fires. Bacteria decomposition of organic matter releases  $\text{NO}_x$  into the atmosphere. Find combustion in stationary sources and in transportation are the primary origins of human-induced  $\text{NO}_x$ .

Nitric oxide ( $\text{NO}$ ) is a relatively inert gas and only moderately toxic. Although  $\text{NO}$ , like  $\text{CO}$ , can combine with haemoglobin to reduce the oxygen-carrying capacity of the blood,  $\text{NO}$  concentrations are generally less than  $1.22 \text{ mg/m}^3$  in the ambient air and are thus not considered health hazards. However,  $\text{NO}$  is readily oxidised to  $\text{NO}_2$ , which has environmental significance.



$\text{NO}_2$  irritates the alveoli of the lungs. Short-term animal studies showed reduced resistance to respiratory infection at exposures of  $6.6 \text{ mg/m}^3$  for 2 hours. Experimental exposures of volunteers to  $9.4 \text{ mg/m}^3$   $\text{NO}_2$ , considerably above the  $7.0 \text{ mg/m}^3$  peak recorded in Los Angeles, for 10 minutes produced a substantial but transient increase in the resistance of the lung's airways to air movement. Concentrations from 47 to  $141 \text{ mg/m}^3$  cause reversible pneumonia. At high concentrations of  $285 \text{ mg/m}^3$  and above, exposures to  $\text{NO}_2$  can be fatal to humans.

### 3.2.5 Ozone ( $\text{O}_3$ )

Ozone, the major photochemical oxidant, makes up approximately 90 percent of the atmospheric oxidant pool. Other important photochemical oxidants in air pollution monitoring include nascent oxygen ( $\text{O}$ ), excited molecular oxygen ( $\text{O}_2$ ), peroxyacetyl nitrate (PAN), peroxypropionyl nitrate (PPN), peroxybutyl nitrate (PBN), nitrogen dioxide ( $\text{NO}_2$ ), hydrogen peroxide ( $\text{H}_2\text{O}_2$ ) and alkyl nitrates.

Ozone is produced in the upper atmosphere by solar radiation, and small concentrations of this gas diffuse downwards. Also, small concentrations are produced by lightning and forest fires. Ozone and other photochemical oxidants can cause coughing, shortness of breath, airway constriction, headache, chest tightness and soreness, impaired pulmonary function, altered red blood cells, pharyngitis, laryngitis, and eye, nose and throat irritation. Exposure of laboratory animals to high levels of ozone has resulted in damage to their chromosomes. Because of this,  $\text{O}_3$  is considered to have effects similar to ionizing radiation. Chromosome



breakage in human cell cultures was observed at exposures of 15673  $\mu\text{g}/\text{m}^3$  for 5 to 10 minutes.

### 3.2.6 Carbon Monoxide (CO)

Colourless, tasteless and odourless CO gas is chemically inert under normal conditions and has an estimated atmospheric mean life of about two and half months. At present ambient levels, it has little or no effects on property, vegetation or materials.

Carbon monoxide sources are both natural and anthropogenic. Oxidation of methane gas from decaying vegetation results in the production of up to three and half billion tonnes of CO per year. In human metabolism, the exhalation of a resting person contains approximately 1ppm CO. However, these productions are so meagre compared to the amounts coming from fossil fuel in complete combustion by stationary or mobile engines, solid-waste disposal and miscellaneous anthropogenic sources.

Carbon monoxide is especially dangerous since it has no odour, colour or taste. Its toxic action is through the displacement of oxygen in the haemoglobin to form carboxyhaemoglobin, thus depriving the tissues of the body of their oxygen supply. Early symptoms of exposure to CO include tiredness, drowsiness, headaches, dizziness, pains in the chest and stomach. Excessive exposure can lead to loss of consciousness, coma and death.

### 3.2.7 Airborne Carcinogens

The substances which have been shown actually or potentially to cause cancer are grouped according to International Agency for Research on Cancer (IARC) into four different categories: based on their ability to cause cancer.

**Group 1 – Proven human carcinogens.** Chemicals for which there is sufficient evidence for epidemiological studies to support a causal association between exposure and cancer e.g. benzene. Benzene has a proven causal association with acute non-lymphocytic leukaemia in humans. The main toxic effects occur on the bone marrow, with toxic exposures producing bone-marrow suppression and reductions in red cells, white cells and blood platelets production (pancytopenia) which may lead to bone-marrow failure (aplastic anaemia).

