

ENVIRONMENTAL EDUCATION AND POLLUTION

Dr. Sangeeta Agarwal



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Contents

<i>Preface</i>	<i>vii</i>
Chapter 1 Introduction	1
Chapter 2 Environmental Pollution and Pollutants	23
Chapter 3 Environmental Education and Management	64
Chapter 4 Elements of Environmental Education	76
Chapter 5 Environmental Science: Pollution Challenges and Implementing Control Strategie	90
Chapter 6 Chemical Substance in Environment	113

Preface

Environmental education and pollution are inextricably linked, forming the basis for understanding and addressing pressing environmental challenges. Environmental education serves as a vital tool for raising awareness, fostering understanding, and promoting action to mitigate pollution and its adverse effects on ecosystems and human health. Through environmental education, individuals and communities gain knowledge about the causes and consequences of pollution, as well as the importance of adopting sustainable practices to reduce pollution levels. This education empowers individuals to make informed decisions and take responsible actions to protect the environment.

Pollution, stemming from various sources such as industrial activities, transportation, agriculture, and waste disposal, poses significant threats to environmental quality and human well-being. It can lead to air and water contamination, habitat destruction, biodiversity loss, and adverse health effects. Environmental education plays a crucial role in addressing pollution by equipping individuals with the knowledge and skills needed to identify, prevent, and mitigate pollution in their communities. By fostering a deeper understanding of the interconnectedness between human activities and the environment, environmental education encourages individuals to adopt sustainable behaviours that minimize pollution and promote environmental sustainability.

Moreover, environmental education emphasizes the importance of collective action and community engagement in tackling pollution. By fostering collaboration among stakeholders, including governments, industries, NGOs, and local communities, environmental education initiatives can leverage collective efforts to address pollution at local, national, and global levels. These initiatives may

include community clean-up campaigns, pollution monitoring programmes, advocacy for policy changes, and promotion of sustainable alternatives to polluting practices.

Furthermore, environmental education promotes critical thinking, problem-solving, and decision-making skills necessary for addressing complex environmental challenges. By encouraging inquiry-based learning and interdisciplinary approaches, environmental education enables individuals to analyze environmental issues from multiple perspectives and develop innovative solutions to mitigate pollution and promote environmental sustainability. Through hands-on experiences, outdoor activities, and experiential learning opportunities, environmental education fosters a deeper connection with nature and instills a sense of stewardship and responsibility for the environment.

Environmental education plays a pivotal role in addressing pollution by raising awareness, fostering understanding, and promoting action to protect the environment and human health. By empowering individuals with the knowledge, skills, and values needed to address pollution effectively, environmental education contributes to building a more sustainable and resilient future for all.

The book on Environmental Education and Pollution provides comprehensive insights and practical strategies for fostering environmental awareness, promoting sustainable practices, and addressing pollution challenges to protect the planet for future generations.

—Author

1

Introduction

The need for environmental education has been explicitly recognized by government policies of several countries. In many cases, policy directives exist for the incorporation of environmental education and communication into mainstream education. While governments are the policy making agencies, NGOs and CBOs are often the source of innovations. They are close to and responsive to community needs and can effectively implement programmes. Thus Government systems and the NGO networks are complementary to each other and a partnership between the two can make EEmore effective.

Environmental Education refers to the branch of Experiential Education that is focused on teaching students about the natural world and their relationship with it. It typically focuses on ecosystems and the role humans play in those ecosystems. Particularly, Environmental Education focuses on the ways human systems impact the environment and the way the environment in turn impacts human society. Some Environmental Education programmes aim to change people's behaviour. Others aim to give students a balanced perspective, allowing them to make their own decisions as to the best way for humans to live sustainably.

Common Environmental Education activities include Forest Ecology, Pond Ecology, Animal Ecology, Predator/Prey, Animal Tracking, Outdoor Living Skills, Garbage Dissection, and Leave No Trace.

Increasingly, Service Learning projects have Environmental Education components to them. These activities commonly include trail maintenance, habitat restoration, control of invasive/exotic species, energy conservation projects, composting projects and gardening.

THE NATURE AND MEANING OF ENVIRONMENT

We have seen that a community or social group sustains itself through continuous self-renewal, and that this renewal takes place by means of the educational growth of the immature members of the group. By various agencies, unintentional and designed, a society transforms uninitiated and seemingly alien beings into robust trustees of its own resources and ideals.

Education is thus a fostering, a nurturing, a cultivating, process. All of these words mean that it implies attention to the conditions of growth. We also speak of rearing, raising, bringing up — words which express the difference of level which education aims to cover. Etymologically, the word education means just a process of leading or bringing up. When we have the outcome of the process in mind, we speak of education as shaping, forming, molding activity — that is, a shaping into the standard form of social activity.

In this chapter we are concerned with the general features of the way in which a social group brings up its immature members into its own social form. Since what is required is a transformation of the quality of experience till it partakes in the interests, purposes, and ideas current in the social group, the problem is evidently not one of mere physical forming. Things can be physically transported in space; they may be bodily conveyed. Beliefs and aspirations cannot be physically extracted and inserted.

How then are they communicated? Given the impossibility of direct contagion or literal inculcation, our problem is to discover the method by which the young assimilate the point of view of the old, or the older bring the young into like-mindedness with themselves. The answer, in general formulation, is: By means of the action of the environment in calling out certain responses. The required beliefs cannot be hammered in; the needed attitudes cannot be plastered on. But the particular medium in which an individual exists leads him to see and feel one thing rather than another; it leads him to have certain plans in order that he may act successfully with others; it strengthens some beliefs and weakens others as a condition of winning the approval of others.

Thus it gradually produces in him a certain system of behaviour, a certain disposition of action. The words “environment,” “medium” denote something more than surroundings which encompass an individual. They denote the specific continuity of the surroundings with his own active tendencies. An inanimate being is, of course, continuous with its surroundings; but the envining circumstances do not, save metaphorically, constitute an environment. For the inorganic being is not concerned in the influences which affect it. On the other hand, some things which are remote in space and time from a living creature, especially a human creature, may form his environment even more truly than some of the things close to him.

The things with which a man varies are his genuine environment. Thus the activities of the astronomer vary with the stars at which he gazes or about which he calculates. Of his immediate surroundings, his telescope is most intimately

his environment. The environment of an antiquarian, as an antiquarian, consists of the remote epoch of human life with which he is concerned, and the relics, inscriptions, *etc.*, by which he establishes connections with that period. In brief, the environment consists of those conditions that promote or hinder, stimulate or inhibit, the characteristic activities of a living being.

Water is the environment of a fish because it is necessary to the fish's activities — to its life. The north pole is a significant element in the environment of an arctic explorer, whether he succeeds in reaching it or not, because it defines his activities, makes them what they distinctively are. Just because life signifies not bare passive existence but a way of acting, environment or medium signifies what enters into this activity as a sustaining or frustrating condition.

THE SCHOOL AS A SPECIAL ENVIRONMENT

The chief importance of this foregoing statement of the educative process which goes on willy-nilly is to lead us to note that the only way in which adults consciously control the kind of education which the immature get is by controlling the environment in which they act, and hence think and feel. We never educate directly, but indirectly by means of the environment. Whether we permit chance environments to do the work, or whether we design environments for the purpose makes a great difference. And any environment is a chance environment so far as its educative influence is concerned unless it has been deliberately regulated with reference to its educative effect. An intelligent home differs from an unintelligent one chiefly in that the habits of life and intercourse which prevail are chosen, or at least coloured, by the thought of their bearing upon the development of children. But schools remain, of course, the typical instance of environments framed with express reference to influencing the mental and moral disposition of their members. Roughly speaking, they come into existence when social traditions are so complex that a considerable part of the social store is committed to writing and transmitted through written symbols.

Written symbols are even more artificial or conventional than spoken; they cannot be picked up in accidental intercourse with others. In addition, the written form tends to select and record matters which are comparatively foreign to everyday life. The achievements accumulated from generation to generation are deposited in it even though some of them have fallen temporarily out of use. Consequently as soon as a community depends to any considerable extent upon what lies beyond its own territory and its own immediate generation, it must rely upon the set agency of schools to insure adequate transmission of all its resources. To take an obvious illustration: The life of the ancient Greeks and Romans has profoundly influenced our own, and yet the ways in which they affect us do not present themselves on the surface of our ordinary experiences. In similar fashion, peoples still existing, but remote in space, British, Germans, Italians, directly concern our own social affairs, but the nature of the interaction cannot be understood without explicit statement and attention.

In precisely similar fashion, our daily associations cannot be trusted to make clear to the young the part played in our activities by remote physical energies, and by invisible structures. Hence a special mode of social intercourse is instituted, the school, to care for such matters. This mode of association has three functions sufficiently specific, as compared with ordinary associations of life, to be noted. First, a complex civilization is too complex to be assimilated in toto. It has to be broken up into portions, as it were, and assimilated piecemeal, in a gradual and graded way. The relationships of our present social life are so numerous and so interwoven that a child placed in the most favourable position could not readily share in many of the most important of them. Not sharing in them, their meaning would not be communicated to him, would not become a part of his own mental disposition. There would be no seeing the trees because of the forest. Business, politics, art, science, religion, would make all at once a clamour for attention; confusion would be the outcome. The first office of the social organ we call the school is to provide a simplified environment.

It selects the features which are fairly fundamental and capable of being responded to by the young. Then it establishes a progressive order, using the factors first acquired as means of gaining insight into what is more complicated. In the second place, it is the business of the school environment to eliminate, so far as possible, the unworthy features of the existing environment from influence upon mental habitudes. It establishes a purified medium of action. Selection aims not only at simplifying but at weeding out what is undesirable. Every society gets encumbered with what is trivial, with dead wood from the past, and with what is positively perverse. The school has the duty of omitting such things from the environment which it supplies, and thereby doing what it can to counteract their influence in the ordinary social environment. By selecting the best for its exclusive use, it strives to reinforce the power of this best.

As a society becomes more enlightened, it realizes that it is responsible not to transmit and conserve the whole of its existing achievements, but only such as make for a better future society. The school is its chief agency for the accomplishment of this end. In the third place, it is the office of the school environment to balance the various elements in the social environment, and to see to it that each individual gets an opportunity to escape from the limitations of the social group in which he was born, and to come into living contact with a broader environment. Such words as “society” and “community” are likely to be misleading, for they have a tendency to make us think there is a single thing corresponding to the single word. As a matter of fact, a modern society is many societies more or less loosely connected. Each household with its immediate extension of friends makes a society; the village or street group of playmates is a community; each business group, each club, is another. Passing beyond these more intimate groups, there is in a country like our own a variety of races, religious affiliations, economic divisions. Inside the modern city, in spite of its nominal political unity, there are probably more communities, more differing customs, traditions, aspirations, and forms of government or control, than existed

in an entire continent at an earlier epoch. Each such group exercises a formative influence on the active dispositions of its members. A clique, a club, a gang, a Fagin's household of thieves, the prisoners in a jail, provide educative environments for those who enter into their collective or conjoint activities, as truly as a church, a labour union, a business partnership, or a political party. Each of them is a mode of associated or community life, quite as much as is a family, a town, or a state. There are also communities whose members have little or no direct contact with one another, like the guild of artists, the republic of letters, the members of the professional learned class scattered over the face of the earth. For they have aims in common, and the activity of each member is directly modified by knowledge of what others are doing. In the olden times, the diversity of groups was largely a geographical matter.

There were many societies, but each, within its own territory, was comparatively homogeneous. But with the development of commerce, transportation, intercommunication, and emigration, countries like the United States are composed of a combination of different groups with different traditional customs. It is this situation which has, perhaps more than any other one cause, forced the demand for an educational institution which shall provide something like a homogeneous and balanced environment for the young. Only in this way can the centrifugal forces set up by juxtaposition of different groups within one and the same political unit be counteracted. The intermingling in the school of youth of different races, differing religions, and unlike customs creates for all a new and broader environment.

Common subject matter accustoms all to a unity of outlook upon a broader horizon than is visible to the members of any group while it is isolated. The assimilative force of the American public school is eloquent testimony to the efficacy of the common and balanced appeal. The school has the function also of coordinating within the disposition of each individual the diverse influences of the various social environments into which he enters. One code prevails in the family; another, on the street; a third, in the workshop or store; a fourth, in the religious association. As a person passes from one of the environments to another, he is subjected to antagonistic pulls, and is in danger of being split into a being having different standards of judgement and emotion for different occasions. This danger imposes upon the school a steadying and integrating office.

THE SOCIAL ENVIRONMENT

A being whose activities are associated with others has a social environment. What he does and what he can do depend upon the expectations, demands, approvals, and condemnations of others. A being connected with other beings cannot perform his own activities without taking the activities of others into account. For they are the indispensable conditions of the realization of his tendencies. When he moves he stirs them and reciprocally. We might as well try to imagine a business man doing business, buying and selling, all by himself, as

to conceive it possible to define the activities of an individual in terms of his isolated actions. The manufacturer moreover is as truly socially guided in his activities when he is laying plans in the privacy of his own counting house as when he is buying his raw material or selling his finished goods.

Thinking and feeling that have to do with action in association with others is as much a social mode of behaviour as is the most overt cooperative or hostile act. What we have more especially to indicate is how the social medium nurtures its immature members. There is no great difficulty in seeing how it shapes the external habits of action. Even dogs and horses have their actions modified by association with human beings; they form different habits because human beings are concerned with what they do. Human beings control animals by controlling the natural stimuli which influence them; by creating a certain environment in other words.

Food, bits and bridles, noises, vehicles, are used to direct the ways in which the natural or instinctive responses of horses occur. By operating steadily to call out certain acts, habits are formed which function with the same uniformity as the original stimuli. If a rat is put in a maze and finds food only by making a given number of turns in a given sequence, his activity is gradually modified till he habitually takes that course rather than another when he is hungry. Human actions are modified in a like fashion. A burnt child dreads the fire; if a parent arranged conditions so that every time a child touched a certain toy he got burned, the child would learn to avoid that toy as automatically as he avoids touching fire. So far, however, we are dealing with what may be called training in distinction from educative teaching. The changes considered are in outer action rather than in mental and emotional dispositions of behaviour.

The distinction is not, however, a sharp one. The child might conceivably generate in time a violent antipathy, not only to that particular toy, but to the class of toys resembling it. The aversion might even persist after he had forgotten about the original burns; later on he might even invent some reason to account for his seemingly irrational antipathy. In some cases, altering the external habit of action by changing the environment to affect the stimuli to action will also alter the mental disposition concerned in the action. Yet this does not always happen; a person trained to dodge a threatening blow, dodges automatically with no corresponding thought or emotion. We have to find, then, some differentia of training from education. A clew may be found in the fact that the horse does not really share in the social use to which his action is put. Some one else uses the horse to secure a result which is advantageous by making it advantageous to the horse to perform the act — he gets food, *etc.*

But the horse, presumably, does not get any new interest. He remains interested in food, not in the service he is rendering. He is not a partner in a shared activity. Were he to become a copartner, he would, in engaging in the conjoint activity, have the same interest in its accomplishment which others have. He would share their ideas and emotions. Now in many cases — too many cases — the activity of the immature human being is simply played upon

to secure habits which are useful. He is trained like an animal rather than educated like a human being. His instincts remain attached to their original objects of pain or pleasure. But to get happiness or to avoid the pain of failure he has to act in a way agreeable to others. In other cases, he really shares or participates in the common activity. In this case, his original impulse is modified. He not merely acts in a way agreeing with the actions of others, but, in so acting, the same ideas and emotions are aroused in him that animate the others.

A tribe, let us say, is warlike. The successes for which it strives, the achievements upon which it sets store, are connected with fighting and victory. The presence of this medium incites bellicose exhibitions in a boy, first in games, then in fact when he is strong enough. As he fights he wins approval and advancement; as he refrains, he is disliked, ridiculed, shut out from favourable recognition. It is not surprising that his original belligerent tendencies and emotions are strengthened at the expense of others, and that his ideas turn to things connected with war. Only in this way can he become fully a recognized member of his group. Thus his mental habitudes are gradually assimilated to those of his group.

If we formulate the principle involved in this illustration, we shall perceive that the social medium neither implants certain desires and ideas directly, nor yet merely establishes certain purely muscular habits of action, like “instinctively” winking or dodging a blow. Setting up conditions which stimulate certain visible and tangible ways of acting is the first step. Making the individual a sharer or partner in the associated activity so that he feels its success as his success, its failure as his failure, is the completing step. As soon as he is possessed by the emotional attitude of the group, he will be alert to recognize the special ends at which it aims and the means employed to secure success.

His beliefs and ideas, in other words, will take a form similar to those of others in the group. He will also achieve pretty much the same stock of knowledge since that knowledge is an ingredient of his habitual pursuits. The importance of language in gaining knowledge is doubtless the chief cause of the common notion that knowledge may be passed directly from one to another. It almost seems as if all we have to do to convey an idea into the mind of another is to convey a sound into his ear. Thus imparting knowledge gets assimilated to a purely physical process. But learning from language will be found, when analysed, to confirm the principle just laid down.

It would probably be admitted with little hesitation that a child gets the idea of, say, a hat by using it as other persons do; by covering the head with it, giving it to others to wear, having it put on by others when going out, *etc.* But it may be asked how this principle of shared activity applies to getting through speech or reading the idea of, say, a Greek helmet, where no direct use of any kind enters in. What shared activity is there in learning from books about the discovery of America? Since language tends to become the chief instrument of learning about many things, let us see how it works. The baby begins of course with mere sounds, noises, and tones having no meaning, expressing, that is, no idea. Sounds

are just one kind of stimulus to direct response, some having a soothing effect, others tending to make one jump, and so on. The sound h-a-t would remain as meaningless as a sound in Choctaw, a seemingly inarticulate grunt, if it were not uttered in connection with an action which is participated in by a number of people.

