ENVIRONMENTAL ENGINEERING

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FOREWORD

Environment and development are two sides of the same coin. The need for development through socio-economic activities, especially with the growing population and a desire for higher standards of living with industrial production, is obvious. With the limited availability of land for cultivation purposes, the need for increasing the application of fertilizers—nitrogenous, phosphatic, potassic, in an appropriate combination—and also the necessity for appropriate pest control through pesticides is also obvious. Practically all socio-economic activities, for example, industry, agriculture, transport, construction—road, housing, etc.—contribute to environmental degradation including water, soil, air, etc. The complexities of these problems, due to involvement of interacting parameters, have necessitated a multi-disciplinary approach to environmental protection, different from the traditional public health engineering limited to civil engineering.

This book will also be useful to planners for industrial development as well as in-service engineers working in industries, government departments, etc. in their search for appropriate planning, especially from an environmental angle as well as pollution control. With the growing need for conservation of materials and energy due to their limited supply, the book should be useful to in-service engineers in their efforts to save both material and energy. The book will also hopefully meet the necessity for a book on environmental engineering with a multi-disciplinary approach. The topics covered are fairly wide and would meet the training requirement for both applied sciences as well as engineering disciplines including civil, chemical, mechanical and biochemical engineering, chemistry, physics, zoology, botany, etc. The extensive use of this book by students, faculty and practising engineers will bring satisfaction to the authors who have put in a lot of effort in writing this book.

J P Singh
Additional Secretary
Ministry of Water Resources
Government of India

PREFACE

The scientific monitoring of environmental pollution is important for many reasons. It is necessary to have some idea of the different methods used for pollution abatement. Information about the desired limit is essential for calculating the extent to which pollution control is required. Proper monitoring would also help in focussing on the seriousness of the problem of environmental pollution and generate real concern among policy planners. An attempt, therefore, has been made in this book to introduce scientific monitoring, development of standards and their present position as well as different methods for pollution abatement.

The book is expected to serve as a reference book to the practising chemical engineer, civil engineer, mechanical engineer, public health engineer and industrial chemist, food technologist, oil technologist, plastic technologist and chemists working in manufacturing departments with an interest in effluent treatment. The book should be of help to those involved in the monitoring and control of environmental pollution. It could also serve as a useful text for undergraduate and postgraduate students of chemical, civil, mechanical, and biochemical engineering, specializing in environmental engineering.

The direct and indirect contributions of both the delivery and receiving sides of several courses organized by us are gratefully acknowledged. Several colleagues specially V N Nigam, U B Chitransi, S K Awasthi, S N Srivastava, S N Yadav and students, viz. Rewa Arora, A Garg, A K Jain, Dhirendra and P K Pandey contributed to the presentation of the final manuscript. Amarika Singh carefully corrected the proofs.

We are also indebted to Dr R B Sundrashan, Director, NEERI, Nagpur, for providing the necessary data. It is impossible for us to acknowledge all the individual contributions that have been made towards writing this book. Published literature and technical journals on the subject have been freely consulted and have been a valuable source of information.

The financial assistance provided by the Indian Society for Technical Education and the University Grants Commission, New Delhi, for organizing some of the courses on environmental pollution, monitoring and control, and the Department of Science and Environment, Lucknow, for finalization of the manuscript, are gratefully acknowledged.

We will greatly appreciate being informed of errors in the book and receiving constructive criticism.

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G N Pandey is currently working as Director, Institute of Engineering and Technology, Lucknow. He has been on the faculty of Banaras Hindu University, and Harcourt Butler Technological Institute (HBTI), Kanpur, for about 20 years. He also spent two years with the University of Michigan, USA, on a research assignment. He served as Director, Directorate of Environment, Uttar Pradesh, and Director (Technical), Indian Turpentine and Resin Company, Bareilly, prior to his joining this institute. He has guided about two dozen Ph D and about 50 M Tech students. He has five books and about 180 papers to his credit. His current interests are environmental engineering, energy systems engineering and computer applications. He has also served as a consultant to several chemical and allied industries.