**Group 2 – Probable human carcinogens.** Chemicals for which evidence ranges from inadequate to almost sufficient.

**Group 2A:** Limited evidence of carcinogenicity in humans and sufficient evidence for carcinogenicity in animals e.g. benzo (a) pyrene, benzo (a) anthracene and other polycyclic aromatic hydrocarbons (PAH<sub>s</sub>).

**Group 2B:** Inadequate evidence for carcinogenicity in humans and sufficient evidence for carcinogenicity in animals e.g. 2-nitrofluorene, 1,6 –dinitropyrene and 1-nitropyrene.

**Group 3: Unclassified chemicals.** Chemicals which cannot be classified in humans, usually because of inadequate evidence.



### 3.2.8 Hydrocarbons

Hydrocarbons are divided into two major classes - **aliphatic** and **aromatic**. The aliphatic hydrocarbons contain alkanes, alkenes and alkynes. The alkanes are fairly inert and generally not active in atmospheric photochemical reactions; they are highly reactive in atmospheric photochemistry. The reactivity of alkenes such as ethylene makes them much more important in the study of air pollution than alkanes, because in the presence of UV radiation they react with  $\text{NO}_2$  at high concentrations to form secondary pollutants such as peroxyacetyl nitrate (PAN) and ozone. The alkynes, though highly reactive, are relatively rare. Hence, they are not of major concern in air pollution studies.

Aromatic hydrocarbons do not display the reactivity characteristic of unsaturated aliphatic hydrocarbons. Nevertheless, the polynuclear group of aromatic hydrocarbons (i.e. polycyclic aromatic hydrocarbons, PAHs) is of concern in any study of air pollution because a number of these compounds have been shown to be carcinogenic. Increases in lung cancer in urban areas have been blamed on the effects of PAHs from automotive exhaust emissions. Benzo-[a]-pyrene has been shown to be the most carcinogenic hydrocarbon for test animals. Benz-[e]-acephenanthrylene and benzo-[j]-fluoranthene follow, and benzo-[3]-pyrene, benz-[a]-anthracene and chrysene are all weakly carcinogenic.

Most natural hydrocarbons found in the air are from biological sources, though small amounts come from geothermal areas, coal fields, natural gas from petroleum fields and natural fires. The more complex, naturally produced hydrocarbons found in the atmosphere, such as volatile terpenes and isoprene, are produced by plants and trees. Industrial sources, notably refineries, have become the major anthropogenic source of hydrocarbons. Other minor sources might include incomplete combustion from car engines, evaporative emissions from petrol stations and fuel tanks, emissions from solid waste disposal, forest fires, agricultural burning and coal waste fires.

### Self-Assessment Exercise

1. (a) Name two examples of (i) particulate pollutants and (ii) gaseous pollutants in the atmosphere.  
  
(b) List three effects, on the humans, of  $\text{SO}_2$  gas if substantially present in the inhaled air.
2. List five air pollutants that are proven human or animal carcinogens. Name their sources.
3. Why are alkenes more important in the study of air pollution than alkanes?

### 3.2.9 Cigarette Smoking

Cigarette smoking is especially dangerous for those with heart disease because combustion of tobacco in this way, with limited oxygen available, introduces CO directly into the bloodstream. The products of cigarette combustion include nicotine, acetaldehyde, acetone, benzene, formaldehyde, N'-nitrosonornicotine, N-nitrosopyrrolidine, benzo-[a]-pyrene. Among the very many products of combustion, nitrosamines, benzo-[a]-pyrene and nicotine are highly poisonous. Nicotine also throws an additional strain on the heart by stimulating the basal metabolic rate. Nitrosamines are known to cause cancer in animals.

Apart from the effect on the heart, tobacco smoking exacerbates bronchial infection and causes 30 - 40percent of all deaths from cancer. The higher incidence of cancer in smokers arises from inhalation of PAHs and nitrosamines. Smoking also increases the risk to workers in industries which generate fine particles.

### 3.2.10 Asbestos Fibres

The group named asbestos is applied to a range of naturally occurring fibrous magnesium silicate minerals with the approximate formula  $\text{Mg}_3\text{P}(\text{Si}_2\text{O}_5)(\text{OH})_4$ . Three common types are used: **crocidolite** (blue asbestos) – most hazardous; **amosite** (brown asbestos) – second most hazardous; **chrysolite** (white asbestos) – least hazardous.

Inhalation of separate dry fibres in a confined air space is the major hazard from asbestos. Such dry fibres can come from damaged thermal insulation, accumulated fibres from the manufacture, wear of asbestos, mineral materials such as brake shoe pad dust, ship breaking, waste disposal, and more insidiously, the exposure of workers' families from particles carried on clothing.