When the mother is taking the infant out of doors, she says “hat” as she puts something on the baby’s head. Being taken out becomes an interest to the child; mother and child not only go out with each other physically, but both are concerned in the going out; they enjoy it in common. By conjunction with the other factors in activity the sound “hat” soon gets the same meaning for the child that it has for the parent; it becomes a sign of the activity into which it enters. The bare fact that language consists of sounds which are mutually intelligible is enough of itself to show that its meaning depends upon connection with a shared experience. In short, the sound h-a-t gains meaning in precisely the same way that the thing “hat” gains it, by being used in a given way. And they acquire the same meaning with the child which they have with the adult because they are used in a common experience by both.

The guarantee for the same manner of use is found in the fact that the thing and the sound are first employed in a joint activity, as a means of setting up an active connection between the child and a grownup. Similar ideas or meanings spring up because both persons are engaged as partners in an action where what each does depends upon and influences what the other does. If two savages were engaged in a joint hunt for game, and a certain signal meant “move to the right” to the one who uttered it, and “move to the left” to the one who heard it, they obviously could not successfully carry on their hunt together.

Understanding one another means that objects, including sounds, have the same value for both with respect to carrying on a common pursuit. After sounds have got meaning through connection with other things employed in a joint undertaking, they can be used in connection with other like sounds to develop new meanings, precisely as the things for which they stand are combined. Thus the words in which a child learns about, say, the Greek helmet originally got a meaning by use in an action having a common interest and end. They now arouse a new meaning by inciting the one who hears or reads to rehearse imaginatively the activities in which the helmet has its use. For the time being, the one who understands the words “Greek helmet” becomes mentally a partner with those who used the helmet. He engages, through his imagination, in a shared activity. It is not easy to get the full meaning of words. Most persons probably stop with the idea that “helmet” denotes a queer kind of headgear a people called the Greeks once wore. We conclude, accordingly, that the use of language to convey and acquire ideas is an extension and refinement of the principle that things gain meaning by being used in a shared experience or joint action; in no sense does it contravene that principle. When words do not enter as factors into a shared situation, either overtly or imaginatively, they operate as pure physical stimuli, not as having a meaning or intellectual value.

They set activity running in a given groove, but there is no accompanying conscious purpose or meaning. Thus, for example, the plus sign may be a stimulus to perform the act of writing one number under another and adding the numbers, but the person performing the act will operate much as an automaton would unless he realizes the meaning of what he does.

HISTORICAL EVOLUTION OF ENVIRONMENTAL EDUCATION

The roots of environmental education can be traced back as early as the 18th century when Jean-Jacques Rousseau stressed the importance of an education that focuses on the environment in *Emile, or On Education*. Several decades later, Louis Agassiz, a Swiss-born naturalist, echoed Rousseau's philosophy as he encouraged students to "Study nature, not books." These two influential scholars helped lay the foundation for a concrete environmental education programme, known as Nature Study, which took place in the late 19th century and early 20th century.

The nature study movement used fables and moral lessons to help students develop an appreciation of nature and embrace the natural world. Anna Botsford Cornstock, the head of the Department of Nature Study at Cornell University, was a prominent figure in the nature study movement and wrote the *Handbook for Nature Study* in 1911, which used nature to educate children on cultural values. Cornstock and the other leaders of the movement, such as Liberty Hyde Bailey, helped Nature Study garner tremendous amounts of support from community leaders, teachers, and scientists and changed the science curriculum for children across the United States.

A new type of environmental education; Conservation Education emerged as a result of the Great Depression and Dust Bowl during the 1920s and 1930s. Conservation Education dealt with the natural world in a drastically different way from Nature Study because it focused on rigorous scientific training rather than natural history. Conservation Education was a major scientific management and planning tool that helped solve social, economic, and environmental problems during this time period.

The modern environmental education movement, which gained significant momentum in the late 1960s and early 1970s, stems from Nature Study and Conservation Education. During this time period, many events - such as Civil Rights, the Vietnam War, and the Cold War - placed Americans at odds with one another and the U.S., government. However, as more people began to fear the fallout from radiation, the chemical pesticides mentioned in Rachel Carson's *Silent Spring*, and the significant amounts of air pollution and waste, the public's concern for their health and the health of their natural environment led to a unifying phenomenon known as environmentalism.

Ultimately, the first Earth Day on April 22nd, 1970, a national teach-in about environmental problems, paved the way for the modern environmental education movement. Later that same year, President Nixon passed the National

Environmental Education Act, which was intended to incorporate environmental education into K-12 schools. Then, in 1971, the National Association for Environmental Education (now known as the North American Association for Environmental Education) was created to improve environmental literacy by providing resources to teachers and promoting environmental education programmes.

In Europe it was during the industrial revolution in the nineteenth century that awoke the attention of the masses towards environmental education. During the period the living conditions of most European countries showed that environmental problems were approaching an unhealthy level.

Professor Geddes (1854-1933) a botanist saw a close link between the quality of education and environment. He was of the view that any improvement in education would have a significant impact on attitudes towards nature. He is sometimes referred to as the father of modern environment education.

Internationally, environmental education gained recognition when the UN Conference on the Human Environment held in Stockholm, Sweden, in 1972, declared environmental education must be used as a tool to address global environmental problems.

The United Nations Education Scientific and Cultural Organization (UNESCO) and the United Nations Environmental Programme (UNEP) created three major declarations that have guided the course of environmental education. These are:

Stockholm Declaration (Sweden. 1972)

This conference was held in Sweden in 1972 and it was a United Nations Conference on Human Environment. This conference clearly recognized the relationship between the environment and society. The conference also discussed the ways in which education can contribute to having effective environmental policies and management.

The conference adopted seven proclamations and twenty six principles “to inspire and guide the peoples of the world in the preservation and enhancement of the human environment”.

The Belgrade Charter (Yugoslavia 1975)

The Belgrade Charter was the outcome of the International Workshop on Environmental Education held in Belgrade, Yugoslavia. The Belgrade Charter was built upon the Stockholm Declaration and adds goals, objectives, and guiding principles of environmental education programmes.

It defines an audience for environmental education, which includes the general public. This workshop was able to come up with a framework for environmental education which was later launched as UNESCO-UNEP International Education Programme. The programme was charged with the responsibility of developing relevant knowledge, skills, attitudes and values for improvement of the environment both for the present and future generations.

The Tbilisi Declaration (USSR 1977)

The Tbilisi Declaration “noted the unanimous accord in the important role of environmental education in the preservation and improvement of the world’s environment, as well as in the sound and balanced development of the world’s communities.” The Tbilisi Declaration updated and clarified The Stockholm Declaration and The Belgrade Charter by including new goals, objectives, characteristics, and guiding principles of environmental education.

Later that decade, in 1977, the Intergovernmental Conference on Environmental Education in Tbilisi, Georgia emphasized the role of environmental education in preserving and improving the global environment and sought to provide the framework and guidelines for environmental education. The Conference laid out the role, objectives, and characteristics of environmental education, and provided several goals and principles for environmental education.

**THE ROLE OF THE ENVIRONMENT
IN DEVELOPMENT**

Human cognitive development is highly dependent on the environment to which an individual is exposed. As a child grows, and as her interactions with the environment expand and diversify, she receives stimulation for further development of meaning-making strategies by encountering new problems that call for finding new solutions. The speed of a child’s development varies widely, given different environments. Developmentally-appropriate stimulation and exposure can support and even accelerate development. For example, giving a child who has outgrown a tricycle a two-wheeler with training wheels can accelerate the speed with which s/he learns to balance and pedal the more difficult vehicle while minimizing the possibility of failure and harm.

The opposite is also true: the absence of stimulation can slow down or weaken the developmental process—so, for example, not talking to a child—naming the foods he eats, colours he wears, things he encounters, and describing actions, feelings, and so forth—may result in late and/or inadequate language development.

WHAT IS MORAL DEVELOPMENT?

As children develop their general thinking skills, they’re expected to start to conform to the morality rules that society dictates. Psychological theories of moral development, differ immensely in their opinions on how moral development occurs. Freud claims that the quality of relationship the child has with his/her parent/s greatly affects the way the child develops morally. Whereas, the Social Learning theory states that children initially learn how to behave morally through modelling (imitating appropriate adult behaviour. Cognitive-developmental theories claim that a child’s ability to reason morally depend on his/her general thinking abilities. All of the theories, although somewhat different from each other, help us in our plight to understand moral development.

THEORIES OF MORAL DEVELOPMENT

Cognitive developmental theorists claim that a child's ability to reason morally depend on his/her level of general thinking abilities.

Piaget investigated moral development in two ways:

- He proposed moral issues to children and analysed their responses
- He observed the way in which children used rules in game playing.

Piaget claimed that children develop an outlook on rules in different stages.

- Preschoolers play for enjoyment and disregard rules
- Six year olds consider rules to be sacred and inflexible
- Ten year olds realise that rules can be manipulated.

Piaget claims that children differ in response to moral dilemmas depending what stage of moral development they are in.

- Children younger than ten are at the stage of development called moral realism. They determine whether an act was good or bad depending on how much damage occurred regardless of the intentions behind the act
- Next, children move onto a stage of moral reasoning called moral relativism. Moral relativism takes motives into account and doesn't believe that every wrong action should necessarily be punished. For example, if a girl broke her sister's porcelain doll she should only be punished if she intentionally broke the doll

Kohlberg asked boys, between the ages of ten and sixteen, moral dilemmas (for example, "should a man steal an overpriced drug that he can't afford, to save his wife from cancer?") in order to analyse moral development. Through analysing the results, Kohlberg determined that there were three distinct levels of moral reasoning.

- The first level, called the preconventional level, is when the child's actions are primarily motivated in order to gain a reward or to avoid punishment
- At the second level, the conventional level, children's moral decisions are greatly influenced by society. The child wants to be an upstanding citizen and therefore wants to obey the rules and laws of society.
- Finally, at the postconventional level, the child is more civic minded. They are able to determine which rules can be bent, but the child also considers some values such as human dignity to be sacred.

IMPORTANCE, OBJECTIVES, SCOPE AND GUIDING PRINCIPLES OF ENVIRONMENTAL EDUCATION

Though formal education is the mandate of the Ministry of Human Resource Development (MHRD), the Ministry of Environment & Forests has been interacting with the MHRD, NCERT, State Departments of Education, *etc.*, to

ensure that environmental components are adequately covered at the school levels by infusion into the school curricula at various levels. The major initiatives taken by the Ministry in this direction recently are mentioned below:

ENVIRONMENT EDUCATION IN SCHOOL SYSTEM

Under this project, which was initiated in 1999, an exercise to strengthen environment education in the formal school curriculum has been undertaken. During the first phase of this project, a comprehensive study was conducted to assess the status of infusion of environment content in the school curriculum in the country and to assess the effectiveness of classroom teaching. The study was conducted in all the States/UTs of the country and textbooks of all the classes from standards I to XII were analysed. Based on the findings of the study, the textbooks in Science, Social Science and Languages of middle school level in eight States (100 schools in each State) are being modified to strengthen the infusion of environmental concepts. The modified textbooks would be used for one academic session (2002-2003) in the selected schools of the selected States on pilot basis. The concerned teachers of the selected schools would also be trained to effectively teach the modified textbooks. The States participating in this project are Andhra Pradesh, Assam, Goa, Jammu & Kashmir, Maharashtra, Orissa, Punjab and Uttaranchal. Depending upon the success of the pilot implementation, the revised curriculum may be taken up in the remaining schools. The findings of the Phase I study are also being shared with the States/UTs which are not participating in this project so that they can also environmentalise their textbooks.

ENVIRONMENTAL APPRECIATION COURSE

Though there are several courses on environmental sciences at present in the formal system, there are no structured courses available outside the formal system for people who desire to learn about environmental issues. The Ministry has taken an initiative in this regard and is presently working out a framework for environmental appreciation courses in consultation with IGNOU.

ENVIRONMENTAL EDUCATION AMONG STUDENTS

The environment scenario of India is very wide indeed. At the first level, special attention must be paid to children. They are to be made aware of health, nutrition, sanitation, hygiene, development, water and food contamination, fodder and fuel wood, *etc.* NGO's have to play a significant role in environmental education and awareness.

Formal Environmental Education

The spectrum of EE has four major interrelated components, *i.e.*, Awareness, real life situation, conservation and sustainable development.



1. *Primary School Stage:* The attempt is made to sensitize the child about environs. Emphasis should be mostly (75%) on building up awareness, followed by real life situation (20%) and conservation (5%). Teaching strategy includes audio-visual and field visits.
2. *Lower Secondary Stage:* At this level objective must be real life experience, awareness and problem identification. The contents are supplemented with general science. Teaching, practicals and field visits are to be done.
3. *Higher Secondary School Stage:* The emphasis must be on conservation, assimilation of knowledge, problem identification and action skills. Contents may be science-based and action oriented work.
4. *College Stage:* Maximum emphasis should be on knowledge regarding sustainable development and conservation. The content must be college based on Science and Technology. Teaching practical's and action-oriented field work is to be done. In the school education, NCERT has been playing vital role in designing syllabi, text books, guide books, charts and kits, etc.
5. *University Education:* EE at this level is being looked after the UGC. The university education has three major components— Teaching, Research and Extension. At post graduate level, four major areas are recognised environmental engineering, conservation and management, environmental health, social ecology.

Non-Formal Environmental Education

This education is designed for any age group, participating in cultural, social, economic development of the country. They form clubs and arrange exhibition, public lectures, meetings, environmental campaigns. Following are the main constituents of this education.

1. *Adult Education:* Adults may influence the society to protect the precious environs by generating posters, slides, audio-visual and information pictures.
2. *Rural Youth and Non-student Youth:* They may act as volunteers.

3. *Tribals and Forest Dwellers*: They are an important media to protect the forest wealth.
4. *Children Activities*: The National Museum of Natural History (NMNH) conducts spot painting, modelling and poster design about environment for children.
5. *Eco-development Camps*: Currently a set of a guide lines has been prepared by D.O. En to create awareness in youth and to acquaint them with the practice of sustainable development.
6. *Non-government Organisations*: There are more than 200 NGOs engaged in environmental protection.
7. *Public Representatives*: India has environmental forums for MPs and MLAs to discuss environmental problems facing the country. They stimulate public interest for saving the environs.
8. *Training Executives*: Regular courses should be arranged for environ activities among administrators.
9. *Research and Development Programmes*: Such R and D efforts are supported by D.O. Environment in Biosphere and Man.
10. *Foundation Courses*: The courses for the probationers selected for the IAS, IFS, IPS and cadets of three wings of Armed Forces need to be supplemented with foundation courses on environment relevant to their area of specialisation.
11. *Development of Educational Material and Teaching Aids*: Materials for media (T.V, radio, films, news -papers, etc.), audio, mobile exhibitions, audio-visual materials must be operated by competent manpower. One such centre in India is Centre for Environmental Education, Ahmedabad.
12. *Development of Trained Manpower*: Department of Environment (DOE) must organise training programmes for the professors, technical personnel, lecturers and legal experts.

Environmental Information

DOE had set up a programme, *i.e.*, Environmental Information System (ENVIS) in 1982. It is a decentralised system using distributed network of data bases for collection of environmental information. ENVIS network with DOE consists of 10 ENVIS centres on diverse areas of environment. It is established in specialised and reputed institutions in the country.

OUTDOOR EDUCATION, ENVIRONMENTAL EDUCATION AND PLACE-BASED EDUCATION

The main purpose of “outdoor education” is to provide meaningful contextual experiences—in both natural and constructed environments—that complement and expand classroom instruction, which tends to be dominated by print and electronic media (Knapp, 1996, p. ix). It is a broader term than “environmental

education,” which can be described as instruction directed towards developing a citizenry prepared to live well in a place without destroying it (Orr, 1994, p. 14). Environmental education can occur both inside and outside the classroom.

Understanding the relationships among place-based education, outdoor education, and environmental education is worthwhile because each concept has been developed somewhat separately by educators who have produced curriculum materials and instructional practices that could be useful within the other concept areas. Further complicating this potential exchange is the variety of labels that have been applied to each of these approaches. For example, as the field of outdoor education matured, it was labeled school camping, camping education, and eventually, outdoor education. Likewise, place-based education has been referred to as “community-oriented schooling,” “ecological education,” and “bioregional education.”

Paul Theobald refers to “place-conscious” elementary and secondary classrooms in his book, *“Teaching The Commons”* (1997, pp. 132-159). He advocates using the immediate locale as “the lens for disciplinary engagement in all schools across the country” (p. 137). In a later article, Theobald and Curtiss (2000) describe the field as “community-oriented schooling.”

Smith and Williams (1999) describe this approach as “ecological education.” They write, “The practice of ecological education requires viewing human beings as one part of the natural world and human cultures as an outgrowth of interactions between species and particular places” (p. 3). The authors outline seven principles, two of which directly reflect outdoor education: (1) practical experiences outdoors through the application of an ethic of care, and (2) grounding learning in a sense of place through investigation of surrounding natural and human communities.