G C Carney is presently a senior lecturer at Bristol Polytechnic, UK. He obtained a B Sc and M Sc, both in Agricultural Entomology, from the University of Durham. He did his Ph D in Entomology from the University of Minnesota, USA.

He was employed by Atomic Energy of Canada where he carried out research on the effects of radioactivity on insects. This interest continued during his subsequent employment as an assistant professor at the University of Bowling Green, Ohio, USA.

He is the author of several scientific publications in the field of environmental toxicology, including the application of radioactive tracers.

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ENVIRONMENTAL POLLUTION: MONITORING AND CONTROL

To fully understand the concept of environmental engineering, it is essential to have an idea of the different terms involved, e.g., the environment, biogeographical regions, biomes, etc. It is equally essential to be familiar with the most common pollutants, their effects, and monitoring techniques.

The Environment

It is a common error to equate man's global environment with the biosphere. It is apparent, however, that since the biosphere is only that region of the earth where life exists, a global girdle extending from some 10,000 m below sea level to 6,000 m above sea level, it must be less in extent than the whole world environment. Problems arising in parts of the environment outside the biosphere, e.g., the upper layers of the atmosphere or deep geological strata, can obviously impinge on man's existence. However, it is usually with problems and processes in the biosphere that we are immediately concerned. The biosphere can be broken down into a number of components and these are briefly discussed below.

Biogeographical Regions

These are regions of the earth's surface which are physically separated from one another and which tend to have their own distinctive flora and fauna. Examples of these regions are Eurasia, Australia, North America and South America.

Biomes

A biome is a major type of environment rather than a locality. Examples include the desert, tundra and steppe. Similar biomes may be found in different biogeographical regions. In the case of polar regions, biomes and biogeographical regions coincide.

Habitat

A habitat is the local environment of an organism or group of organisms.

Physical Environment

The physical environment consists of the non-living elements within the biosphere, biogeographical region, biome or habitat. Examples of these physical elements include:

1. pH
2. Temperature
3. Relative humidity
4. Topography
5. Salinity (if aquatic)
6. Soil type, etc.

Biotic Environment

This is the living component of the environment. It consists of all the plants, animals and microorganisms which are present.

Ecosystems

An ecosystem consists of the physical and biotic components of a stable and self-perpetuating environment. The dynamic relationships which exist within the ecosystem are clearly an important component in maintaining the stability.

An ecosystem may exist at any level from the whole biosphere (the global ecosystem) to the specialised, artificial ecosystem, e.g., one which exists within an activated sludge plant.

Resources

Timber, minerals, water, atmosphere, land, etc., are important elements within the environment. A detailed treatment of these, is however, outside the scope of the present book. Nevertheless, resources are particularly important in the present context when they are able to act as a media of dispersal for pollutants. The media of land, water and air are important.

The Origin of Waste

One characteristic peculiar to man is that he progressively changes his environment to meet his biological and social needs. On a socially organised basis man provides himself with the materials necessary for life which he removes initially as raw materials from his environment. It is in the provision and utilisation of these material necessities, that worthless and sometimes harmful byproducts originate. Such products go to make up wastes of all descriptions and they are the inevitable results of man's interaction with his physical and biological surroundings. Unless removed, they reduce the wholesomeness and quality of these surroundings. To separate waste from the environment has been one of Man's oldest pursuits.

Historic and Cultural Background

In primitive nomad societies, the problem of waste disposal was the least worrying. The nomad separated waste from his environment by changing his surroundings. It is when man exists in permanent communities that the removal of his waste products must be conducted on an organised basis. It is of interest to note that it was the transition from palaeolithic society, based on hunting and gathering, to neolithic society, based on farming and agriculture, which stressed the need for waste disposal. The excesses of the industrial revolution and its aftermath up to the present day have however resulted in a qualitatively different type of problem. Although waste disposal must, as a minimum requirement, conserve the environment's ability to sustain human life, the degree to which it is practised, at levels above this minimum, depends on the economic, political, cultural and aesthetic values of the waste producing society.