Asbestos fibres can cause lung and bowel cancer as well as non-cancerous lung diseases. Approximately 50percent of the inhaled fibres are cleared from the lungs and swallowed, which then exposes the throat and digestive system to their hazardous effects. Water from asbestos-cement pipes also poses a further source of digestive tract exposure. Respiratory diseases include asbestosis (a pneumonia-like condition), bronchial cancer and mesothelioma, which has a latency period of 20-30 years. There appeared to be a synergistic reaction between cigarette smoke and asbestos in that the onset of disease is more pronounced in heavy smokers than in non-smokers.

### 3.2.11 Toxic Metals

Toxic metals are those metals that are harmful in relatively small amounts e.g. As, Hg, Cd and Pb. Very often, a given metal or its compounds are found in association with other environmental particles. As a result, there are several routes by which such metals get into the atmosphere, for example, Pb can be added into the air through exhaust emissions, re-suspension of particles, flaking of old Pb painted houses, fumes from soldering and plumbing processes, and so on.

Depending on their particle sizes and speciation, such metals can be inhaled along with the air and find their ways into vital organs in the human system. Many of the toxic metals negatively impact the nervous system. Anaemia, renal failure and neuropsychological impairment are also part of the health infarctions that can be attributed to toxic metals.

### 3.2.12 Radioactive Gases

The penetration of buildings by chemically inert radon gas presents a more serious risk to human health than the hazards posed by occasional failure of control of nuclear power stations. The decay of  $^{238}\text{U}$  produces  $^{222}\text{Rn}$  which emanates from radioactive minerals in building foundations. Because it has a half-life of only 3.8 days, the risk is only significant when the gas can rise quickly into the immediate sub-soil, conditions which obtain above fissured granite. Radon has seven times the density of air and so basements and ground floor rooms are the most exposed.

The worst cancer risk from Rn arises from the first four solid decay products of Rn:



These products are dangerous because they are associated with moisture and dust, and become deposited in the lung, so exposing the epithelium to  $\alpha$ -particles from  $^{218}\text{Po}$  and  $^{214}\text{Po}$ . Other nuclides of Rn exist but they do not present the same risk as that from  $^{222}\text{Rn}$  e.g.  $^{220}\text{Rn}$  formed by decay of  $^{232}\text{Th}$  has too short a half-life to allow survival above ground. Increased incidence of lung cancer in uranium miners in western USA and Czechoslovakia was attributed to their inhaling  $^{222}\text{Rn}$ .

## Self-Assessment Exercise

1. What hazards are posed by the polycyclic aromatic hydrocarbons (PAH<sub>s</sub>)?
2. Which two of the gases that make up the oxides of nitrogen are of primary concern in air pollution considerations and why?
3. Name the major photochemical oxidant found in the atmosphere. What detrimental effects does this oxidant have on humans and animals?

## 4.0 Conclusion

Undoubtedly, the amount of each pollutant in the atmosphere is escalating and the types are also increasing. This is because of increasing anthropogenic activities some of which include the introduction of new products and by-products. While the full health effects of the already known pollutants are continuously being investigated, there is the greater challenge of not knowing yet the effects of “new” products that may have far reaching health implications on the universe as a whole. It is important to keep research activities vibrant especially in the areas of risk assessments and risk reduction with respect to environmental pollutants generally.

## 5.0 Summary

In this unit, you have learnt that:

- airborne chemical substances mostly and particulate matters, to some extent, are responsible for atmospheric pollution.
- the sources of pollutants can be natural or anthropogenic;  
both amount of a pollutant and length of exposure it determine the extent of health problems arising from such pollutant;
- health effects arising from atmospheric pollutants can be at the levels of cells, organs, systems and may even lead to death.

## 6.0 Self-Assessment Exercise

- I. (a) Mention two situations that can lead to heightened levels of CO in the indoor air at home.  
  
(b) Describe the mechanism of toxic action of CO as an indoor pollutant.
2. Name four principal sources of air pollution and the major types of pollutants produced by each source.
3. Discuss briefly the major health hazards associated with SO<sub>2</sub> in a dusty atmosphere.

## 7.0 References/Further Reading

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## Unit 3 Soil Pollution

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### 1.0 Introduction

Soil is an essential component of terrestrial ecosystems because the growth of plants and biogeochemical cycling of nutrients depend upon it. Pollution, along with other types of degradation, such as erosion and the continuing spread of urbanization, poses a threat to the sustainability of soil resources. Soil pollution can also be a hazard to human health when potentially toxic substances move through the food chain or reach groundwater which serves as drinking water.