Traina and Darley-Hill (1995) extend “locale” to include “bioregional education,” encouraging students and teachers to know their place and to consider the impact of lifestyles on the resources of that bioregion. Similarly, Orr’s (1994) call for “ecoliteracy” presents principles for rethinking education that clearly relate place-based education to outdoor education: (1) students should understand the effects of this knowledge on real people and their communities; and (2) learning through direct experiences outside the classroom is as important as the content of particular courses.

Thomashow (1995) writes about the goal of achieving “ecological identity” through the examination of four basic questions: What do I know about the place where I live? Where do things come from? How do I connect to the earth? What is my purpose as a human being? He integrates these questions into activities by incorporating reflective learning in the school, home, community, and the workplace (p. xvii). These questions focus curriculum and instruction on understanding and appreciating students’ immediate surroundings.

Haymes (1995) speaks directly to a “pedagogy of place” and addresses issues of race and class as they are made manifest in the construction of urban environments and in the power and politics that emerge from those constructs.

His work takes a cultural studies perspective and contributes a much-needed complement to more conventional outdoor/environmental curriculum and instruction.

THE ESSENTIAL CHARACTERISTICS OF PLACE-BASED EDUCATION

A survey of the literature on place-based education reveals characteristic patterns to this still-evolving approach that make it distinctive.

- It emerges from the particular attributes of a place. The content is specific to the geography, ecology, sociology, politics, and other dynamics of that place. This fundamental characteristic establishes the foundation of the concept.
- It is inherently multidisciplinary.
- It is inherently experiential. In many programmes this includes a participatory action or service learning component; in fact, some advocates insist that action must be a component if ecological and cultural sustainability are to result.
- It is reflective of an educational philosophy that is broader than “learn to earn.” Economics of place can be an area of study as a curriculum explores local industry and sustainability; however, all curricula and programmes are designed for broader objectives.
- It connects place with self and community. Because of the ecological lens through which place-based curricula are envisioned, these connections are pervasive. These curricula include multigenerational and multicultural dimensions as they interface with community resources.

PLACE-BASED EDUCATION IMPORTANT

Some critics of place-based education believe that the primary goal of schooling should be to prepare students to work and function in a highly technological and consumer-oriented society. In contrast, place-based educators believe that education should prepare people to live and work to sustain the cultural and ecological integrity of the places they inhabit. To do this, people must have knowledge of ecological patterns, systems of causation, and the long-term effects of human actions on those patterns (Orr, 1994). One of the most compelling reasons to adopt place-based education is to provide students with the knowledge and experiences needed to actively participate in the democratic process.

CONCLUSION AND RECOMMENDATIONS FOR FUTURE DIRECTIONS

Place-based education represents a recent trend in the broad field of outdoor education. It recaptures the ancient idea of “listening to the land” and living

and learning in harmony with the earth and with each other. As society becomes increasingly urbanized and technologized, educators must continue to adopt and adapt more of the goals, theory, and practice of place-based education.

EDUCATIONAL ENVIRONMENT

Education in the largest sense is any act or experience that has a formative effect on the mind, character or physical ability of an individual. In its technical sense, education is the process by which society deliberately transmits its accumulated knowledge, skills and values from one generation to another.

Etymologically, the word education is derived from *educare* (Latin) “bring up”, which is related to *educere* “bring out”, “bring forth what is within”, “bring out potential” and *ducere*, “to lead”.

Teachers in educational institutions direct the education of students and might draw on many subjects, including reading, writing, mathematics, science and history. This process is sometimes called schooling when referring to the education of teaching only a certain subject, usually as professors at institutions of higher learning.

There is also education in fields for those who want specific vocational skills, such as those required to be a pilot. In addition there is an array of education possible at the informal level, such as in museums and libraries, with the Internet and in life experience. Many non-traditional education options are now available and continue to evolve.

Education is a concept, referring to the process in which students can learn something:

- Instruction refers to the facilitating of learning towards identified objectives, delivered either by an instructor or other forms.
- Teaching refers to the actions of a real live instructor designed to impart learning to the student.
- Learning refers to learning with a view towards preparing learners with specific knowledge, skills, or abilities that can be applied immediately upon completion.

PRESCHOOL EDUCATION

Preschool education or Infant education is the provision of education for children before the commencement of statutory and obligatory education, usually between the ages of zero or three and five, depending on the jurisdiction. In British English, nursery school or simply “nursery” or playgroup is the usual term for preschool education. In the United States preschool and Pre-K are used, while “nursery school” is an older term. Preschool work is organized within a framework that professional educators create. The framework includes structural (administration, class size, teacher-child ratio, services, *etc.*), process (quality of classroom environments, teacher-child interactions, *etc.*), and alignment (standards, curriculum, assessments) components that are associated with each individual unique child that has both social and academic outcomes. Arguably the first pre-

school institution was opened in 1816 by Robert Owen in New Lanark, Scotland. The Hungarian countess Theresa Brunszvik followed in 1828. In 1837, Friedrich Fröbel opened one in Germany, coining the term “kindergarten”.

DEVELOPMENTAL AREAS

The areas of development which preschool education covers varies from country to country. However, the following main themes are represented in the majority of systems.

- Personal, social, economical, and emotional development
- Communication, including sign language, talking and listening
- Knowledge and understanding of the world
- Creative and aesthetic development
- Educational software
- Mathematical awareness and development
- Physical development
- Playing
- Self-help skills
- Social skills.

Allowing preschool aged children to discover and explore freely within each of these areas of development is the foundation for developmental learning. While the National Association for the Education of Young Children (NAEYC) and the National Association of Child Care Professionals (NACCP) have made tremendous strides in publicizing and promoting the idea of developmentally appropriate practice, there is still much work to be done.

It is widely recognized that although many preschool educators are aware of the guidelines for developmentally appropriate practice, putting this practice to work effectively in the classroom is more challenging.

The NAEYC published that although 80% of Kindergarten classrooms claim to be developmentally appropriate, only 20% actually are.

AGE AND IMPORTANCE

Preschool is generally considered appropriate for children between zero or three and five years of age, between the baby or toddler and school stages. During this stage of development, children learn and assimilate information rapidly, and express interest and fascination in each new discovery.

It is well established that the most important years of learning are begun at birth. A child's brain at this age is making connections that will last the rest of their life. During these early years, a human being is capable of absorbing more information at a time than they will ever be able to again. The environment of the young child influences the development of cognitive skills and emotional skills due to the rapid brain growth that occurs in the early years. Studies have shown that high quality preschools have a short and long term effect in improving the outcomes of a child, especially a disadvantaged child. However, some more recent studies dispute the accuracy of the earlier results which cited benefits to

preschool education, and actually point at preschool being detrimental to a child's cognitive and social development. A study by UC Berkeley and Stanford University on 14,000 Kindergarteners revealed that while there is a temporary cognitive boost in pre-reading and math, preschool holds detrimental effects on social development and cooperation.

The Universal Preschool movement is an international effort to make access to preschool available to families in a similar way to compulsory primary education. Various jurisdictions and advocates have differing priorities for access, availability and funding sources. There has been a shift from preschools that operated primarily as controlled play groups to educational settings in which children learn specific, if basic, skills. It examines several different perspectives on teaching in kindergarten, including those of the developmentally appropriate practice, the academic approach, the child-centered approach, and the Montessori approach to the curriculum.

GRATUITY

The gratuity of infant education has been established in some countries, as Spain, beginning in the second cycle (from three to six years), but extending to the first cycle (from birth to three years).

FUTURE THROUGH ENVIRONMENTAL EDUCATION

Environmental education is to a large extent predicated on concern for the future; to the extent that humans fail to behave in an environmentally responsible fashion, the future may be projected to be correspondingly bleak. This is held to be true in terms of use, overuse, and abuse of natural resources, both potentially sustainable and unequivocally non-renewable, and with respect to more immediate environmental pollution considerations. There is also great interest in "the future" as an area of study: it is often associated with global concerns. To the extent that global and/or future studies attend to environmental considerations, they become appropriate vehicles for environmental education. From another perspective, future/global studies which do not emphasize the environment are at best incomplete and are quite likely to be misleading and/or simplistic.

ARE FUTURE STUDIES "SCIENTIFIC?"

As an area of scientific study, "futurology" found an early spokesperson in the Rev. Robert Thomas Malthus, who nearly two centuries ago published the results of studies of the evolving relationships between agricultural production and human population growth. Employing rigorous analysis of sound data, Malthus concluded that incremental, eventually catastrophic, deficits in availability of food supplies were in humankind's future.

His conclusions were based on linear projections of historically established and verifiable trends of increases in food production and human population: the former was clearly rising arithmetically, the latter geometrically.

Projections such as these are based on the assumption that the trends will continue; prediction enters the picture at the point where possible and/or probable outcomes are hypothesized, particularly with respect to interactions among projections.

Malthus's procedures provide a prime example, perhaps the prime example, of classical methods of looking at the future. Until the quite recent past, linear projections have been the commonly employed procedure of looking at the future in situations where scientific data were available and used. Malthus's predictions have not come true on a global scale and are at present discounted by many. At the very least, his time line has not proved true. The most significant cause of this failure was the unpredictable, spectacularly rapid advancement of technology, as exemplified by the Industrial Revolution and, more recently, the Green Revolution. Some will argue that it is as reasonable to project rapid technological advancement as it is to project other changes in a linear fashion. Had Malthus done so, his predictions would no doubt have been appreciably less drastic, certainly not so dire. But on what basis might he have projected technological advancement?

How are Projections Developed?

To project trends, data are needed; the greater the quantity and quality of properly selected and organized data available, the greater the level of confidence that may be attached to the projections derived from them. The scientific enterprise thrives on data and has increasingly done so for half a millenium. For studies dealing with the future, it is first necessary to identify and gather the data needed for establishing trends of interest; then, these data must be "processed" in such a manner that meaningful information is derived.

The introduction of high-capacity, high-speed computer technology has provided a mechanism for dealing with such data-processing concerns. One of the first to apply these technologies to future studies was Forrester (1971), who dealt with trends in human population growth, agricultural production, capital investment, environmental pollution, natural resource depletion, and "quality of life."

His data were aggregated on a global scale; his procedure did not include a specific projection dealing with technological advancement; his conclusions were Malthusian in the "gloom and doom" sense. The better-known Club of Rome LIMITS TO GROWTH report was an expansion of the Forrester study—more data, more precisely defined relationships, but not much difference in conclusions.

During the past decade, a number of additional studies using computer models to project future conditions have appeared. In general, they have attempted to sharpen their projections by subsuming more data and disaggregating it so as to approach analyses on regional, as opposed to global, levels.

The intent of disaggregation is not to deemphasize global implications of projections made, but to fine-tune the understanding and predictive power of relationships detected and projected—that is, to make them more realistic in terms of their implications for the future.

Recent Futuristic Projections Suggest

That the future has been a topic of continuing public interest is evidenced by THE GLOBAL 2000 REPORT TO THE PRESIDENT: ENTERING THE TWENTY-FIRST CENTURY, developed by U.S., federal government agencies under the leadership of the President's Council on Environmental Quality and the U.S., Department of State. The report consists of projections of what might be expected to happen in terms of human populations, resources, and the environment if policies in force during the late 1970s continued.

Its stated purpose was to serve as the foundation for long-term governmental planning. The report's projections indicated the potential for "global problems of alarming proportions by the year 2000," much as have many future-oriented studies of the recent past. In this particular case, projections were made to the year 2000, but not beyond.

Valid are Such Projections

Because the outcomes anticipated in such studies are based on the assumption of the continuation of existing trends, the outcomes change when the trends change, whether planned or otherwise. Thus, it appears that a valid use of projections and associated predicted outcomes lies, after a set of interacting projections is made, in evaluating the desirability of the apparent outcomes, then evaluating various possible changes in trends, projections, and potential outcomes which might be forthcoming.

For example, the GLOBAL 2000 study developed projections based on continuation of existing policies, as noted above. But what if those policies were changed? It takes little imagination to realize that the projections would also change. The questions of concern are, how? and so what?

2

Environmental Pollution and Pollutants

The change in any component of the environment which leads to its deterioration is termed as pollution of the environment.

It is the undesirable change in the physical or biological components which adversely alters the environment.

Pollutants:

- The substances which are present in harmful concentration and is the agent who causes pollution is termed as the pollutant.

CLASSIFICATION OF POLLUTANTS

On the basis of existence in nature:

- *Quantitative Pollutants:* The substances which are already present in the environment, but are termed as pollutants when their concentration increases in the environment, *e.g.*, CO₂ is present in the environment in greater quantity than normal and is hence termed as a quantitative pollutant.
- *Qualitative pollutant:* The substances which are not normally present in the environment and are added by human beings and are pollutants by nature. *E.g.*, insecticides, pesticides

On the basis of the form in which they persist:

- *Primary Pollutants:* The substances which are directly emitted from the source and remain in that form are termed as primary pollutants eg, smoke, fumes, ash, dust, nitric oxide and sulphur dioxide

- *Secondary pollutants*: The substances which are formed by chemical reaction between the primary pollutants and constituents of the environment.

On the basis of disposal:

- *Bio-degradable pollutants*: The pollutants which are decomposed by natural processes eg domestic sewage.
- *Non bio-degradable pollutants*: The pollutants which don't decompose naturally or decompose slowly *e.g.*, DDT, aluminium cans.

POLLUTION

Environmental pollution is any discharge of material or energy into water, land, or air that causes or may cause acute (short-term) or chronic (long-term) detriment to the Earth's ecological balance or that lowers the quality of life. Pollutants may cause primary damage, with direct identifiable impact on the environment, or secondary damage in the form of minor perturbations in the delicate balance of the biological food web that are detectable only over long time periods.

Until relatively recently in humanity's history, where pollution has existed, it has been primarily a local problem. The industrialization of society, the introduction of motorized vehicles, and the explosion of the human population, however, have caused an exponential growth in the production of goods and services. Coupled with this growth has been a tremendous increase in waste by-products. The indiscriminate discharge of untreated industrial and domestic wastes into waterways, the spewing of thousands of tons of particulates and airborne gases into the atmosphere, the "throwaway" attitude towards solid wastes, and the use of newly developed chemicals without considering potential consequences have resulted in major environmental disasters, including the formation of smog in the Los Angeles area since the late 1940s and the pollution of large areas of the Mediterranean Sea. Technology has begun to solve some pollution problems, and public awareness of the extent of pollution will eventually force governments to undertake more effective environmental planning and adopt more effective antipollution measures.

ENVIRONMENTAL HAZARD

'Environmental hazard' is a generic term for any situation or state of events which poses a threat to the surrounding environment. This term incorporates topics like pollution and Natural Hazards such as storms and earthquakes.

I feel that this sight has no information on what I am looking for! There are five types of environmental hazards:

1. Chemical
2. Physical
3. Mechanical
4. Biological
5. Psychosocial

The term can also refer to biological hazards; a large algal bloom is an environmental hazard because it makes the lake uninhabitable for other organisms.

Natural Hazards

A natural hazard is a threat of an event that will have a negative effect on people or the environment. Many natural hazards are related, *e.g.*, earthquakes can result in tsunamis, drought can lead directly to famine and disease. A concrete example of the division between hazard and disaster is that the 1906 San Francisco earthquake was a disaster, whereas earthquakes are a hazard. Hazards are consequently relating to a future occurrence and disasters to past or current occurrences.

Notable avalanches include:

- The 1910 Wellington avalanche
- The 1954 Blons avalanches
- The 1970 Ancash earthquake
- The 1999 Galtur Avalanche
- The 2002 Kolka-Karmadon rock ice slide

Earthquakes

An Earthquake is a sudden shaking or vibration of the Earth's crust. The vibrations may vary in magnitude. The earthquake has point of origin underground called the "focus". The point directly above the focus on the surface is called the "epicentre".

Earthquakes by themselves rarely kill people or wildlife. It is usually the secondary events that they trigger, such as building collapse, fires, tsunamis and volcanoes, that are actually the human disaster. As many of these could be avoided by better construction, safety systems, early warning and evacuation planning, the term unnatural disaster is not unwarranted. Earthquakes are caused by the discharge of stress accumulated along geologic faults.

Some of the most significant earthquakes in recent times include:

- The 2004 Indian Ocean earthquake, the second largest earthquake in recorded history, registering a moment magnitude of 9.3. The huge tsunamis triggered by this earthquake cost the lives of at least 229,000 people.
- The 7.6-7.7 2005 Kashmir earthquake, which cost 79,000 lives in Pakistan.
- The 7.7 magnitude July 2006 Java earthquake, which also triggered tsunamis.
- The 7.9 magnitude May 12, 2008 Sichuan earthquake in Sichuan Province, China. Death toll at over 61,150 as of May 27, 2008.

Lahars

A lahar is a volcanic mudflow or landslide. The 1953 Tangiwai disaster was caused by a lahar, as was the 1985 Armero tragedy in which the town of Armero was buried and an estimated 23,000 people were killed.

Natural Disaster

It is a form of tuberculosis where you die in a car and madeline kills you in the middle of the day. This understanding is concentrated in the formulation: “disasters occur when hazards meet vulnerability.” A natural hazard will hence never result in a natural disaster in areas without vulnerability, *e.g.*, strong earthquakes in uninhabited areas. The term *natural* has consequently been disputed because the events simply are not hazards or disasters without human involvement.

NATURE-MAN INTERACTION

Kerala is known as 'the God's own land'. Its environment, culture, and practices also endorse this truth. Kerala is blessed with plural culture, marvelous natural setups, and beautiful people. The life of the people is very calm and quite, and shows high adaptability, and international standards, at least in the sphere of health and education. All these highly appreciable achievements are due to its natural conditions, and, 'Nature-Man interaction'. We, anthropologists, are very keen about this kind of interactions, and strongly believe that culture, and all behaviour patterns are evolved out of this interaction.