Pollutants

Wastes are not necessarily pollutants in themselves but all have the capacity to be so. In exactly the same way as there is no single taxonomic group of plants which can be considered to be weeds. Rather, the designation 'weed' depends on the locality occupied by the plant, so a waste becomes a pollutant when it occurs in the wrong place. It should be appreciated that production of waste is an inevitable consequence of the first and second laws of thermodynamics: the production of actual pollutants is far from inevitable.

The following definition of a pollutant has been given by Werner (1973):

> A substance or effect is normally considered to be a pollutant if it adversely alters the environment by changing the growth rate of a species, interferes with the food chain, is toxic, or interferes with health, comfort, amenities, or property values of people. Generally, a pollutant is a substance or effect introduced into the environment in significant amounts as sewage, waste, accidental discharge or as a byproduct of manufacturing process or other human activity. A polluting substance can be a solid, semi-solid, liquid, gas or sub-molecular particle. A polluting effect is normally some kind of waste energy such as heat, noise or vibration.

Pollution

Pollution is the result of the action or presence of a pollutant in a part of the environment where it is considered to have deleterious effects.

The definition given by Darling (1970) is:

> Pollution comes from getting rid of wastes at the least possible cost.

TABLE 1.1

Pollutants causing air pollution, along with their sources and harmful effects and tolerance limits

Pollutants	*Major sources*	*Principal effects*	*Pollutants*	*Tolerance limits*
1. Ammonia	Ammonia and urea plant	Adverse health effect, toxicity to fish and equatic life	m. tons/yr	1.2 mg/l as nitrogen
2. Arsenic	Gas purification plant in ammonia and urea manufacture	Causes black foot disease and slow poisoning to plants and crops	—	1.0 mg/l
3. Boron	Manufacture of synthetic borons	Causes tonic effects for living organisms, destruction of plants		1.0 mg/l
4. Carbon monoxide	(i) Transportation (ii) Fuel combustion (iii) Industrial processes (iv) Solid waste disposal	Reduction in the oxygen carrying capacity of blood, reduces visual and mental activity	71.2 1.9 7.8 5.7	
5. Carbon dioxide	(i) Transportation (ii) Fuel combustion (iii) Industrial processes (iv) Solid waste disposal	Causes eye irritation suffocation and cloud dust	1.2 6.0 5.9 1.6	
6. Colour	Various process plants	Excess colour is objectionable aesthetically to all the living beings	—	—
7. Dust	Various process plants	Reduces visibility	—	—
8. Fluoride	Effluent in phosphoric acid and super phosphate plants	Causes dental and skeletal fluoros is affects hatching of eggs in fish	—	2 mg/las F
9. Lead	Various industrial and mining effluents	Strong poison and higher contamination may be fatal	—	0.05 mg/l
10. Nitrogen oxide nitric oxide and nitrous oxide	(i) Transportation (ii) Fuel combustion (iii) Processing (iv) Solid waste disposals	Visibility reduction, sensory irritation and plant damage	13.8 0.7 3.5 5.6	—
11. Odour and taste	Due to presence of some organic compounds and dissolved gases like	Bad odour and taste make the air, water and edibles unfit for use.	—	—

	hydrogen sulfide and inorganic salts of iron, zinc, copper, etc.			
12. Oil and Grease	Lubrication of machinery gasoline filling stations, and fat manufacturing plants	Suppresses dissolution of oxygen in water floats on water and forms ugly sticks causes toxic and synergic effects	—	10 mg
13. pH	Due to presence of acids or alkalis	Higher or lower pH affects aquatic life and makes it unfit for human use	—	5.5 to 9
14. Phosphate	Phosphoric acid and complex fertiliser units	Phosphates along with ammonia causes algal blooms which increases cost of water treatment	—	—
15. Sulphur oxides	(i) Transportation (ii) Fuel combustion (iii) Industrial processes (iv) Solid waste disposal	Causes sensory and respiratory irritation, plant damage corrosion, adverse effects on health	0.4 22.0 7.2 0.70	
16. Temperature	Industrial cooling	Prolonged exposure may produce undesirable physiological effects, causes adverse affects on aquatic life taste and odour	—	85°F or 29°F
17. Turbidity	Due to presence of suspended clay or dispersed organics and micro-organics	Affects aquatic life also objectionable from aesthetic point of view	—	—
18. Urea	Urea plant	Toxicity of ammonia for hydrolysis, entrophication of water bodies	—	1.2 mg/l as nitrogen

The Royal Commission of Environmental Pollution has said the following in its Fifth Report:

> Pollution occurs when as a result of man's activities, enough of a substance is present in the environment to have harmful effects. Many substances which can become pollutants are present naturally in the environment in lesser amounts and may be beneficial or even essential to it.