In comparison with air and water, the soil is more variable and complex in composition and it functions as a sink for pollutants, a filter which retards the passage of chemicals to the groundwater and a bioreactor in which many organic pollutants can be decomposed. As a result of its occurrence at the interface between the land and the atmosphere, soil is the recipient of a diverse range of polluting chemicals transported in air. Further inputs of pollutants to the soil occur as a result of agricultural and waste disposal practices, but in general, the most severe pollution usually results from industrial and urban land use.

### 2.0 Objectives

At the end of this unit, you should be able to:

- name specific soil pollutants and their sources
- explain the transport mechanisms conveying pollutants to soil
- explain the mechanisms of pollutant sorption in the soil and
- state the consequences of soil pollution.

### 3.0 Main Content

#### 3.1 Soil Pollution and Contamination: A Global View

Certain contaminants/pollutants such as heavy metals are part of the earth naturally. Their natural background levels in soils are altered to various levels of pollution usually as a result of anthropogenic activities.

It is generally accepted that most of the soil in technologically advanced regions of the world is polluted or contaminated, at least, to some extent. Realistic estimate of areas affected by soil pollution is difficult owing to unreliable official figures and paucity of data for many parts of the world. Industrially contaminated land tends to contain higher concentrations and a greater possible range of pollutants than other sources of pollution. There are between 50,000 and 100,000 contaminated sites in the United Kingdom (UK) which occupy up to 100 000 ha. In the United States of America (USA), 25,000 contaminated sites have been identified, 6000 sites are being cleaned-up in the Netherlands, there are known to be at least 3,115 sites in Denmark and 40,000 suspect areas have been identified on 5,000 – 6,000 sites in the former western part of Germany.

## 3.2 Soil Pollutants and Their Sources

### 3.2.1 Heavy Metals

Heavy metals have a density of  $\geq 6\text{gcm}^{-3}$  and occur naturally in rocks. They belong to the group of elements geochemically described as “trace elements” because they collectively comprise less than 1 percent of the rocks in the earth’s crust. All trace metals are toxic to living organisms at excessive concentrations, but some are essential for normal healthy growth and reproduction by plants and/or animals at certain critical concentrations e.g. Co (for bacteria and animals), Cr (animals), Cu (plants and animals), Mn (plants and animals), Mo and Ni (plants), Se (animals) and Zn (plants and animals). Elements like Ag, As, Ba, Cd, Hg, Pb, Sb and Tl have no known essential function, but cause toxicity above a certain tolerance level. The most important heavy metals with regard to potential hazards and occurrence in contaminated soils are As, Cd, Cr, Hg, Pb and Zn.

Sources of heavy metals that contaminate or pollute a given soil site are:

**Metalliferous mining** e.g. As, Cd, Cu, Ni, Pb and Zn

**Metal smelting** e.g. As, Cd, Pb and Tl

**Metallurgical industries**

**Other metal-using industries** e.g. the electronics industry (using Cd, Ni, Pb, Hg, Se and Sb); pigments and paints (Pb, Cr, As, Sb, Se, Mo, Cd, Co, Ba and Zn); the plastics industry (polymer stabilizers e.g. Cd, Zn, Sn and Pb) and chemical industry (using catalysts and electrodes e.g. Hg, Pt, Ru, Mo, Ni, Sm, Sb, Pd and Os);

**Waste disposal**

**Corrosion of metals** in use

**Agriculture** – As, Cu and Zn (from pig and poultry feeds), Cd and U impurities (in some phosphatic fertilizers), As, Cu, Pb and Zn (from metal-based pesticides);

**Forestry-wood preservatives** containing As, Cr and Cu;

**Fossil fuel combustion** – Cd, Zn, As, Sb, Se, Ba, Cu, Mn and V (from coals and oils) and Se, Te, Pb, Mo, Mn and Li (added to fuels and lubricants to improve their properties);

**Sports and leisure activities** – game and clay pigeon shooting involving the use of pellets containing Pb, Sb, Mo and Bi.

### 3.2.2 Hydrocarbon Pollutants

Hydrocarbon pollutants from petroleum mainly comprise a range of saturated alkanes from  $\text{CH}_4$  to  $\text{C}_{76}\text{H}_{154}$ . Aromatic hydrocarbons and organic components containing nitrogen and sulphur can also be important constituents of some petroleum deposits. The hydrocarbons derived from coal and petroleum tend to form the main group of organic macropollutants in soils. Organic solvents can be important soil pollutants at industrial sites.