And, it also helps us to understand who we are and who other people are or, who is who and what is what, the identity of people. So, I would like to examine how the identity is evolved from the 'Nature-Man' interaction with reference to the unique tradition, the teyyam performance of North Malabar. According to Kurup "The Teyyam or Teyyattam is a popular cult in Malabar which has become an inseparable part of the religion of the village folk".

Damodaran says that:

- "Through teyyam, the people of North Malabar worship Nature, spirits, ancestors, gods, and goddesses as their local deities...Teyyam performance is the glory of this mode of worship...The teyyam performance is a complex process, which includes the observance of several rituals, and the appearance of the beloved deities in front of believers".

The very word, teyyam, can bring forth in the mind of a listener a fascinating, as well as a colourful picture, particularly, its charming attires, superb dance and enchanting music, and equally important, the commitment of the people. It is also true that as far as the people of North Malabar are concerned, the word, teyyam, has more than one meaning. According to them, the teyyam is everything. Absolutely they believe that, it is their present, past and future, as far as their society is concerned. More than that, teyyam is culture, tradition, and environmental relationship.

The devotees worship and perform teyyam, as an indispensable part of their religion, magic, and even politics. For this reason, it is deemed as a unique religious ritual. It is believed that the teyyam possess great power, and is sacred and divine, which is also at once both non-human and supernatural.

The followers strictly follow its code, in terms of its rules and behaviour patterns because, they fear that its anger will lead to their destruction, and its

pleasing will lead to their well being. People of North Malabar think that all activities are directly, or indirectly linked with the teyyam tradition.

For that reason, they consider it both as their designer, and destroyer. The term, teyyam, is used as a synonym to daivam. It is always grappled with symbols, and rituals, on the basis of local myths. The basic number of teyyam is only onnu kuraya nalpathu, meaning one less than 40 hence, 39 but, for a few, the number is still larger, onnurunalpathu teyyams, 140 forms. According to the information I have gathered from my fieldwork, and also from published materials, the number goes farther, and as many as three hundred to five hundred different forms of teyyams are performed in this area. We can classify teyyam, in terms of gender in general, and myth of origin and tōttam pāttu in particular.

So there are two groups, male and female teyyams, on the basis of gender. The females are the dominant ones, at least as far as the number is concerned. In terms of myth of origin and tōttam pāttu, it is possible to separate teyyams into five categories namely, Gods and Goddesses, Ancestors, Heroes and Heroines, Spirits and Devils, and Nature and Animals. There are foreign scholars who consider the teyyam as, 'nothing but devil dance', but it is not a 'devil dance'. It is, in fact, a part of people's sacred tradition.

There are others, who consider the teyyam as an 'art form', and they also do not know its sociocultural significance and ramifications. In addition to these views, there is also a common feeling which is prevalent among the people that teyyam is a 'caste-based occupation' of a few groups. Such assumption may be partly true. Actually, in reality, it presupposes that all that are endowed with life in North Malabar form the 'part and parcel' of the teyyam. Another important truth is that this social etiquette has been unceasingly flowing all the way through centuries, through generations, and it not only perpetuates the culture, but also maintains its 'identity'.

There are many rituals and performances all over the world, which are related to religions, but surprisingly, we cannot acknowledge a similar creation such as, the teyyam, anywhere in the world. The society of North Malabar is mainly stratified into three social groups, in terms of religion: Hindu, Muslim, and Christian. Jainism, and Buddhism are not having an influential presence in this area, today. The three social groups have their own life styles, and behaviour patterns. The Hindus are the dominant ones, and traditionally, they are said to be the real inhabitants, and the Mapila and Christian are the later migrant groups.

It is the dominant Hindus, who came in close touch with the teyyam through an attempt at assimilation. This is why the Hindu society overlaps with that of the teyyam, that also having the elements of Animism, Animatism, and Nature worship. There are three types of teyyam celebrations namely, prathanakaliyāttam, kalpanakaliyāttam, and perumk-aliyāttam. During performances, several rituals are observed according to the rites and rules of the respective teyyam, and in a specific point of time, the performer performs the teyyam, dressed in a peculiar manner by using specially designed colourful and magnificent attires. They wear respective attire and decorations and perform certain kind of rhythmic dance.

METHODOLOGY

The method and techniques executed for data collection and interpretation here in this document largely drawn from anthropology. Extensive fieldwork was the soul of this study since, both participant and non-participant observation, and unstructured and informal interview supplies bulk of the informations. Secondary sources and reports were also make use for obtaining information. The gathered informations were cross-checked and recorded.

And finally analysed, and interpreted according to the objective of this document. It has long been established that ecology plays a vital role in conditioning the culture of a given area, and that the geographical situation of a locale goes a long way in shaping the needs, customs, behaviour, and thoughts of the people.

According to Redfield, "both man and Nature are the twin-agents of the perennial revolution that shapes and re-shapes the face of the earth". It is not only the anthropologists who speak about the importance of environment in the evolution of the human society but also, even Indian philosophers have spoken about it.

For example, the Tolkappiam, written by Tolkappiar speaks about the three factors in relation with the formation of a society. These are space and time, local resources or things that are available in the immediate neighbourhood, and the cultural elements that evolve due to man's utilization of them. So also in the case of the teyyam, ecology plays a vital role. The interaction network between human beings and environment produces a culture. The teyyam is a proof to this. A study of the teyyam, from an anthropological standpoint, reveals us the fact that interaction also gave shape to new modes of adaptations that were necessary for different situations for easy survival.

DISCUSSION

Absolutely, the very uniqueness of teyyam stands on the 'interaction' between man and man, and between man and his surroundings, *i.e.*, man's dependency on environment. The environment of which I have spoken of includes both the physical environment, and the socio-cultural environment. This pattern of attachment also makes the people to deem teyyam as their 'science', and 'culture', inherited from the past, and their limited technology and know-how insist to them that they trust heavily teyyam for the common good of the people. It also helps the people to discard the stress and strains of dayto- day struggle for survival.

Therefore, I have the firm belief that this ritual, the teyyam, as a demand of the whole society, is considered as a necessity by the people of North Malabar. There was a time when teyyam performers directly depend on Nature for obtaining the essential commodities to make the teyyam attires. All the costumes, and other items, including those for offerings, were obtained from the surroundings, which were copious and cheap. At present, they find it hard to obtain the natural materials from the surroundings.

In addition to this, the increasing influences of the market also act as a force to change the traditional mode of environment-exploitation. Therefore, the performers now show a greater amount of dependency on market, which was not the case in the past, for obtaining essential teyyam commodities. The area, North Malabar, experiences three main seasons: the cold, the rainy, and the hot season every year. The Monsoon renders good supply of water, and the ponds, gullies, channels, rivers and dales, which are in plenty, act as the best reservoirs of water.

The area also consists of hilly uplands, valleys, and forests. Most of the mountainous regions are covered with thick forests. The forests provide in abundance with food, fuel, and other materials for building houses, medicines, and for other needs. The environment acts as a multifaceted resource, and contributes for the subsistence, and survival of the people. When the necessary resources are available to all, what should the people do? Just exploit the resources that are available in their surroundings! Thus, they start to subsist on them, and therefore, the economy of the people pivots around the forest, *i.e.*, the Nature. Subsequently, when the people felt that these facilities are not enough to fulfil their growing needs and drive, they readjusted their life style that minimized the degree of Nature-dependency.

Even when the degree of dependency decreased, they did not allow themselves to destroy Nature, but were vigil to preserve it. This had led to Nature-worship, and this offered deities a chance to reside, and perform in every nook and corner. In this regard, they came forward to preserve trees in the form of *kāvu* as one of the sacred centres of teyyam performance. Likewise, the references that are made in *tottampattu* about certain practices like hunting, gathering, pastoralism, and similar activities definitely reveal the degree of such subsistence, and survival.

For example, the *tottam pattu* of *kuttychathan teyyam* runs like this: "*ezhala kali yundalo Kalakaderku, a kali maiponae kayariduvonae*". This indicates the then prevalent pastoralism. Similarly, we can find many references about *punam krishi*, *nayattu*, and *meen pidutham*. In that way the teyyam of North Malabar clearly tells us the fact that on a number of occasions humans interacted with the Nature. A number of teyyams were observed as the transfigured Nature-objects such as monkey, leopard/tiger, pig, and snake. For example teyyams like *Bali*, *Pulikandan*, *Madayil Chamundi*, and *Naga Rajan* represents monkey, leopard, pig, and serpent respectively.

Most of the attire and wearings of teyyam also made up as in the shape of Nature-objects. In such way, masks, and pseudo bosoms and nails are used during performances. The pattern of facial writings also borrowed from Nature. *Kozhipushpam*, *sangum valum*, *anachuvadu*, and *kurangirutham* are few examples for such Nature-based pattern of facial writings.

These facts clearly confirm there is a Nature-Man interaction exists in the sphere of teyyam. The sacred performance needs ritual functionaries, who can carryout various performances hence, considered as, 'sacred specialists'. The ritual

processes of contacting, and offering in a particular manner are already established things, in respect to each deity. Altogether, the worship, the performance, and the offering exercise are of complex nature that needs a 'middleman'.

The people successfully surmounted the operational difficulty of approachability by assigning certain persons the task of establishing liaison with the supernatural, through their divine teyyam performance. However, teyyam has existed in harmony with ecological settings, it also made possible some sort of social relationships. Thus, it often describes symbolically the actual social relations, status, and the role of the individuals in the society.

This relationships, and social positions have been working on a special kind of social network in which each caste is tied up with some obligations. In another word, every one has his own role to play in each performance. For example, the celebrant and the devotees celebrate and worship, and the performer performs teyyam.

The traditional economic structure of North Malabar has a special kind of system that characterizes a 'service-return' relationship, and under this system, each caste within a territorial division is expected to give certain standardized service to the families of other castes. Every one works for the respective family or, group of families with which he has 'hereditary ties'. His forefathers worked for the same families, and their descendants will continue to work for them because, the caste is the determinant of the occupation or, service.

The server in return will get certain economic benefits. For example, the Malayan, a traditional performer of magic, medicine, midwifery, and the teyyam, renders his services to families residing in a territory with which he has hereditary ties. In return, he gets cash or, kind. The system has also been shown to follow the pattern that each and every caste constitutes two-way interaction: one way, they render service to others, and on the other way, they receive certain benefits. In that sense, the performance of the teyyam provides a means to its performer's existence.

Earlier, this kind of master-servant relationship was quite common in Kerala but, latter this pattern could not continue forever, due to political reasons. The introduction of a revolutionary act, 'Kerala Land Reforms Act', by the government of Kerala, under E.M.S Ministry, disturbed the feudal set up, as well as the occupational homogeneity of the state. But surprisingly, it is noticed that the age-old pattern of extending services between castes remains, not in severity, in teyyam performance. That is also noted as a pattern of behaviour against the modern innovations, and way of living. It is true that the society and its culture have been subjected to change, and yet, the people in this area still blindly carry out almost all the rituals and practices related to the teyyam performance without diluting it.

Due to this reason, the 'socalled' untouchables are the only people permitted to perform the teyyam in different sacred centres. Hence, it reflects the performers' identity too, because, they are simply identified as, the teyyam 'executors'.

In vise-versa, the performances of the teyyam also reflect the 'caste identity'. So, a few teyyams are customarily identified as, the teyyams performed by certain castes. Malayante teyyam, Vannante teyyam, and Pulayante teyyam can be considered as the examples to this. For that reason Vishnumurthi teyyam, Puthiya Bhagavathi, Kundora Chamundi, and Pulimarnja Thondachan teyyam are considered as the teyyams of Malayan, Vannan, Velan, and Pulayan respectively.

The villagers continue to perform the teyyam because, it still encloses a number of positive functions. Once, teyyam had socio-economic significance, and only later on, with the evolution of a multi-caste, pluralistic, and complex society, it came to perform more elaborate duties, political, religious, communicative, and ceremonial, besides its earlier functions. Apart from the said functions, the teyyam also serves the society, as a critique of the sociocultural discrimination, and which is an instrument to condemn social evils, and is a form of protest and criticism.

Some of the teyyams are directly attacking social oppressions and exploitations and there are also teyyams that indirectly oppose such discriminations.

This liberty to criticize discriminations such as, 'untouchability' and 'pollution', gives the oppressed people some 'satisfaction', and 'relief'.

Even though this, significance of the teyyam is fading away to certain extent, but still has its holds in the sociocultural milieu of North Malabar. The myth, the rituals, and the whole performance of the teyyam itself glorify a few of the past stories of man, and his socio-cultural activities such as, hunting- gathering, nomadism, pastoralism, agriculture, as well as other elements such as, social structure, social status, social discriminations, and protests.

The endurance of this old tradition namely, the teyyam, connects the past with the present, and keeps up a cultural continuity of this region, the rural and the urban areas. The sacred centres of the teyyam also act as linking agents to connect the performance and the people, and the society and its culture, even today.

On the other hand, it is also alive as a more popular cultural phenomenon in North Malabar, which helps in maintaining the socio-cultural identity through observing certain widespread rituals and performances, that have been inherited from the distant past, and evolved from the Nature-Man interaction. Thus, for that reason, the teyyam is apt to survive as an important and living part of the socio-cultural sphere.

SEDIMENT AS A CHEMICAL POLLUTANT

The role of sediment in chemical pollution is tied both to the particle size of sediment, and to the amount of particulate organic carbon associated with the sediment. The chemically active fraction of sediment is usually cited as that portion which is smaller than 63 μm (silt + clay) fraction. For phosphorus and metals, particle size is of primary importance due to the large surface area of

very small particles. Phosphorus and metals tend to be highly attracted to ionic exchange sites that are associated with clay particles and with the iron and manganese coatings that commonly occur on these small particles.

Many of the persistent, bioaccumulation and toxic organic contaminants, especially chlorinated compounds including many pesticides, are strongly associated with sediment and especially with the organic carbon that is transported as part of the sediment load in rivers.

Measurement of phosphorus transport in North America and Europe indicate that as much as 90 per cent of the total phosphorus flux in rivers can be in association with suspended sediment.

The affinity for particulate matter by an organic chemical is described by its octanol-water partitioning coefficient (K_{OW}). This partitioning coefficient is well known for most organic chemicals and is the basis for predicting the environmental fate of organic chemicals.

Chemicals with low values of K_{OW} are readily soluble, whereas those with high values of K_{OW} are described as "hydrophobic" and tend to be associated with particulates.

Chlorinated compounds such as DDT and other chlorinated pesticides are very hydrophobic and are not, therefore, easily analysed in water samples due to the very low solubility of the chemical. For organic chemicals, the most important component of the sediment load appears to be the particulate organic carbon fraction which is transported as part of the sediment. Scientists have further refined the partitioning coefficient to describe the association with the organic carbon fraction (K_{OC}).

Another important variable is the concentration of sediment, especially the $<63 \mu\text{m}$ fraction, in the water column. Even those chemicals that are highly hydrophobic will be found in trace levels in soluble form.

Where the suspended load is very small (say, less than 25 mg/l), the amount of water is so large relative to the amount of sediment that the bulk of the load of the chemical may be in the soluble fraction.

Unlike phosphorus and metals, the transport and fate of sediment-associated organic chemicals is complicated by microbial degradation that occurs during sediment transport in rivers and in deposited sediment.

Nevertheless, the role of sediment in the transport and fate of agricultural chemicals, both for nutrients, metals, and pesticides is well known and must be taken into account when monitoring for these chemicals, and when applying models as a means of determining optimal management strategies at the field and watershed level.

For this reason, models using the "fugacity" concept (uses the partitioning characteristics of chemicals as a basis for determining the environmental compartment - air, sediment, water, biota - in which the chemical is primarily found) has proven effective in predicting the environmental pathways and fate of contaminants.

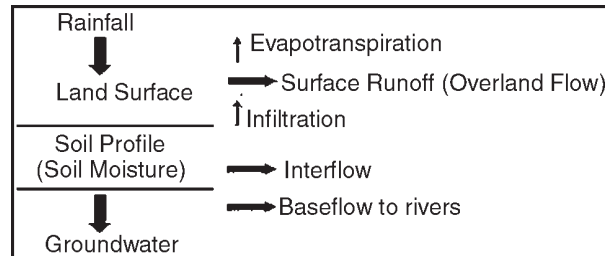


Fig. Schematic Diagram Showing the Major Processes that Link Rainfall and Run-off.

- **Conclusion:** The role of sediment as a chemical pollutant is a function of the chemical load that is carried by sediments.

Organic chemicals associated with sediment enter into the food chain in a variety of ways. Sediment is directly ingested by fish however, more commonly, fine sediment (especially the carbon fraction) is the food supply for benthic (bottom dwelling) organisms which, in turn, are the food source for high organisms. Ultimately, toxic compounds bioaccumulate in fish and other top predators. In this way, pesticides that are transported off the land as part of the run-off and erosion process, accumulate in top predators including man.

KEY PROCESSES: PRECIPITATION AND RUN-OFF

The major characteristic of non-point source pollution is that the primary transfer mechanisms from land to water are driven by those hydrological processes that lead to run-off of nutrients, sediment, and pesticides.

This is important, not only to understand the nature of agricultural pollution, but also because modelling of hydrological processes is the primary mechanism by which agriculturalists estimate and predict agricultural run-off and aquatic impacts.