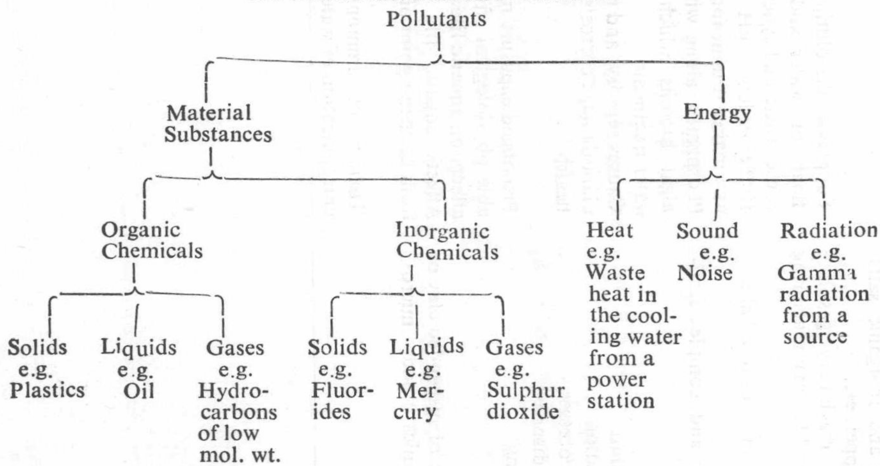
Classification of Pollution and Pollutants

It is well known that no substance or form of energy is automatically a pollutant as this depends upon its effect which in turn depends on where in the environment it has been liberated. This has resulted in a variety of classification schemes which individually reflect the interests and priorities of their designers.

A Formal but Simplistic Approach

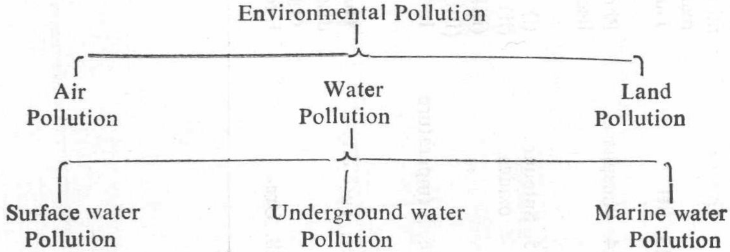
An example of this is given in the key below. Whilst it has a certain appeal, it suffers from the drawbacks which have been discussed below.

A Formal Classification of Pollutants



A Medium-Based Approach

Here pollution is categorised according to the medium of dispersal.



This approach has been most preferred by those who have set up control agencies. Traditionally, pollution control agencies have been allocated a single medium of dispersal to deal with. This has created many problems, for a mobile pollutant may move through one medium into another, and out of the jurisdiction of one agency into the control (or lack of control) of another.

To cite one example, a recognised method of alleviating pollution due to sulphur dioxide from power stations is to scrub the gases as they ascend the stack. This forms a dilute solution of sulphurous acid. If this liquid is discharged into a water course then deoxygenation of the water occurs due to the oxidation of sulphurous acid. The equation is:

$$2H_2SO_3 + O_2 \longrightarrow 2H_2SO_4$$

This is an example of pollution conversion, which merely transfers problems without solving them.

An Ecological Approach

Here it is possible to divide pollutants into two major classes:

(a) Those which have counterparts in nature, e.g., sulphur dioxide, and the organic component of sewage

(b) Those which have no counterpart in nature, e.g., DDT, plastics freons and PCDs.