Sources of hydrocarbon pollutants include fuel storage and distribution, disposal of used lubricating oils, leakage of solvents from industrial sites and coal stores.

### 3.2.3 Toxic Organic Micropollutants (TOMPs)

The most common toxic organic micropollutants in the soil environments include: polycyclic aromatic hydrocarbons (PAHs), polyheterocyclic hydrocarbons (PHHs), polychlorinated biphenyls (PCBs), polychlorinated dibenzodioxins (PCDDs), polychlorinated dibenzofurans (PCDFs) and pesticide residues and their metabolites e.g. organochlorines (DDT, BHC, Endrin), organophosphates (Malathion, Parathion) and Carbamates (Aldicarb). The most serious problems associated with TOMPs are the subsequent contamination of surface and groundwaters and entry into the food chain through crops, especially.

### 3.2.4 Other Industrial Chemicals

It has been estimated that between 60,000 and 90,000 different chemicals are in current commercial use, worldwide. Although not all of these constitute potential toxicity hazards, many will cause pollution of soils as a result of leakage during storage, from use in the environment or from their disposal either directly, or of wastes containing them. Apart from industrial uses, a large number of chemicals are used in domestic products and so their use and disposal is less controlled than that of industrial chemicals which are subjected to strict regulations. The total world production of hazardous and special wastes was  $338 \times 10^6$  tonnes in 1990.

### 3.2.5 Nutrient-Rich Wastes

The major nutrient-rich wastes are sewage sludges and livestock manures. Sewage sludge, though a valuable source of plant nutrients (N and P especially) and of organic matter which has beneficial effects on soil aggregate stability, contains potentially harmful substances such as heavy metals (Cd, Cu, Ni, Pb and Zn) and toxic organic micropollutants (polychlorinated biphenyls, PCBs; polychlorinated terphenyls, PCTs; polychlorinated naphthalenes, PCNs; polychlorinated benzenes; polychlorinated dibenzodioxins, PCDDs; halogenated aliphatics; polycyclic aromatic hydrocarbons, PAHs; aromatic amines; nitrosamines; phthalate esters and pesticides). Also, livestock manures contain large amount of N, P and K, but the manures may also contain residues of feed additives which may include As, Cu and Zn and antibiotics such as sulfonamides fed to pigs and poultry.

### 3.2.6 Radionuclides

Nuclear accidents like those at Windscale (UK) in 1957 and Chernobyl (Ukraine) in 1986 resulted in many different radioactive substances being dispersed into the environment. The greatest long-term pollution problem with radionuclides in soils is caused by  $^{137}\text{Cs}$  which has a half-life of 30 years and behaves in a manner similar to K in soils and ecosystems. Atmospheric testing of nuclear weapons dispersed large amounts of  $^{90}\text{Sr}$  which has a half-life of 29 years and behaves similarly to Ca in biological systems and poses a particularly dangerous hazard to humans because it is stored in the skeleton.

### 3.2.7 Pathogenic Organisms

Soils can be contaminated with pathogenic organisms such as bacteria, viruses and parasitic worm eggs from various sources: the burial of dead animals and humans, manures and sewage and germ warfare experiments. The soil's own microbial biomass will destroy many of these pathogens but some appear to survive for relatively long times.

## 3.3 Transport Mechanisms Conveying Pollutants to Soils

Pollutants reach soils by four main pathways: atmospheric deposition of particulates; sorption of gases; fluvial transport and deposition; and placement.

**Atmospheric deposition:** Light particulates can become airborne and get transported from one location to the other. For example, there have been cases where pollution is directly traceable in soil up to 40 kilometres downwind of smelters. The critical factors determining the distance transported and the area of land affected are: the height of the emission above the ground, the wind speed, stability of the atmosphere and the size, shape and density of the particles and amounts of the pollutants emitted.

**Sorption of gases:** Volatile organic solvents become dispersed in the atmosphere and later get sorbed from the atmosphere onto soils or plants.

**Fluvial transport and deposition:** This mechanism is only important in land subjected to flooding. This was an important pollution pathway in areas of metalliferous mining in the nineteenth century when Pb-Zn mines in the UK discharged waters from ore dressing operations directly into streams and rivers. This led to the alluvial soils in most flood plains of rivers draining mining areas being severely contaminated with Pb, Zn and other metals. Soils on the flood plains of many major rivers in the world which drain industrial and urbanized areas have been significantly contaminated with a diverse range of substances from flood waters.