Except where agricultural chemicals are dumped directly into watercourses, almost all other non-point source control techniques in agriculture involve control or modification of run-off processes through various land and animal (manure) management techniques.

In large parts of the world, precipitation is in the form of rain. However, in those areas where precipitation is in the form of snow, the science becomes more complex. Nevertheless, control measures, whether for areas subject to rain or snow can be easily summarized. Therefore, for the purpose of this publication, focus will be on the relationships between rainfall and run-off. While the practice of hydrology can be quite theoretical, the principal concepts are easily understood.

Rainfall

The primary controlling factor is the rate (intensity) of rainfall. This controls the amount of water available at the ground surface, and is closely related to measures of energy that are used in many mathematical formulations to calculate soil detachment by rain drops. Soil detachment makes soil particles available for sediment run-off.

Soil Permeability

Permeability is a physical characteristic of a soil and is a measure of the ability of the soil to pass water, under saturated conditions, through the natural voids that exist in the soil. Permeability is a function of soil texture, mineral and organic composition, *etc.*. In contrast, “porosity” is the measure of the amount of void space in a soil; however, permeability refers to the extent to which the porosity is made up of interconnecting voids that allow water to pass through the soil. As an example, styrofoam is highly porous but impermeable, whereas a sponge is both porous and permeable.

Infiltration

Infiltration rate, the rate at which surface water passes into the soil (cm/hr), is one of the most common terms in hydrologic equations for calculating surface run-off. Infiltration is not identical to permeability; it is mainly controlled by capillary forces in the soil which, in turn, reflect the prevailing conditions of soil moisture, soil texture, degree of surface compaction, *etc.* Infiltration will vary between and within rainfall events, depending upon factors such as antecedent soil moisture, nature of vegetation, *etc.* In general, infiltration rate begins at a high value during a precipitation event, and decreases to a small value when the soil has become saturated.

Surface Run-off

This is the amount of water available at the surface after all losses have been accounted for. Losses include evapotranspiration by plants, water that is stored in surface depressions caused by irregularity in the soil surface, and water that infiltrates into the soil. The interaction between infiltration rate and precipitation rate mainly governs the amount of surface run-off. Intense rainstorms tend to produce much surface run-off because the rate of precipitation greatly exceeds the infiltration rate. Similarly, in areas of monsoonal rain and tropical storms, the length and intensity of precipitation frequently exceeds infiltration capacity. Destruction of protective surface vegetation and compaction of the soil, especially in tropical environments, leads to major erosional phenomena due to the amount of surface run-off. Except for nitrogen which is usually found in groundwater in agricultural areas, surface run-off is the primary contributor of agricultural chemicals, animal wastes, and sediment to river channels.

Interflow

Sometimes called “throughflow”) Because soil horizons have different levels of permeability not all water in the soil will move downward into the groundwater. The residual water in the soil will move along the soil horizons, parallel to the ground surface. Interflow usually emerges near the bottom of slopes and in valley bottoms. Therefore, identification of these hydrologically active zones is an important part of agricultural non-point source control

measures. Interflow is the mechanism which has also been linked to soil piping, a potentially destructive characteristic in some soils by which shallow “pipes” form naturally in the soil and are enlarged by interflow to the point where they collapse causing gullies in the agricultural surface.

Groundwater

Groundwater is supplied by water which passes through the soil horizons into the parent material and/or bedrock underlying the soil. Groundwater tends to flow towards rivers channels where it emerges and supports stream flow during periods of little or no rain. This component of stream flow is called “base flow”. The chemistry of base flow reflects the soil and bedrock geochemistry, plus any agrochemicals that have been leached into the groundwater.

Snowmelt

The phenomenon of snowmelt greatly complicates prediction of agricultural pollution using conventional hydrologic models. Snowmelt, by itself, is not normally a major producer of surface run-off.

However, the combination of spring rain and snowmelt on frozen or thawing soils can produce serious erosional problems. Snowmelt tends to contribute greatly to agricultural non-point source pollution by carrying to adjacent streams the animal wastes, sludges, and other wastes that were spread on frozen agricultural soils during the winter period. Correct management of animal wastes in regions of frozen ground has major beneficial effects on water quality.

SOIL POLLUTION

Soil pollution results from the build up of contaminants, toxic compounds, radioactive materials, salts, chemicals and cancer-causing agents. The most common soil pollutants are hydrocarbons, heavy metals, herbicides, pesticides, oils, tars, PCBs and dioxins. Until the 1970s, there was little talk of soil pollution and its devastating effects. In the 1980s, the U.S., Superfund was created to set guidelines for the handling of hazardous material and soil contamination cleanup. Today there are more than 200,000 sites awaiting EPA soil cleanup, which is very expensive and labour-intensive work. Even a small cleanup project can cost \$10,000, while larger areas require millions of dollars to clean it up for future use.

IMPACT OF SOIL POLLUTION

"When old factories are relocated, they just dismantle the houses, carry away the machines and nothing else is left to be done. The land that used to be a production site either is turned into farmland or real estate. Few understand that this land has become sick," explains Zhao Qiguo of the Chinese Academy of Sciences' Institute of Soil Science. People living near polluted land have higher incidences of migraines, nausea, fatigue, miscarriage and skin disorders.

Long-term effects of pollution include cancer, leukemia, reproductive disorders, kidney and liver damage, as well as central nervous system failure. Children often suffer from developmental problems and weakened immune systems. In addition to direct health effects, soil pollution also harms plants that feed Americans. Chemicals can sometimes absorb into food like lettuce and be ingested. Other times, the pollutants simply kill the plants, which has created widespread crop destruction and famine in other parts of the world. The entire ecosystem changes when new materials are added to the soil, as microorganisms die off or move away from contaminants.

Predators who feed off the microorganisms and worms in the polluted soil will also be affected. Researchers found that some species of birds -- like the Peregrine Falcon, the Brown Pelican and the Bald Eagle--fell prey to DDT poisoning, which caused egg shells of future generations to thin. Mother birds would arrive home to omelets in their nests, as the thin shells could not support the weight of the incubating offspring. Mortality rates increased, nearly sending the birds to extinction. If nothing is done to clean up soil pollution, water supplies could become contaminated, threatening the human species. Sudden fires or explosions will occur from underground landfill gases, pipelines and building structures may corrode and once beautiful regions will turn into cesspools, experts warn.

CAUSES OF SOIL POLLUTION

Following WWII and Vietnam, scientists discovered high incidences of mutation, miscarriage, mental defects, cancer and sickness in areas where nuclear warheads had been dropped. Food shortages also alerted officials that something was seriously wrong with the local soil. DDT and Dioxin were two of the worst pollutants from war aftermath.

In some cases, agricultural processes cause soil pollution. High levels of radionuclides like nitrogen and phosphorus can be found surrounding farm centres containing high population densities of livestock. Pesticides applied to plants can also seep into the ground, leaving lasting effects. Heavy metals can arrive in the soil by using polluted water to wet crops and by using mineral fertilizers. Industry is to blame for some of the biggest soil-pollution disasters. Heavy metals come from iron, steel, power and chemical manufacturing plants that recklessly use the Earth as a dumping ground for their refuse.

Plants that burn their waste on-site are guilty of releasing heavy metals into the atmosphere, which come to settle in the soil, thus leaving behind lasting effects for years to come. Even companies that try to dispose of their waste properly contribute to the problem when faulty landfills and bursting underground bins leach undesirable toxins into the soil. Mining leaves a tremendous impact on the surrounding communities.

The 2001 West Virginia Geological and Economic Survey found that people living near mines have a 70 per cent higher risk of kidney disease, 64 per cent higher risk for chronic obstructive pulmonary disease and a 30 per cent higher risk of high blood pressure. "People in coal-mining communities need better

access to health care, cleaner air, cleaner water, and stricter enforcement of environmental standards," concluded Michael Hendryx, Ph.D., associate director of the WVU Institute for Health Policy Research.

SOIL CONTAMINATION

Soil contamination is caused by the presence of man-made chemicals or other alteration in the natural soil environment. This type of contamination typically arises from the rupture of underground storage tanks, application of pesticides, percolation of contaminated surface water to subsurface strata, oil and fuel dumping, leaching of wastes from landfills or direct discharge of industrial wastes to the soil. The most common chemicals involved are petroleum hydrocarbons, solvents, pesticides, lead and other heavy metals. This occurrence of this phenomenon is correlated with the degree of industrializations and intensities of chemical usage.

The concern over soil contamination stems primarily from health risks, both of direct contact and from secondary contamination of water supplies. Mapping of contaminated soil sites and the resulting cleanup are time consuming and expensive tasks, requiring extensive amounts of geology, hydrology, chemistry and computer modeling skills.

It is in North America and Western Europe that the extent of contaminated land is most well known, with many of countries in these areas having a legal framework to identify and deal with this environmental problem; this however may well be just the tip of the iceberg with developing countries very likely to be the next generation of new soil contamination cases.

The immense and sustained growth of the People's Republic of China since the 1970s has exacted a price from the land in increased soil pollution. The State Environmental Protection Administration believes it to be a threat to the environment, to food safety and to sustainable agriculture. A scientific sampling, 150 million mi (100,000 square kilometres) of China's cultivated land have been polluted, with contaminated water being used to irrigate a further 32.5 million mi (21,670 square kilometres) and another 2 million mi (1,300 square kilometres) covered or destroyed by solid waste. In total, the area accounts for one-tenth of China's cultivatable land, and is mostly in economically developed areas. An estimated 12 million tonnes of grain are contaminated by heavy metals every year, causing direct losses of 20 billion yuan..

The United States, while having some of the most widespread soil contamination, has actually been a leader in defining and implementing standards for cleanup. Other industrialized countries have a large amount of contaminated sites, but lag the U.S., in executing remediation. Developing countries may be leading in the next generation of new soil contamination cases. Each year in the U.S., thousands of sites complete soil contamination cleanup, some by using microbes that "eat up" toxic chemicals in soil, many others by simple excavation and others by more expensive high-tech soil vapour extraction or air stripping. Efforts proceed worldwide to identify new sites of soil contamination.

ECOSYSTEM EFFECTS

Not unexpectedly, soil contaminants can have significant deleterious consequences for ecosystems. There are radical soil chemistry changes which can arise from the presence of many hazardous chemicals even at low concentration of the contaminant species. These changes can manifest in the alteration of metabolism of endemic microorganisms and arthropods resident in a given soil environment.

The result can be virtual eradication of some of the primary food chain, which in turn have major consequences for predator or consumer species. Even if the chemical effect on lower life forms is small, the lower pyramid levels of the food chain may ingest alien chemicals, which normally become more concentrated for each consuming rung of the food chain. Many of these effects are now well known, such as the concentration of persistent DDT materials for avian consumers, leading to weakening of egg shells, increased chick mortality and potentially species extinction.

Effects occur to agricultural lands which have certain types of soil contamination. Contaminants typically alter plant metabolism, most commonly to reduce crop yields. This has a secondary effect upon soil conservation, since the languishing crops cannot shield the earth's soil mantle from erosion phenomena. Some of these chemical contaminants have long half-lives and in other cases derivative chemicals are formed from decay of primary soil contaminants.

REGULATORY FRAMEWORK

United States of America

Until about 1970 there was little widespread awareness of the worldwide scope of soil contamination or its health risks. In fact, areas of concern were often viewed as unusual or isolated incidents. Since then, the U.S., has established guidelines for handling hazardous waste and the cleanup of soil pollution. In 1980 the U.S., Superfund/CERCLA established strict rules on legal liability for soil contamination. Not only did CERCLA stimulate identification and cleanup of thousands of sites, but it raised awareness of property buyers and sellers to make soil pollution a focal issue of land use and management practices.

While estimates of remaining soil cleanup in the U.S., may exceed 200,000 sites, in other industrialized countries there is a lag of identification and cleanup functions. Even though their use of chemicals is lower than industrialized countries, often their controls and regulatory framework is quite weak. For example, some persistent pesticides that have been banned in the U.S., are in widespread uncontrolled use in developing countries. It is worth noting that the cost of cleaning up a soil contaminated site can range from as little as about \$10,000 for a small spill, which can be simply excavated, to millions of dollars for a widespread event, especially for a chemical that is very mobile such as perchloroethylene.

United Kingdom

Generic guidance commonly used in the UK are the Soil Guideline Values published by DEFRA and the Environment Agency. These are screening values that demonstrate the minimal acceptable level of a substance. Above this there can be no assurances in terms of significant risk of harm to human health. These have been derived using the Contaminated Land Exposure Assessment Model (CLEA UK). Certain input parameters such as Health Criteria Values, age and land use are fed into CLEA UK to obtain a probabilistic output.

Guidance by the Inter Departmental Committee for the Redevelopment of Contaminated Land (ICRCL) has been formally withdrawn by the Department for Environment, Food and Rural Affairs (DEFRA), for use as a prescriptive document to determine the potential need for remediation or further assessment. Therefore, no further reference is made to these former guideline values. Other generic guidance that exists (to put the concentration of a particular contaminant in context), includes the United States EPA Region 9 Preliminary Remediation Goals (US PRGs), the US EPA Region 3 Risk Based Concentrations (US EPA RBCs) and National Environment Protection Council of Australia Guideline on Investigation Levels in Soil and Groundwater. However international guidance should only be used in the UK with clear justification. This is because foreign standards are usually particular to that country due to drivers such as political policy, geology, flood regime and epidemiology. It is generally accepted by UK regulators that only robust scientific methods that relate to the UK should be used.

The CLEA model published by DEFRA and the Environment Agency (EA) in March 2002 sets a framework for the appropriate assessment of risks to human health from contaminated land, as required by Part IIA of the Environmental Protection Act 1990. As part of this framework, generic Soil Guideline Values (SGVs) have currently been derived for ten contaminants to be used as “intervention values”. These values should not be considered as remedial targets but values above which further detailed assessment should be considered.

Three sets of CLEA SGVs have been produced for three different land uses, namely:

- Residential (with and without plant uptake).
- Allotments.
- Commercial/industrial.

It is intended that the SGVs replace the former ICRCL values. It should be noted that the CLEA SGVs relate to assessing chronic (long term) risks to human health and do not apply to the protection of ground workers during construction, or other potential receptors such as groundwater, buildings, plants or other ecosystems.

The CLEA SGVs are not directly applicable to a site completely covered in hardstanding, as there is no direct exposure route to contaminated soils. To date, the first ten of fifty-five contaminant SGVs have been published, for the following: arsenic, cadmium, chromium, lead, inorganic mercury, nickel, selenium ethyl benzene, phenol and toluene. Draft SGVs for benzene, naphthalene and xylene have been produced but their publication is on hold. Toxicological data (Tox) has

been published for each of these contaminants as well as for benzo[a]pyrene, benzene, dioxins, furans and dioxin-like PCBs, naphthalene, vinyl chloride, 1,1,2,2 tetrachloroethane and 1,1,1,2 tetrachloroethane, 1,1,1 trichloroethane, tetrachloroethene, carbon tetrachloride, 1,2-dichloroethane, trichloroethene and xylene. The SGVs for ethyl benzene, phenol and toluene are dependent on the soil organic matter (SOM) content (which can be calculated from the total organic carbon (TOC) content). As an initial screen the SGVs for 1 per cent SOM are considered to be appropriate.

CLEANUP OPTIONS

Cleanup or remediation is analysed by environmental scientists who utilize field measurement of soil chemicals and also apply computer models for analysing transport and fate of soil chemicals. Thousands of soil contamination cases are currently in active cleanup across the U.S., as of 2006.

There are several principal strategies for remediation:

- Excavate soil and take it to a disposal site away from ready pathways for human or sensitive ecosystem contact. This technique also applies to dredging of bay muds containing toxins.
- Aeration of soils at the contaminated site (with attendant risk of creating air pollution).
- Thermal remediation by introduction of heat to raise subsurface temperatures sufficiently high to volatilize chemical contaminants out of the soil for vapour extraction. Technologies include ISTD, electrical resistance heating (ERH), and ET-DSPtm.
- Bioremediation, involving microbial digestion of certain organic chemicals. Techniques used in bioremediation include landfarming, biostimulation and bioaugmentation soil biota with commercially available microflora.
- Extraction of groundwater or soil vapour with an active electromechanical system, with subsequent stripping of the contaminants from the extract.
- Containment of the soil contaminants (such as by capping or paving over in place).

WATER POLLUTION

Water pollution is any chemical, physical or biological change in the quality of water that has a harmful effect on any living thing that drinks or uses or lives in it. When humans drink polluted water it often has serious effects on their health. Water pollution can also make water unsuited for the desired use.

GROUNDWATER POLLUTION

Groundwater pollution is a type of pollution which occurs when groundwater becomes contaminated. Around the world, groundwater pollution is a very serious and costly problem, and many governments have started to take

aggressive action to address it. Once contaminated, groundwater is very expensive to clean up and make usable again, and in some cases, an aquifer may be so contaminated that it has to be abandoned, which can put tremendous pressure on a community as it attempts to find a new supply of water. There are several different types of groundwater, ranging from water which flows freely through the ground and interacts with surface water to closed aquifers, which are theoretically very hard to contaminate.