Specialised Systems

These are devised for special purposes. One example is of a system which reflects the route of entry into the body, e.g., pollutants which are ingested, pollutants which are inhaled, and those which traverse the skin.

The Function Approach

This very useful system was proposed by Holdgate. It is less a method of classification and more a system of characterising waste according to its intrinsic properties:

Toxicity An important parameter when assessing risks to life.

Persistence A measure of how long a pollutant remains in the environment.

Mobility A high degree of mobility is not necessarily a useful attribute. In disposing of a pollutant, two basic strategies may be adopted: concentrate and contain, and dilute and disperse. Clearly, mobility is undesirable in the first case, but an advantage in the second.

Ability to Concentrate in Living Tissue Certain pollutants can accumulate in living tissue, a phenomena known as Bio-concentration of biological amplification. Substances which can show this effect include DDT and certain heavy metals, e.g., mercury and lead. This is an important factor which must be taken into consideration when devising limits and standards.

Controllability A measure of how readily a pollutant may be removed or neutralised.

Monitoring

Monitoring of pollutants for environmental analysis may be carried out continuously or intermittently although with the advent of monitoring units which are well funded, the use of continuous monitoring systems has increased. Monitoring systems basically fall into five categories.

Instrumental Systems for Measuring Physical Properties

Examples:

1. Sound level meters
2. Geiger counters
3. Thermometers
4. Oxygen meter
5. Hydrometers
6. Colorimeter

Instrumental Methods of Chemical Analysis

Until recently these were restricted to the research laboratory, but now they are used quite extensively in the environmental field. Examples of instrumental methods currently used in environmental analysis are:

1. Atomic absorption spectroscopy
2. Infra-red spectrophotometry
3. Gas chromatography
4. Spectrophotometry

Wet Method of Chemical Analysis

This is an extensive field which is not quite so important today as it once was, as many of the traditional techniques have been replaced by instrumental methods. Two important wet techniques are:

1. Volumetric analysis
2. Gravimetric analysis

Biological Systems of Monitoring

The type and number of living organisms are used to assess the quality of an environment. Biological systems are referred to as environmental indicators. They sum up the entire effect of all the pollutants present in the locality. Two examples are given below:

1. The use of aquatic invertebrates and their larvae to assess water quality as in the Trent Biotic Index.

2. The use of lichens to estimate concentrations of sulphur dioxide in the air.

Hybrid Systems

In practice, many of the complex analytical systems used employ elements from two or more of the above. Thus the Biochemical Oxygen Demand Test is a hybrid of either a wet chemical technique and a biological system, or an instrumental chemical system and a biological system.

Environmental Pollution Control

Environmental pollution control could be analysed on the pattern of process control. A closer scrutiny would reveal the analogy between process control and environmental pollution control.

There are four questions invariably asked about any control which are equally applicable to environmental control:

1. What is to be controlled?
2. How far is it to be controlled?
3. How fast is it to be controlled?
4. How should it be controlled?

1. The first question clearly falls within the jurisdiction of medical scientists who could very well identify the main or potential pollutants, viz., solids, liquids and gases which are undesirable to human beings and should be controlled. The list is given in Table 1.1 which clearly indicates the undesirable pollutants and their effects on human beings.

2. In order to determine how far to control it is essential to know the desired limit or tolerance limit which is appropriate for each substance. This too can be decided only with the help of medical scientists. The second aspect of this question is to determine the present level of each pollutant in the environment. This can be done by proper and effective monitoring of the pollutants. The difference between the present level of pollutants and the desired or permissible level will decide the extent to which these pollutants should be removed from the environment. It is essential that an independent agency executes the monitoring, in order to determine the position of the present level of pollutants.

3. How fast to control these pollutants really depends upon the degree of undesirable effects and hazards associated with the pollutant. Another factor that determines this process is the need to see that the pace of industrialisation is not reduced.

4. The question of pollution control really falls in the jurisdiction of technologists and microbiologists due to the increasing role of micro-organisms. As far as possible, recycling should be used, which will not only help control the environment but will also assist the economy of the country by proper utilisation of chemicals joining the effluents. This