**Placement:** This can occur in many ways: dumping injection, surface spreading, etc; the most obvious being the spreading of wastes such as sewage sludge or metal-rich manures from pigs or poultry. Phosphatic fertilizers can contain significant concentrations of Cd and U and have been partially responsible for the significantly elevated concentrations of these elements in many parts of the world.

## 3.4 The Consequences of Soil Pollution

Soil pollution can restrict the uses to which land is put because of the ability of pollutants to be hazardous to human health, harmful to living resources or to damage buildings and services.

### 3.4.1 Types of Hazards Associated with Contaminated Soil

Direct **ingestion** of contaminated soil: As, Cd, Pb,  $\text{CN}^-$ ,  $\text{Cr}^{6+}$ , Hg, coal tars (PAHs), PCBs, dioxins, phenols, pathogenic bacteria, viruses, eggs of parasites.

- Inhalation of dusts and volatiles from contaminated soil: organic solvents, radon, Hg, asbestos.



- Plant uptake from soil: As, Cd,  $^{137}\text{Cs}$ , Hg, Pb,  $^{90}\text{Sr}$ , Tl, PAHs, various pesticides. Phytotoxicity:  $\text{S}^{2-}$ ,  $\text{O}_4^{2-}$ , Cu, Ni, Zn,  $\text{CH}_4$ , Cr, B.
- Toxicity to soil microbial biomass: Cd, Cu, Ni, Zn.
- Deterioration of building materials and services:  $\text{SO}_4^{2-}$ ,  $\text{SO}_3^{2-}$ ,  $\text{Cl}^-$ , tar, phenols, mineral oils, organic solvents.
- Fires and explosions:  $\text{CH}_4$ , S, coal and coke dust, petroleum oil, tar, rubber, plastics, high calorific value wastes.
- Contact with contaminants during demolition and site development: tars, phenols, asbestos, radionuclides, PCBs, TCDDs, bacteria, viruses.
- Water contamination:  $\text{CN}^-$ ,  $\text{SO}_4^{2-}$ , metal salts, hydrocarbons, solvents, surfactants, sewage, farm wastes, pesticides.

### 3.4.2 Soil-Plant Transfer of Pollutants

The transfer of pollutants from soil into plants through the roots varies considerably depending on the properties of the plants (genotypic factors) and the extent to which the pollution is absorbed in the soil in an unavailable form. The general orders of magnitude of the transfer coefficients for several heavy metals are 0.01 - 0.1 for As, Co, Cr, Hg, Pb and Sn; 0.1 - 1.0 for Cu and Ni; and 1.0 - 10 for Cd, Tl and Zn (which are the most readily accumulated by plants). Organic pollutants tend to have lower coefficients; a value of 0.033 has been suggested for dioxins and PCBs. The lower chlorinated congeners of PCBs tend to be more bioavailable and biodegradable than those with higher numbers of Cl atoms in their structure.

### 3.4.3 Ecotoxicological Implications of Soil Pollution

Zinc concentrations close to the maximum permissible level of 300 mg/g for European soils treated with sewage sludge, can cause a mark in the activity of the nitrogen-fixing bacteria of the species *Rhizobium leguminosum* by trifolii which occur in nodules in the roots of white clover. Although it appears that the order of toxicity of heavy metals to these bacteria is  $\text{Cu} > \text{Cd} > \text{Ni} > \text{Zn}$ , the greatest risk is posed by Zn. This is because many soils which have received several applications of sewage sludge may be approaching the maximum permissible concentration of 300 ug/g for Zn, but remains well below the maxima for these other metals.

### Self-Assessment Exercise

1. List five important sources of soil heavy metal pollution and give two examples of metals from each source.
2. Give two reasons why  $^{137}\text{Cs}$  and  $^{90}\text{Sr}$  are considered serious pollution problems in soils.

## 3.5 Cases of Exposure to Pollution

### 3.5.1 The Seveso Chemical Plant Explosion

On 10<sup>th</sup> July, 1976, a massive release of 2, 3, 7,8-tetrachlorodibenzo-p-dioxin occurred from a chemical plant in Seveso near Milan in Northern Italy. The chemical plant was being used for manufacturing 2, 4, 5-trichlorophenol (2, 4, 5 - TCP). A safety disc in a reaction vessel ruptured and a plume of chemicals containing 2, 4, 5 - TCP below 30 to 50 m above the factory. As it cooled, the material in it was deposited over a cone shaped area downwind from the factory about 2kilometres long and 700 metres wide.