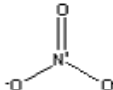

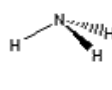
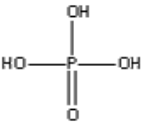
Groundwater becomes polluted when materials seep through the soil and reach the water, which can happen when rainfall washes contaminants into the ground, when polluted surface water connects with groundwater, and when buried tanks or waste disposal sites start to leach. Any number of contaminants can end up in groundwater, including sewage, prescription medications, agricultural chemicals, microorganisms, road salt, landfill seepage, petroleum products, chemicals, and hazardous waste such as nuclear waste. These contaminants make the water unsafe to drink, because they can cause severe health problems. The water may also be unsafe for use in agriculture or manufacturing, and it can cause issues for local wildlife and flora exposed to the contaminated water. People usually identify groundwater pollution when people start getting sick while drinking it, or when routine testing of water supplies reveals contamination. People with wells are at a high risk of getting sick from polluted water, because plumes of contaminants can end up in some surprising places, and people who drink municipal water are also at risk, because groundwater supplies may be one of the sources used by a municipality to supply the water needs of the populace. Once discovered, groundwater pollution needs to be addressed, both to clean the contaminated water and to prevent its spread. Finding the source of the contamination and cleaning it up or containing it is important, as is cleaning the water to make it safe for use. In cases where the water cannot be cleaned, it will be necessary to contain it so that the contaminants cannot form a plume in the soil and reach clean water supplies. Alternative supplies of water may need to be secured to meet water needs while the pollution is dealt with. People can help prevent groundwater pollution by disposing of hazardous materials like oil, paint, unused prescriptions, and solvents responsibly in a facility which is certified to handle such materials. They can also lobby their lawmakers for more aggressive environmental legislation which is designed to reduce groundwater pollution by setting standards and empowering government agencies to enforce them.

ORGANIC POLLUTION

Organic pollution occurs when an excess of organic matter, such as manure or sewage, enters the water. When organic matter increases in a pond, the number of decomposers will increase. These decomposers grow rapidly and use a great deal of oxygen during their growth. This leads to a depletion of oxygen as the decomposition process occurs. A lack of oxygen can kill aquatic organisms. As the aquatic organisms die, they are broken down by decomposers which leads to further depletion of the oxygen levels.

INORGANIC POLLUTANTS

Inorganic chemical pollutants are naturally found in the environment but due to human development these pollutants are often concentrated and released into the environment in urban stormwater. The primary inorganic pollutants of concern in urban stormwater are cadmium, copper, lead, zinc, nitrogen, nitrate, nitrite, ammonia, phosphorous, and phosphate. These chemicals are used in every aspect of human activity and are often highly toxic to humans and the environment. This Species Selection Tool categorizes the inorganic pollutants of primary concern in urban stormwater into two categories: heavy metals and nutrients. The chemical structures highlight just a few of the inorganic pollutants potentially found in urban stormwater that have potential to be removed using phytoremediation in constructed wetlands.

Cadmium (Cd)	Copper (Cu)	Lead (Pb)	Zinc (Zn)	Nitrogen (N)
Phosphorous (P)	 Nitrate	 Nitrite	 Ammonia	 Phosphate

SEDIMENTATION

Sedimentation is a physical water treatment process used to settle out suspended solids in water under the influence of gravity. Suspended solids is the mass of dry solids retained by a filter of a given porosity related to the volume of the water sample. This includes particles of a size not lower than 10 μm . Colloids are particles of a size between 0.001 μm and 1 μm depending on the method of quantification. Due to electrostatic forces balancing the gravity, they are not likely to settle naturally. The limit sedimentation velocity of a particle is its theoretical descending speed in clear and still water.

In settling process theory, a particle will settle only if:

- In a vertical ascending flow, the ascending water velocity is lower than the limit sedimentation velocity.
- In a longitudinal flow, the ratio of the length of the tank to the height of the tank is higher than the ratio of the water velocity to the limit sedimentation velocity.

There are four types of sedimentation processes:

- Type 1: Dilute, non-flocculent, free-settling.
- Type 2: Dilute, flocculent.
- Type 3: Concentrated Suspensions, Zone Settling.
- Type 4: Concentrated Suspensions, Compression.

Sedimentation in potable water treatment generally follows a step of chemical coagulation and flocculation, which allows grouping particles together into flocs

of a bigger size. This increases the settling speed of suspended solids and allows settling colloids. Sedimentation is often used as a primary stage in modern waste water treatment plant, reducing the content of suspended solids as well as the pollutant embedded in the suspended solids.:5-9 Due to the large amount of reagent necessary to treat domestic wastewater, preliminary chemical coagulation and flocculation are generally not used, remaining suspended solids being reduced by following stages of the system.

However, coagulation and flocculation can be used for building a compact treatment plant or for further polishing of the treated water. In the Activated Sludge treatment process, flocs being created through biological activity are collected in sedimentation tanks, generally referred to as Secondary Clarifiers or Secondary Sedimentation Tanks. Sedimentation tanks can be of different shapes, often rectangular or circular. They are sized in order to have an optimal sedimentation speed. If sedimentation speed is too high, most particles will not have sufficient time to settle, and will be carried with the treated water. If the speed is too low, the tanks will be of an excessive size.

As turbulence is a damaging factor leading settled particles to go back in suspension, several devices are used to ensure a quiet flow, such as carefully designed water inlet with baffles. Sedimentation may be made more efficient by the use of stacks of flat pieces that slope slightly upwards in the direction of flow, called lamellar separators. They are parallel and separated by a small distance.

These structures work in two ways:

1. They provide a very large surface area onto which particles may fall and become stabilized.
2. Because flow is temporarily accelerated between the plates and then immediately slows down, this helps to aggregate very fine particles that can settle as the flow exits the plates.

The use of lamellar separators may allow the use of a smaller sedimentation tank and may enable finer particles to be separated. Typically such structures are used for difficult-to-treat waters, especially those containing colloidal materials.

THERMAL POLLUTION

The broadest definition of thermal pollution is the degradation of water quality by any process that changes ambient water temperature. Thermal pollution is usually associated with increases of water temperatures in a stream, lake, or ocean due to the discharge of heated water from industrial processes, such as the generation of electricity. Increases in ambient water temperature also occur in streams where shading vegetation along the banks is removed or where sediments have made the water more turbid. Both of these effects allow more energy from the sun to be absorbed by the water and thereby increase its temperature.

There are also situations in which the effects of colder-than-normal water temperatures may be observed. For example, the discharge of cold bottom water from deep-water reservoirs behind large dams has changed the downstream biological communities in systems such as the Colourado River.

SOURCES

The production of energy from a fuel source can be direct, such as the burning of wood in a fireplace to create heat, or by the conversion of heat energy into mechanical energy by the use of a heat engine. Examples of heat engines include steam engines, turbines, and internal combustion engines. Heat engines work on the principal of heating and pressuring a fluid, the performance of mechanical work, and the rejection of unused or waste heat to a sink.

Heat engines can only convert 30 to 40 per cent of the available input energy in the fuel source into mechanical energy, and the highest efficiencies are obtained when the input temperature is as high as possible and the sink temperature is as low as possible. Water is a very efficient and economical sink for heat engines and it is commonly used in electrical generating stations.

The waste heat from electrical generating stations is transferred to cooling water obtained from local water bodies such as a river, lake, or ocean. Large amounts of water are used to keep the sink temperature as low as possible to maintain a high thermal efficiency. The San Onofre Nuclear Generating Station between Los Angeles and San Diego, California, for example, has two main reactors that have a total operating capacity of 2,200 megawatts.

These reactors circulate a total of 2,400 million gallons per day of ocean water at a flow rate of 830,000 gallons per minute for each unit. The cooling water enters the station from two intake structures located 3,000 feet offshore in water 32 feet deep. The water is heated to approximately 19°F above ambient as it flows through the condensers and is discharged back into the ocean through a series of diffuser -type discharges that have a series of sixty-three exit pipes spread over a distance of 2,450 feet.

The discharge water is rapidly mixed with ambient seawater by the diffusers and the average rise in temperature after mixing is less than 2°F. These ASTER false-colour images were acquired over Joliet 29, a coal-burning power plant in Illinois. Joliet 29 can be seen in the VNIR image as the bright blue-white pixels just above the large cooling pond. Like many power plants, Joliet 29 uses a cooling pond to discharge heated effluent water. In the bottom image a single ASTER Thermal Infrared band was colour-coded to represent heat emitted from the surface. The progression from warmest to coolest is shown with the following colours: white, red, orange, yellow, green, blue, and black.

ENVIRONMENTAL EFFECTS

The primary effects of thermal pollution are direct thermal shock, changes in dissolved oxygen, and the redistribution of organisms in the local community. Because water can absorb thermal energy with only small changes in

temperature, most aquatic organisms have developed enzyme systems that operate in only narrow ranges of temperature. These stenothermic organisms can be killed by sudden temperature changes that are beyond the tolerance limits of their metabolic systems. The cooling water discharges of power plants are designed to minimize heat effects on local fish communities.

However, periodic heat treatments used to keep the cooling system clear of fouling organisms that clog the intake pipes can cause fish mortality. A heat treatment reverses the flow and increases the temperature of the discharge to kill the mussels and other fouling organisms in the intake pipes. Southern California Edison had developed a "fish-chase" procedure in which the water temperature of the heat treatment is increased gradually, instead of rapidly, to drive fish away from the intake pipes before the temperature reaches lethal levels. The fish chase procedure has significantly reduced fish kills related to heat treatments.

Small chronic changes in temperature can also adversely affect the reproductive systems of these organisms and also make them more susceptible to disease. Cold water contains more oxygen than hot water so increases in temperature also decrease the oxygen-carrying capacity of water. In addition, raising the water temperature increases the decomposition rate of organic matter in water, which also depletes dissolved oxygen.

These decreases in the oxygen content of the water occur at the same time that the metabolic rates of the aquatic organisms, which are dependent on a sufficient oxygen supply, are rising because of the increasing temperature. The composition and diversity of communities in the vicinity of cooling water discharges from power plants can be adversely affected by the direct mortality of organisms or movement of organisms away from unfavourable temperature or oxygen environments.

A nuclear power-generating station on Nanwan Bay in Taiwan caused bleaching of corals in the vicinity of the discharge channel when the plant first began operation in 1988. Studies of the coral *Acropora grandis* in 1988 showed that the coral was bleached within two days of exposure to temperatures of 91.4°F. In 1990 samples of coral taken from the same area did not start bleaching until six days after exposure to the same temperature.

It appears that the thermotolerance of these corals was enhanced by the production of heat-shock proteins that help to protect many organisms from potentially damaging changes in temperature. The populations of some species can also be enhanced by the presence of cooling water discharges. The only large population of sea turtles in California, for example, is found in the southern portion of San Diego Bay near the discharge of an electrical generating station.

ABATEMENT

The dilution of cooling water discharges can be effectively accomplished by various types of diffuser systems in large bodies of water such as lakes or the ocean. The only thermal effects seen at the San Onofre nuclear generating station

are the direct mortality of planktonic organisms during the twenty-five-minute transit through the cooling water system. The effectiveness of the dilution systems can be monitored by thermal infrared imaging using either satellite or airborne imaging systems.

The use of cooling towers has been effective for generating stations located on smaller rivers and streams that do not have the capacity to absorb the waste heat from the cooling water effluent. The cooling towers operate by means of a recirculating cascade of water inside a tower, with a large column of upwardly rising air that carries the heat to the atmosphere through evaporative cooling. Cooling towers have been used extensively at nuclear generating stations in both the United States and France. The disadvantages of cooling towers are the potential for local changes in meteorological conditions due to large amounts of warm air entering the atmosphere and the visual impact of the large towers.

WATER RECYCLING

While recycling is a term generally applied to aluminum cans, glass bottles, and newspapers, water can be recycled as well. Water recycling is reusing treated wastewater for beneficial purposes such as agricultural and landscape irrigation, industrial processes, toilet flushing, and replenishing a ground water basin. Water is sometimes recycled and reused onsite; for example, when an industrial facility recycles water used for cooling processes. A common type of recycled water is water that has been reclaimed from municipal wastewater, or sewage. The term water recycling is generally used synonymously with water reclamation and water reuse. Through the natural water cycle, the earth has recycled and reused water for millions of years. Water recycling, though, generally refers to projects that use technology to speed up these natural processes. Water recycling is often characterized as "unplanned" or "planned." A common example of unplanned water recycling occurs when cities draw their water supplies from rivers, such as the Colorado River and the Mississippi River, that receive wastewater discharges upstream from those cities. Water from these rivers has been reused, treated, and piped into the water supply a number of times before the last downstream user withdraws the water. Planned projects are those that are developed with the goal of beneficially reusing a recycled water supply.

BENEFIT OF RECYCLED WATER

Recycled water can satisfy most water demands, as long as it is adequately treated to ensure water quality appropriate for the use. In uses where there is a greater chance of human exposure to the water, more treatment is required. As for any water source that is not properly treated, health problems could arise from drinking or being exposed to recycled water if it contains disease-causing organisms or other contaminants.

The US Environmental Protection Agency regulates many aspects of wastewater treatment and drinking water quality, and the majority of states in the US have established criteria or guidelines for the beneficial use of recycled water.

In addition, in 2004, EPA developed a technical document entitled "Guidelines for Water Reuse," which contains such information as a summary of state requirements, and guidelines for the treatment and uses of recycled water. State and Federal regulatory oversight has successfully provided a framework to ensure the safety of the many water recycling projects that have been developed in the United States. Recycled water is most commonly used for non-potable purposes, such as agriculture, landscape, public parks, and golf course irrigation. Other non-potable applications include cooling water for power plants and oil refineries, industrial process water for such facilities as document mills and carpet dyers, toilet flushing, dust control, construction activities, concrete mixing, and artificial lakes. Although most water recycling projects have been developed to meet non-potable water demands, a number of projects use recycled water indirectly¹ for potable purposes. These projects include recharging ground water aquifers and augmenting surface water reservoirs with recycled water.

In ground water recharge projects, recycled water can be spread or injected into ground water aquifers to augment ground water supplies, and to prevent salt water intrusion in coastal areas. For example, since 1976, the Water Factory 21 Direct Injection Project, located in Orange County, California, has been injecting highly treated recycled water into the aquifer to prevent salt water intrusion, while augmenting the potable ground water supply.

Indirect potable reuse refers to projects that discharge recycled water to a water body before reuse. Direct potable reuse is the use of recycled water for drinking purposes directly after treatment. While direct potable reuse has been safely used in Namibia, it is not a generally accepted practice in the US. While numerous successful ground water recharge projects have been operated for many years, planned augmentation of surface water reservoirs has been less common.

However, there are some existing projects and others in the planning stages. For example, since 1978, the upper Occoquan Sewage Authority has been discharging recycled water into a stream above Occoquan Reservoir, a potable water supply source for Fairfax County, Virginia. In San Diego, California, the Water Repurification Project is currently being planned to augment a drinking water reservoir with 20,000 acre-feet per year of advanced treated recycled water.

WASTE AND WATER POLLUTION

When toxic substances enter lakes, streams, rivers, oceans, and other water bodies, they get dissolved or lie suspended in water or get deposited on the bed. This results in the pollution of water whereby the quality of the water deteriorates, affecting aquatic ecosystems. Pollutants can also seep down and affect the groundwater deposits.

The effects of water pollution are not only devastating to people but also to animals, fish, and birds. Polluted water is unsuitable for drinking, recreation, agriculture, and industry. It diminishes the aesthetic quality of lakes and rivers.

More seriously, contaminated water destroys aquatic life and reduces its reproductive ability. Eventually, it is a hazard to human health. Nobody can escape the effects of water pollution.

Importance of Water

Water is our lifeline that bathes us and feeds us. In ancient cultures water represented the very essence of life. The Romans were the first to pipe water into their growing cities, especially with their aqueducts. They also realised that sewage water could cause damage to their people, and needed to be removed from large areas of people. Water has played a role not only in the history of countries, but in religion, mythology, and art.

Water in many religions cleanses the soul through holy water. The water at Lourdes, France is thought by many religions to be sacred water with healing powers. In Egyptian mythology, the Nu was the beginning of everything and represented water. It brought life to their people, but in drought, produced chaos. The water or hydrologic cycle explains interactions between the atmosphere, hydrosphere, and lithosphere. The water or hydrologic cycle is a major driving force on our planet. Water is in constant motion, evaporating into the atmosphere from oceans, lakes, rivers and streams.

When the atmosphere can no longer support the moisture within the clouds, we experience rain, snow, hail, or sleet. Some water is locked in the form of ice at the polar caps and in glaciers. Water melts in the spring, producing run-off, that percolates through the Earth as groundwater (subsurface) or makes its way back to the sea (surface). The oceans contain most of the water, but it is salt water which is unusable by most organisms. Only pure H₂O (water) can interact with organisms. The movement of the oceans also has a direct effect on the atmosphere.

The atmosphere is that envelope of gas that keeps organisms living on this planet. Oceans and atmosphere interact to give us weather. Water provides the Earth with the capacity of supporting life. An organism doesn't have to be told how important water is to their existence. An amphibian knows to lay their eggs in water or else there will be no new born. Even flies know to lay their eggs in fresh water. The only organism that doesn't understand the importance of water is humans, especially in industrialized countries.

Children in those societies turn on the water in a sink and never think about the trouble someone has gone for that "miracle" to occur. Dams, reservoirs, filtering plants, and pipes all bring clean water when the facet is turned on. Sewage water is only mixed with recycled water supplies after the water goes through rigorous cleaning methods. Water borne diseases are any illnesses caused by drinking contaminated water. Diseases can include infection from bacteria (Salmonella), viruses, or by small parasites (Cryptosporidia, Giardia, and Toxoplasma). These organisms and viruses cause diseases like cholera, typhoid fever, malaria, botulism, polio, dysentery, giardia, and hepatitis.

A one of the first symptoms of these diseases is diarrhea, which cause about three million deaths throughout the world. Sewage is sometimes discharged into rivers, where children downstream might be taking a bath or using the water to drink. The simplest treatment method is boiling. Just bring the water to a boil for at least one minute, then allow it to cool. But this is not always effective in heavily chemical polluted water supplies. Without water, organisms could not exist.

Water is a resource that should not be taken for granted. It needs to be conserved, just as we save other valuable resources. Water is one of the weirdest compounds known to humans. The difference between the boiling point and freezing point of water is one of the largest ranges of any compound. It is this span of temperature that mirrors the range of where life can exist, from bacteria to humans. Water also has a very high specific heat, which means that it can absorb or lose much heat before its temperature changes. This is important in maintaining body heat in mammals.

It also takes a lot of energy before vapourization can occur. For this reason, water evaporates slowly from ponds and lakes, where many life forms are dependent on a stable, warm environment. Water is less dense in its solid state than in its liquid state, so that ice floats instead of sinking. This property permits life to develop in polar and subpolar regions where ice floats and allows life to continue living below the surface. If ice were heavier than water, it would sink, and more ice would form on top of it. As a result, all life in the waters would be trapped in the ice in the many areas of the world where it gets cold enough to freeze water.

Resistance of Water to a Disturbance

Water also exhibits viscosity. One can observe the effects of viscosity alongside a stream or river with uniform banks. The water along the banks is nearly still, while the current in the centre may be swift. This resistance between the layers is called viscosity. This property allows smaller fish to live near the shore, while larger fish are able to swim efficiently in strong currents. Viscosity is also responsible for the formation of eddies, creating turbulence that leads to good mixing of air in the water and more uniform distribution of microscopic organisms. Domestic sewage refers to waste water that is discarded from households.

Also referred to as sanitary sewage, such water contains a wide variety of dissolved and suspended impurities. It amounts to a very small fraction of the sewage by weight. But it is large by volume and contains impurities such as organic materials and plant nutrients that tend to rot. The main organic materials are food and vegetable waste, plant nutrient come from chemical soaps, washing powders, *etc.* Domestic sewage is also very likely to contain disease-causing microbes. Thus, disposal of domestic waste water is a significant technical problem.

Industrial Effluents

Waste water from manufacturing or chemical processes in industries contributes to water pollution. Industrial waste water usually contains specific and readily identifiable chemical compounds. During the last fifty years, the number of industries in India has grown rapidly. But water pollution is concentrated within a few subsectors, mainly in the form of toxic wastes and organic pollutants.

Out of this a large portion can be traced to the processing of industrial chemicals and to the food products industry. In fact, a amount of large- and medium-sized industries in the region covered by the Ganga Action Plan do not have adequate effluent treatment facilities. Most of these defaulting industries are sugar mills, distilleries, leather processing industries, and thermal power stations. Most major industries have treatment facilities for industrial effluents. But this is not the case with small-scale industries, which cannot afford enormous investments in pollution control equipment as their profit margin is very slender.

Effects of Run-off Pollution

Rain picks up dirt and silt and carries it into the water. If the dirt and silt settle in the water body, then these sediments prevent sunlight from reaching aquatic plants. If the Sun can't reach the plants, these perish. These sediments also clog fish gills and smother organisms that live on the bottom of the body of the water.

Effects of Oil Pollution and Antifreeze

If oil is spilled on the water, the effects on the ecosystem and the components are harmful. Many animals can be annihilated in case they ingest oil. Oil contaminated prey may be a reason of death for many. If the oil coats the feathers of birds, these may die. Oil and antifreeze makes the water have a foul odour and there is a sticky film on the surface of water that kills animals. Oil is the most harmful pollutant in the water.

Contaminated Ground Water Effects

If contaminated water enters the ground, there may be serious effects. People may become very sick and there is a probability of developing liver or kidney problems and cancer or other illnesses.

Fertilizers and Other Chemicals

Nitrates in drinking water leads to diseases of infants that may lead to their death. Cadmium is a metal in sludge-derived fertilizer. This can be absorbed by crops. When people ingest this, they may cause diarrheal disorders, liver and kidney damage. The inorganic substances like mercury, arsenic and lead are the causes of pollution. Other chemicals can also lead to problems concerning the taste, smell and colour of water. Pesticides, PCBs and PCPs are all poisonous to all sorts of life. Pesticides are used in farming, homes and forestry. PCBs are found as insulators in old electrical transformers. PCPs are found in products like wood preservatives.

Effects of Agricultural Water Pollution

Rain and irrigation water drains off cultivated land that has been fertilized and treated with pesticides, the excess nitrogen and poisons are mixed with it into the water supply. These pesticides are toxic and pollute the water in a different mode. Aquatic plants growth cause deoxygenation of water and annihilate flora and fauna in a stream, lake and river. Fertilizers enhance the growth of bacteria that are in water and increase the concentration of bacteria to hazardous levels.

Effects of Thermal Water Pollution

Machinery in the industries are cooled with water from lakes and rivers. This water reaches the river in a heated state. This water decreases the ability of the aquatic system to hold oxygen and raises the growth of warm water species.

Effects of Heavy Metal Water Pollution

Heavy metals like lead, mercury, iron, cadmium, aluminum and magnesium are present in water sources. If these metals are present in the sediment, these reach the food chain through plants and aquatic animals. This causes heavy metal poisoning in case the level in the water is very high.

AIR POLLUTION

One of the formal definitions of air pollution is as follows— ‘The presence in the atmosphere of one or more contaminants in such quality and for such duration as is injurious, or tends to be injurious, to human health or welfare, animal or plant life.’ It is the contamination of air by the discharge of harmful substances. Air pollution can cause health problems and it can also damage the environment and property. It has caused thinning of the protective ozone layer of the atmosphere, which is leading to climate change. Modernisation and progress have led to air getting more and more polluted over the years. Industries, vehicles, increase in the population, and urbanization are some of the major factors responsible for air pollution. The following industries are among those that emit a great deal of pollutants into the air: thermal power plants, cement, steel, refineries, petro chemicals, and mines. Air pollution results from a variety of causes, not all of which are within human control.

Dust storms in desert areas and smoke from forest fires and grass fires contribute to chemical and particulate pollution of the air. The source of pollution may be in one country but the impact of pollution may be felt elsewhere. The discovery of pesticides in Antarctica, where they have never been used, suggests the extent to which aerial transport can carry pollutants from one place to another.

Sources of Air Pollution

The combustion of gasoline and other hydrocarbon fuels in automobiles, trucks, and jet airplanes produces several primary pollutants: nitrogen oxides,

gaseous hydrocarbons, and carbon monoxide, as well as large quantities of particulates, chiefly lead. In the presence of sunlight, nitrogen oxides combine with hydrocarbons to form a secondary class of pollutants, the photochemical oxidants, among them ozone and the eye-stinging peroxyacetylnitrate (PAN). Nitrogen oxides also react with oxygen in the air to form nitrogen dioxide, a foul-smelling brown gas.

In urban areas like Los Angeles where transportation is the main cause of air pollution, nitrogen dioxide tints the air, blending with other contaminants and the atmospheric water vapour to produce brown smog. Although the use of catalytic converters has reduced smog-producing compounds in motor vehicle exhaust emissions, recent studies have shown that in so doing the converters produce nitrous oxide, which contributes substantially to global warming. Air may be severely polluted not only by transportation but also by the burning of fossil fuels (oil and coal) in generating stations, factories, office buildings, and homes and by the incineration of garbage.

The massive combustion produces tons of ash, soot, and other particulates responsible for the gray smog of cities like New York and Chicago, along with enormous quantities of sulphur oxides (which also may be result from burning coal and oil). These oxides rust iron, damage building stone, decompose nylon, tarnish silver, and kill plants. Air pollution from cities also affects rural areas for many miles downwind. Every industrial process exhibits its own pattern of air pollution.

Petroleum refineries are responsible for extensive hydrocarbon and particulate pollution. Iron and steel mills, metal smelters, pulp and paper mills, chemical plants, cement and asphalt plants—all discharge vast amounts of various particulates. Uninsulated high-voltage power lines ionize the adjacent air, forming ozone and other hazardous pollutants. Airborne pollutants from other sources include insecticides, herbicides, radioactive fallout, and dust from fertilizers, mining operations, and livestock feedlots.

Sources And Major Air Pollutants

Carbon monoxide (CO) is a colourless, odourless gas that is produced by the incomplete burning of carbon-based fuels including petrol, diesel, and wood. It is also produced from the combustion of natural and synthetic products such as cigarettes. It lowers the amount of oxygen that enters our blood. It can slow our reflexes and make us confused and sleepy. Carbon dioxide (CO₂) is the principle greenhouse gas emitted as a result of human activities such as the burning of coal, oil, and natural gases.

Chlorofluorocarbons (CFC) are gases that are released mainly from air-conditioning systems and refrigeration. When released into the air, CFCs rise to the stratosphere, where they come in contact with few other gases, which leads to a reduction of the ozone layer that protects the earth from the harmful ultraviolet rays of the sun. Lead is present in petrol, diesel, lead batteries, paints, hair dye products, *etc.* Lead affects children in particular.

It can cause nervous system damage and digestive problems and, in some cases, cause cancer. Ozone occurs naturally in the upper layers of the atmosphere. This important gas shields the earth from the harmful ultraviolet rays of the sun. However, at the ground level, it is a pollutant with highly toxic effects. Vehicles and industries are the major source of ground-level ozone emissions. Ozone makes our eyes itch, burn, and water. It lowers our resistance to colds and pneumonia. Nitrogen oxide (Nox) causes smog and acid rain. It is produced from burning fuels including petrol, diesel, and coal. Nitrogen oxides can make children susceptible to respiratory diseases in winters.

Suspended particulate matter (SPM) consists of solids in the air in the form of smoke, dust, and vapour that can remain suspended for extended periods and is also the main source of haze which reduces visibility. The finer of these particles, when breathed in, can lodge in our lungs and cause lung damage and respiratory problems. Sulphur dioxide (SO₂) is a gas produced from burning coal, mainly in thermal power plants. Some industrial processes, such as production of paper and smelting of metals, produce sulphur dioxide. It is a major contributor to smog and acid rain. Sulphur dioxide can lead to lung diseases.

Chemical Pollution

In some parts of the world, the bodies of whales and dolphins washing ashore are so highly contaminated that they qualify as toxic waste and have to be specially disposed of.

There are many different sources of chemical pollution, including:

- Domestic sewage
- Industrial discharges
- Seepage from waste sites
- Atmospheric fallout
- Domestic run-off
- Accidents and spills at sea
- Operational discharges from oil rigs
- Mining discharges and
- Agricultural run-off.

Health Effects of Air Pollution

The human health effects of poor air quality are far reaching, but principally affect the body's respiratory system and the cardiovascular system. Individual reactions to air pollutants depend on the type of pollutant a person is exposed to, the degree of exposure, the individual's health status and genetics.

People who exercise outdoors on hot smoggy days increase their exposure to pollutants in the air. The health effects caused by air pollutants may range from subtle biochemical and physiological changes to difficulty breathing, wheezing, coughing and aggravation of existing respiratory and cardiac conditions. These effects can result in increased medication use, increased doctor or emergency room visits, more hospital admissions and even premature death.

- Human Respiratory System
- Human Cardiovascular System
- Heart and Lung Diseases
- Pyramid of Health Effects
- Populations at Risk
- Leading Causes of Hospitalization
- Leading Causes of Death
- Estimating Health Benefits

AIR POLLUTION AND BIOSPHERE

The biosphere is the biological component of earth systems, which also include the lithosphere, hydrosphere, atmosphere and other "spheres". The biosphere includes all living organisms on earth, together with the dead organic matter produced by them. The biosphere concept is common to many scientific disciplines including astronomy, geophysics, geology, hydrology, biogeography and evolution, and is a core concept in ecology, earth science and physical geography.

A key component of earth systems, the biosphere interacts with and exchanges matter and energy with the other spheres, helping to drive the global biogeochemical cycling of carbon, nitrogen, phosphorus, sulphur and other elements. From an ecological point of view, the biosphere is the "global ecosystem", comprising the totality of biodiversity on earth and performing all manner of biological functions, including photosynthesis, respiration, decomposition, nitrogen fixation and denitrification.

The biosphere is dynamic, undergoing strong seasonal cycles in primary productivity and the many biological processes driven by the energy captured by photosynthesis. Seasonal cycles in solar irradiation of the hemispheres is the main driver of this dynamic, especially by its strong effect on terrestrial primary productivity in the temperate and boreal biomes, which essentially cease productivity in the winter time. The biosphere has evolved since the first single-celled organisms originated 3.5 billion years ago under atmospheric conditions resembling those of our neighbouring planets Mars and Venus, which have atmospheres composed primarily of carbon dioxide.

Billions of years of primary production by plants released oxygen from this carbon dioxide and deposited the carbon in sediments, eventually producing the oxygen-rich atmosphere we know today. Free oxygen, both for breathing and in the stratospheric ozone that protects us from harmful UV radiation, has made possible life as we know it while transforming the chemistry of earth systems forever. As a result of long-term interactions between the biosphere and the other earth systems, there is almost no part of the earth's surface that has not been profoundly altered by living organisms. The earth is a living planet, even in terms of its physics and chemistry. A concept related to, but different from, that of the biosphere, is the Gaia hypotheses, which posits that living organisms have and continue to transform earth systems for their own benefit.

HISTORY OF THE BIOSPHERE CONCEPT

The term "biosphere" originated with the geologist Eduard Suess in 1875, who defined it as "the place on earth's surface where life dwells". It is Vernadsky's work that redefined ecology as the science of the biosphere and placed the biosphere concept in its current central position in earth systems science.

AIR QUALITY STANDARDS

This nation-wide programme was initiated in 1984. As on March 31, 1995, the network comprised 290 stations covering over 90 towns/cities distributed over 24 States and 4 Union Territories.

The National Ambient Air Quality Monitoring network is operated through the respective States Pollution Control Boards, the National Environmental Engineering Research Institute, Nagpur and also through the CPCB. The pollutants monitored are Sulphur dioxide, Nitrogen dioxide and Suspended Particulate Matter besides the meteorological parameters, like wind speed and direction, temperature and humidity.

In addition to the three conventional parameters, NEERI monitors special parameters, like Ammonia, Hydrogen Sulphide, Respirable Suspended Particulate Matter and Polyaromatic Hydrocarbons. Based on Annual Mean Concentration of SO_2 , NO_2 and SPM and the Notified Ambient Air Quality Standards, the Ambient Air Quality Status is described in terms of Low, Moderate, High and Critical for Industrial, Residential and mixed use areas of Cities/Towns in different States/UTs.

PRIMARY POLLUTANTS

Describing a primary pollutant, the Environmental Protection Agency states it is "emitted into the atmosphere directly from the source of the pollutant and retains the same chemical form."

The secondary variety forms as a result of chemical reactions that take place after a substance is released into the air. Understanding the characteristics of pollutants as well as how they get into the environment is crucial to understanding the effects.

PARTICULATE MATTER

Encompassing things as varied as dust, ash, smoke, sand and mist, PM or particulates occur both naturally and as the result of human actions. Natural sources include volcanic eruptions, wind-blown dust and wildfires. Anthropogenic source examples are automobiles, industrial processes, wood burning stoves and dust kicked up by construction projects. PM size is measured in microns. The most problematic are particulates 10 microns or less. These are small enough to be inhaled deep into the lungs, causing and aggravating asthma and other breathing disorders.

SULPHUR DIOXIDE

Introduced to the air mainly from the burning of coal, sulphur dioxide is a primary pollutant and the cause of acid rain. Normal water has a pH of about 5.5; SO_2 can reduce this to as low as 4.0. The phenomenon was one of the first recognized primary regional pollutants, as the effects go beyond the cities where the industrial polluting processes are taking place. Acid rain acidifies lakes and streams, and damages trees and soils, among other negative consequences. Direct health effects also include eye, nose and throat irritation as well as headaches, nausea and dizziness.

NITROGEN OXIDES

Burning of fossil fuels is a big contributor to nitrogen oxide pollution. Automobiles and industrial smelting processes are also major culprits. Nitrogen dioxide is common and can at times be seen over cities as a reddish brown gas. The EPA points out that NO_x "reacts with ammonia, moisture, and other compounds to form nitric acid and related particles." These particles contribute to all sorts of respiratory illnesses. Nitrogen is a nutrient, which when introduced in high quantities to water bodies, contributes to increased biochemical oxygen demand and eutrophication, described as the enrichment of water by plant nutrients. Nitrous oxide is a greenhouse gas.

VOLATILE ORGANIC COMPOUNDS

VOCs are extremely reactive organic compounds. Harmful ground-level ozone is made from a reaction between NO_x and VOCs when exposed to sunlight. Other health and environmental problems like VOCs entering aquifers are also a concern. Automobiles, industrial processes, cleaning solvents and paints are some of the leading VOC emitters.

CARBON MONOXIDE

Being odourless, colourless and tasteless makes the highly toxic gas CO extremely dangerous. Sources include incomplete combustion, malfunctioning furnaces, space heaters and fireplaces. According to the University of Virginia Health System, CO not only prevents your body from using oxygen properly, but damages the central nervous system.

WARNING

Carbon monoxide detectors are essential for every building, considering the multitude of potential sources and the inherently dangerous nature of the gas if undetected.