Dioxin is both extremely toxic and stable, and at sufficient dose levels, it is known to affect foetal development and to have porphyrinogenic effects (often manifesting as digestive system and skin disorders). It is not used commercially, but found as a contaminant when 2, 4, 5 - TCP is synthesized by the hydrolysis of tetrachlorobenzene at high temperatures, and it is used to make 2, 4, 5 - T and 2, 4 - D (herbicides); dioxin is often present in trace amounts in these compounds. Dioxin is also produced as a by-product of waste incineration and it continues to be of major concern as a general environmental pollutant.

A few months after the accident, 176 individuals, mostly children, were found to have the skin condition chloracne, 50 of whom came from the most contaminated area. Some neurological abnormalities including polyneuropathy were also noted. There was also evidence of liver enlargement initially, and later, reported cases of increased hepatobiliary (liver) cancer, elevated levels of leukaemias and other haematologic neoplasms in men and increased myeloma and myeloid leukaemia (bone marrow cancers) in women. Finally, many farm animals died and the site became a wasteland of dying plants and deserted homes.

### 3.5.2 The Bhopal Catastrophic Release of Methyl Isocyanate

The accident at Bhopal, India occurred on 3<sup>rd</sup> December, 1984 at the Union Carbide factory which had been producing the insecticide carbaryl for about eighteen years. Methyl isocyanate (MIC) was one of the main ingredients of carbaryl. MIC was produced from monomethylamine (MMA) and phosgene, phosgene being produced by reacting chlorine and carbon monoxide; chloroform served as the solvent. On the night of the accident, some water probably inadvertently got into a tank where 40 tonnes of MIC were being stored, causing a runaway chemical reaction. The heat caused by the reaction led to a devastating explosion. About 100,000 people living in the vicinity were affected with at least 2,000 deaths reported.

### 3.5.3 Toxic Oil Syndrome in Spain

Between May and August 1981, in Madrid (Spain), there was an endemic of cooking oil poisoning that affected about 20000 persons with nearly 400 deaths. The illness began in each patient with a fever followed by severe (acute) respiratory symptoms and a variety of skin rashes similar to measles. Many of the patients developed signs of cerebral oedema (swelling of the brain) and cardiological abnormalities.

The cause of the disease was traced to adulterated cooking oil which was fraudulently sold to the public as pure olive oil. On analysis, the oil was discovered to contain up to 90percent rapeseed oil, varying amounts of soya oil, castor-oil, olive oil and animal fats. The

oil also contained between one and 50 ppm aniline, 1500 and 2000 ppm of acetanilide and a number of other anilides. These compounds might have been responsible for the symptoms produced by the toxic oil.

### 3.5.4 River Oil Contamination by the Toxic Oil

In 1968, in Japan and Taiwan, a number of families developed chloracne, the skin condition which affected the victims of Seveso. Chloracne is more severe than the type of acne that occurs in adolescents and it has a rather different distribution on the body. Epidemiological studies revealed that those affected had been exposed to a particular batch of rice oil that was contaminated with PCBs.

At the end, the individuals examined were considered to have met the diagnostic criteria for what has come to be known as *Yusho* disease. In addition to chloracne, the patients of *Yusho* disease had a number of systemic complaints including loss of appetite, lassitude, nausea and vomiting, weakness and loss of sensation, and hyperpigmentation of the face and nails, in some cases. A number of non-specific symptoms that persisted in the patients include feeling of fatigue, headache, abdominal pain, cough with sputum, numbness and pain, changes in menstruation in females, sensory neuropathy, retarded growth in children, abnormal teeth development and anaemia in some patients. The most striking observation was a marked increase in serum triglyceride levels. To what extent the non specific symptoms are seen in the patients with *Yusho* disease were entirely due to PCBs is difficult to say since it is known that they were also exposed to polychlorinated dibenzofurans (PCDFs) and polychlorinated quarterphenyls (PCQs) – compounds formed when PCBs are heated. In animal models, PCDFs and PCQs are more toxic than PCBs.

### 3.5.5 Polybrominated Biphenyls (PBBs) in Cattle Feed

Polybrominated biphenyl is used mainly in plastics as a fire retardant. At Michigan in May and June of 1973, some 10 to 20 bags of PBB (labelled “Firemaster”) were sent in error, instead of magnesium oxide (a livestock food additive, “Nutrimaster”), to a grain elevator. Thus PBB became incorporated into the feed and distributed throughout the state to be fed to the unsuspecting cows.

Soon, reports of sick cows began to surface. Dairy products and meat from the affected cows were contaminated. Over 1000 farmers were adversely affected. Some of the adverse effects included acne, dry skin, hyperpigmentation and discolouration of the nails, headaches, nausea, depression and a number of non-specific symptoms. Serum levels of hepatic enzymes were higher in the Michigan farmers than their neighbouring controls.

### 3.5.6 Mercury Poisoning in Minamata and Niigata

The Minamata Bay disease (*Kibyo* or “mystery illness”) was first noted at the end of 1953 when an unusual neurological disorder began to affect the villagers who lived on Minamata Bay, Japan. Those who were affected presented with a mixture of signs relating to the peripheral and central nervous systems. The prognosis of the condition was poor, many patients became disabled and bedridden and about 40percent died.

The disorder was associated with the consumption of fish and shellfish caught from the bay. The fish and shellfish were contaminated with methyl mercury. The source of the mercury was effluent released into the bay from a factory which was manufacturing vinyl chloride using mercury based catalyst prior to the time when there were regulations forbidding its use in Japan.

The Minamata Bay disease involved about 700 people and there was another outbreak of methyl mercury poisoning in Japan (Niigata) in 1965 affecting about 500 individuals. This resulted from pollution of the Agano River by industrial effluent containing methyl mercury and subsequent consumption of contaminated fish by the local population.

### 3.5.7 Methyl Mercury Poisoning in Iraq

Iraqi government imported a large consignment of seed grain treated with an alkyl mercury fungicide and distributed them to the largely illiterate rural population for sowing. The sacks were marked with warning labels “for sowing and not for eating” in English and Spanish. The seed had been treated with a red dye to distinguish it from edible grain, but the farmers found that they could remove the dye by washing and equated this with the removal of the poison.

The grain was first used to make bread in November, 1971 and the first cases of poisoning appeared in December. By the end of March 1972, there had been over 6,530 admissions to hospital and 459 of these had died. On the whole, this episode became a major outbreak in which the incidence of disease was estimated to be as high as 73 per 10,000.

### 3.5.8 Love Canal Chemical Odours

Love Canal was a waste disposal site containing both municipal and chemical waste disposal of over a 30 year period up to 1953. Homes were then built on the site during the 1960s and leachates began to be detected in the late 1960s.

The reporting of chemical odours in the basements of homes in the Love Canal district, USA, led to a toxicological investigation which made this area famous in the history of waste disposal and resulted in vigorous regulatory activity in the USA. Dibenzofurans and dioxins were among the chemicals detected in the organic phase of the leachates. Animal studies indicated possible risks of immunotoxic, carcinogenic and teratogenic effects. The episode resulted in significant fears of ill-health and much psychological stress. Limited follow-up of residents identified low birth weights in the offspring of Love Canal residents.

## 4.0 Conclusion

Soil pollution represents, on the average, the pollution phenomenon that could directly threaten all forms of organisms whether they are aerobic or anaerobic. Depending on the nature of the pollutants, it may take several years to overcome the effects of a given pollutant in a soil environment. When it happens, plants, animals, humans, fauna and flora may suffer varying degrees of stress and in some cases, be faced with possible extinction. Thus, it is better to control and prevent the occurrence of soil pollution than to embark on remediation steps after pollution has taken place; it is more costly.

## 5.0 Summary

In this unit, you have learnt that:

- Compared with air and water, soil constitutes a more variable and complex sink for pollutants.
- Developed countries have been able to map out specific contaminated/polluted sites within their geographical borders, but developing countries have paucity of data with respect to soil pollution.
- Soil pollutants include heavy metals, hydrocarbons, toxic organic micropollutants, industrial chemicals, nutrient-rich wastes, radionuclides and pathogenic organisms.
- Soil pollution can result directly or indirectly in the health infarction of plants, animals and humans.
- There have been cases of massive catastrophic exposure to chemicals as a result of accidental or incidental chemical plant explosions or test-running of radiochemical substances.

## 6.0 Self-Assessment Exercise

Discuss briefly each of the following soil pollutants (a) lead, (b) Sr-90 and (c) organochlorines, under the sub-topics: source, mechanism of transportation to soil and health effects.

## 7.0 References/Further Reading

Harrison, R. (1996). *Pollution: Causes, Effects and Control*. (3rd ed). London: The Royal Soc. of Chemistry.

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Ademoroti, C. (1996). *Environmental Chemistry and Toxicology*. Ibadan: Foludex Press Ltd.