PHOTOCHEMICAL SMOG

Photochemical smog is a unique type of air pollution which is caused by reactions between sunlight and pollutants like hydrocarbons and nitrogen

dioxide. Although photochemical smog is often invisible, it can be extremely harmful, leading to irritations of the respiratory tract and eyes. In regions of the world with high concentrations of photochemical smog, elevated rates of death and respiratory illnesses have been observed. Smog itself is simply airborne pollution which may obscure vision and cause various health conditions. It is caused by small particles of material which become concentrated in the air for a variety of reasons. Commonly, smog is caused by an inversion, in which cool air presses down on a column of warm air, forcing the air to remain stationary. Inversions are notorious in Southern California, where smog can sometimes get so severe that people are warned to stay indoors.

Some of the particulate matter in the air can oxidize very readily when exposed to the UV spectrum. Nitrogen dioxide and various hydrocarbons produced through combustion will interact with sunlight to break down into hazardous chemicals. It doesn't have to be sunny for photochemical smog to form; UV light can also penetrate clouds. The pollutants released through human activity in this situation are known as "primary pollutants," and they include sulphur dioxide, carbon monoxide, and other volatile organic compounds. When these compounds interact with the sun, they form "secondary pollutants" like ozone and additional hydrocarbons. While ozone is an excellent thing in the upper atmosphere, since it protects the delicate environment of the Earth, it is not desired at ground level.

Ozone can be extremely irritating to the respiratory tract, leading to fits of coughing and various medical conditions if exposure is prolonged. The mixture of hazardous pollutants formed by the reaction between UV rays and smog can travel on the wind to rural areas, meaning the photochemical smog does not just impact big cities. Some measures have been taken around the world to reduce photochemical smog.

Tight emissions regulations on vehicles and factories are one such step; many factories must use scrubbers and treatment systems before releasing air from their manufacturing facilities, for example. The use of harmful chemicals is also restricted in some regions of the world, since these chemicals can create photochemical smog. Government agencies also monitor air quality through testing, citing companies which violate the law and issuing warnings when smog levels are dangerous.

SULPHUR DIOXIDE

Sulphur dioxide is the chemical compound with the formula SO_2 . It is produced by volcanoes and in various industrial processes. Since coal and petroleum often contain sulphur compounds, their combustion generates sulphur dioxide unless the sulphur compounds are removed before burning the fuel. Further oxidation of SO_2 , usually in the presence of a catalyst such as NO_2 , forms H_2SO_4 , and thus acid rain. Sulphur dioxide emissions are also a precursor to particulates in the atmosphere. Both of these impacts are cause for concern over the environmental impact of these fuels.

NITROGEN OXIDE

In general chemistry, nitrogen oxide is a term for a couple of different combinations of the elements - nitrogen and oxygen. The two common variants of nitrogen oxide are nitric oxide and nitrogen dioxide respectively, where both have a single nitrogen atom attached to either one or two oxygen atoms. Other kinds of nitrogen-oxygen combinations such as nitrous oxide are also sometimes referred to as a nitrogen oxide. The two kinds of common nitrogen oxides are sometimes notated NO_x, where x represents a variable for the one or two parts of oxygen in the molecule.

A lot of NO_x is produced from combustion in traditional engines, and gets distributed into the atmosphere. Scientists are looking at nitrogen oxide emissions as part of an overall chemical process that changes the air around us, and affects the response of the environment to worsening air quality. One issue in studying atmospheric health is the result of NO_x linking up with a class of chemicals called Volatile Organic Compounds or VOCs. Although manufacturers are trying to limit the commercial applications of VOCs, they are still present in many consumer materials. When NO_x blends with VOCs, it creates ozone.

This can lead to "smog" in the air, and cause health problems for some residents of a particular area where the ozone is excessive. Local and federal agencies are looking at trying to limit the proliferation of nitrogen oxide elements into the atmosphere. The U.S., Environmental Protection Agency has issued a full set of information resources for the effects of nitrogen oxide variations on its web site, for educating the general public on what these chemical elements are, and what they can do. The international Kyoto Protocol that limits certain types of emissions sometimes called "greenhouse gases" is contemplating the inclusion of nitrogen oxides in their list of targeted emissions.

In addition, various studies continue to look at how engines can regulate the production of nitrogen oxide as a by-product of combustion. The gas nitrous oxide is sometimes thrown in with the above molecular types, although it should technically be called dinitrous oxide. This gas is used as a type of limited anesthetic, and as a propellant for some types of consumer products. Other types of nitrogen/oxygen combinations also include two nitrogen atoms. Items like these, such as dinitrous trioxide, are generally unstable and are not commonly found in nature.

CARBON MONOXIDE

Carbon monoxide also called carbonous oxide, is a colourless, odourless and tasteless gas which is slightly lighter than air. It is highly toxic to humans and animals in higher quantities, although it is also produced in normal animal metabolism in low quantities, and is thought to have some normal biological functions. It consists of one carbon atom and one oxygen atom, connected by a covalent double bond and a dative covalent bond.

It is the simplest oxocarbon, and is an anhydride of formic acid. In coordination complexes the carbon monoxide ligand is called carbonyl. Carbon

monoxide is produced from the partial oxidation of carbon-containing compounds; it forms when there is not enough oxygen to produce carbon dioxide such as when operating a stove or an internal combustion engine in an enclosed space. In presence of oxygen, carbon monoxide burns with a blue flame, producing carbon dioxide.

Coal gas, which was widely used before the 1960s for domestic lighting, cooking and heating despite its toxicity, had carbon monoxide as a primary constituent. Some processes in modern technology, such as iron smelting, still produce carbon monoxide as a byproduct. Worldwide, the largest source of carbon monoxide is natural in origin, due to photochemical reactions in the troposphere which generate about 5×10^{12} kilograms per year.

Other natural sources of CO include volcanoes, forest fires, and other forms of combustion. In biology, carbon monoxide is naturally produced by the action of heme oxygenase 1 and 2 on the heme from hemoglobin breakdown. This process produces a certain amount of carboxyhemoglobin in normal persons, even if they do not breathe any carbon monoxide. Following the first report that carbon monoxide is a normal neurotransmitter in 1993, as well as one of three gases that naturally modulate inflammatory responses in the body carbon monoxide has received a great deal of clinical attention as a biological regulator. In many tissues, all three gases are known to act as anti-inflammatories, vasodilators and encouragers of neo-vascular growth. Clinical trials of small amounts of carbon monoxide as a drug, are on-going.

ANTIQUITY OF AIR POLLUTION

Air pollution, particularly in cities, is certainly not a new problem. Back in the Middle Ages the use of coal in cities such as London was beginning to escalate. The problems of poor urban air quality even as early as the end of the 16th century are well documented.

In the UK the Industrial Revolution during the 18th and 19th centuries was based on the use of coal. Industries were often located in towns and cities, and together with the burning of coal in homes for domestic heat, urban air pollution levels often reached very high levels. During foggy conditions, pollution levels escalated and urban smogs were formed. These often brought cities to a halt, disrupting traffic but more dangerously causing death rates to dramatically rise. The effects of this pollution on buildings and vegetation also became obvious. The 1875 Public Health Act contained a smoke abatement area to try and reduce smoke pollution in urban areas.

During the first part of the 20th century, tighter industrial controls lead to a reduction in smog pollution in urban areas. The 1926 Smoke Abatement Act was aimed at reducing smoke emissions from industrial sources, but despite the declining importance of coal as a domestic fuel, pollution from domestic sources remained significant.

The Great London Smog of 1952, which resulted in around 4,000 extra deaths in the city, led to the introduction of the Clean Air Acts of 1956 and 1968. These

introduced smokeless zones in urban areas, with a tall chimney policy to help disperse industrial air pollutants away from built up areas into the atmosphere.

Following the Clean Air Acts, air quality improvements continued throughout the 1970s. Further regulations were introduced through the 1974 Control of Air Pollution Act. This included regulations for the composition of motor fuel and limits for the sulphur content of industrial fuel oil.

However, during the 1980s the number of motor vehicles in urban areas steadily increased and air quality problems associated with motor vehicles became more prevalent. In the early 1980s, the main interest was the effects of lead pollution on human health, but by the late 1980s and early 1990s, the effects of other motor vehicle pollutants became a major concern. The 1990s have seen the occurrence of wintertime and summertime smogs. These are not caused by smoke and sulphur dioxide pollution but by chemical reactions occurring between motor vehicle pollutants and sunlight. These are known as 'photochemical smogs'.

In 1995, the Government passed its Environment Act, requiring the publication of a National Air Quality Strategy to set standards for the regulation of the most common air pollutants. Published in 1997, the National Air Quality Strategy has set commitments for local authorities to achieve new air quality objectives throughout the UK by 2005. It is reviewed periodically.

HUMAN HEALTH

Healthy people do not normally notice any effects from air pollution, except when the pollution is very high. However, people sensitive to pollution, such as asthmatics, and those with heart conditions or lung diseases, may experience distress and other health effects, even at lower levels of pollution. The Government uses an air pollution banding system to describe the potential health impacts of poor air quality. Particulates may be seen as the most critical of all pollutants, and some estimates have suggested that particulates are responsible for up to 10,000 premature deaths in the UK each year.

The extent to which particulates are considered harmful depends largely on their composition. Sea salt, for example, is believed to have a positive effect on health. Man-made sources of particulates, however, are rarely harmless. In towns and cities, these are extensively from diesel vehicle exhausts. The effects of particulate emissions are considered detrimental due to their composition, containing mainly unburned fuel oil and hydrocarbons that are known to be carcinogenic among laboratory animals.

Very fine particulates can penetrate deep into the lung and cause more damage, as opposed to larger particles that may be filtered out through the airways' natural mechanisms. Ozone differs from most pollutants in that it is created as a secondary pollutant by the action of sunlight on volatile organic compounds (VOCs) and oxides of nitrogen. Ozone is a toxic gas that can bring irreversible damage to the respiratory tract and lung tissue if delivered in high quantities. Asthmatics are known to adopt these symptoms more easily.

Nitrogen oxides consist mainly of nitrogen dioxide (NO₂) and nitric oxide (NO). Nitric oxide is more readily emitted to the atmosphere as a primary pollutant, from traffic and power stations, and is often oxidised to nitrogen dioxide following dispersal.

The amount of nitrogen dioxide emitted directly to the atmosphere is relatively small. Nitric oxide is relatively non-toxic, but at high concentrations the health effects include changes to lung function. Nitrogen dioxide, however, is damaging to health, due to its toxicity. Health effects of exposure to nitrogen dioxide include shortness of breath and chest pains.

Transport, tobacco smoke and gas appliances are the major sources of carbon monoxide. Its link with haemoglobin, the oxygen carrying component of the blood stream, forms carboxyhemoglobin (COHb) which can be life-threatening in high doses. The effects of carbon monoxide pollution are more damaging to pregnant women and their foetus. Research into smoking and pregnancy shows that concentrations within the blood stream of unborn infants is as high as 12 per cent, causing retardation of the unborn child's growth and mental development.

A significant proportion of atmospheric lead comes from traffic emissions, due to the lead content in petrol. This has been significantly reduced in recent years but lead is still a serious air pollutant especially to those living near to areas of dense traffic. Damage to the central nervous system, kidneys and brain can result from high concentrations in the blood. Children, however, display vulnerability to the toxic effects of lead at much lower concentrations than for adults. It has been shown that there is a strong link between high lead exposures and impaired intelligence.

Even moderate concentrations of sulphur dioxide may result in a fall in lung function in asthmatics. Tightness in the chest and coughing may also result at higher levels. Sulphur dioxide pollution is considered more harmful when particulate and other pollution concentrations are high. This is known as the "cocktail effect." Some VOCs are quite harmful. Benzene, for example, has been linked with an increase susceptibility to leukaemia, if exposure is maintained over a period of time.

INDOOR AIR POLLUTION

We spend a large part of our lives indoors at home. Keeping the air which we breathe at home clean is therefore of necessary importance, particularly for certain vulnerable members, including babies, children, pregnant women and the unborn babies, the elderly, and those suffering from respiratory or allergic diseases, such as asthma.

In most homes the level of indoor air pollution is very low, because there are controls on the design and construction of buildings. However, if ventilation of rooms is poor, or household appliances are faulty, pollution can build up to levels which may be detrimental to human health. There are many possible sources of air pollutants in the home and indoor air quality can vary widely. DIY work may lead to a temporary increase in indoor pollutants such as volatile

organic compounds (VOCs), during painting or stripping in enclosed spaces, or laying loft insulation. Another significant source of indoor pollution is the burning of fuels in flueless appliances, such as paraffin stoves, portable gas heaters, gas stoves and ovens.

If the appliance is faulty, incomplete combustion may result in the release of carbon monoxide, a highly poisonous gas. Carbon monoxide also builds up when people smoke cigarettes indoors. Dirty homes or houses in disrepair may be a source of dust mite and mould spores. In some parts of the UK, and in other parts of the world, the radioactive gas radon can seep into the house from the underlying geology, and accumulate indoors if ventilation is poor.

Housing and public health legislation exists to help prevent air quality problems arising indoors in the first place. In the majority of homes there is no need for concern over existing levels of pollutants.

INDUSTRY AND POWER GENERATION

Industry and power generation are main sources of sulphur dioxide emissions, a common air pollutant and the precursor for sulphuric acid in acid rain. In the UK power stations and all other types of industry account for 90 per cent of all sulphur dioxide pollution. During the Industrial Revolution industries were often located in urban areas. Following the UK Clean Air Acts in the 1950s and 1960s, and with the decline in heavy industry, few large industries and power stations are located in towns and cities today.

Many large industries are now located in the more rural areas of the UK. Consequently, sulphur dioxide pollution in urban areas has been significantly reduced. The requirement of industries and power stations to disperse waste gases at elevated levels via a stack or chimney has also helped to reduce ground level concentrations of sulphur dioxide.

However, this has significantly expanded the area of pollution dispersal, such that acid deposition is now the main pollution concern attributable to industry and power generation. Power stations contribute significantly to the total emissions of nitrogen oxides in the UK. In 1999, 21 per cent of nitrogen oxides came from this source and a further 13 per cent from other industries, iron and steel and refineries. The major source of nitrogen oxides pollution in the UK is now road transport (44 per cent). Like sulphur dioxide, nitrogen oxides are also converted into acidic compounds when combined with water in the atmosphere, and contribute to acid rain.

LEGISLATION

Ever since air pollution was recognised as a problem, legislators, regulators and governments have tried to control it. As early as 1273 the use of coal was prohibited in London as being “prejudicial to health”. In 1306 the Royal Proclamation prohibited craftsmen from using sea-coal (a soft coal) in their furnaces. Since the beginning of the Industrial Revolution in Britain, numerous Acts have been passed in an attempt to reduce air pollution.

These have included the Railway Clauses Consolidated Act of 1845 (requiring railway engines to consume their own smoke), the Improvement Clauses Act of 1847 (to reduce factory smoke), the Sanitary Act of 1866 (empowering sanitary authorities to take action in cases of smoke nuisances), the Public Health Act of 1875 (containing smoke abatement legislation that has been used to the present day), and the Smoke Abatement Act of 1926. In the aftermath of the Great London Smog of 1952, the Government pass the two Clean Air Acts of 1956 and 1968, which aimed to control domestic sources of smoke pollution by introducing smokeless zones, and control industrial sources of pollution by the use of tall chimneys for waste gas dispersal.

Since the 1970s when the UK joined the European Union, European legislation has been used to control the amount of pollution being emitted by industry, and now increasingly by transport. Over the last 30 years the European Commission has passed a number of EC directives to limit emissions of carbon monoxide, lead, hydrocarbons and smoke emissions from road vehicles, and to set health limits for the common air pollutants, including sulphur dioxide, particulate matter, lead and nitrogen dioxide.

In response to European legislation, the UK Government passed the Environmental Protection Act (1990) and the Environment Act (1995), bringing many smaller emission sources under air pollution control by local authorities for the first time, and providing a new statutory framework for local air quality management. In 1997 the National Air Quality Strategy was published which sets air quality standards and targets for the pollutants of most concern. Many of these targets will need to be met by 2005.

3

Environmental Education and Management

The relationship between environmental education and management presents a dilemma. The dilemma is whether greater emphasis should be placed globally on environmental education (information, the raising of awareness of these issues) or on environmental management (regulating practices, providing the resources to meet objectives, and ensuring norms are respected).

At the heart lies the problem of attributing responsibilities: Responsibility lies either with the people, the residents as individuals, or with society as a facilitating or impeding structure of behaviours and the authorities as establishers of norms and controllers.

However, the dilemma is false since both levels share the responsibilities, and, therefore, both are necessary and complementary. Furthermore, as Corraliza points out, an environmental management that adequately considers the psychological processes involved in the changes of attitude and behaviour required of the residents is in itself a tool for education to advance towards sustainability.

CRITICISMS MADE OF SUSTAINABLE DEVELOPMENT

The concept of sustainable development is not exempt from criticism. One criticism can be summarised in the fact that the Brundtland Report offers only technocratic solutions that in the medium term are not sustainable, whereas the best solutions would preserve the self-sufficiency of the world's regions.

The solution is not provided by growing more but rather by redistributing resources and technology more equitably, respecting the local forms of production adapted to the capacity of the ecosystem. Milbrath identifies the problem as lying within the current system of beliefs of the “dominant social paradigm.” Corson recommends that environmental awareness programmes be intensified while social and political injustices should be reduced.

ENVIRONMENTAL MANAGEMENT AND THE ROLE OF THE PSYCHOLOGIST

Environmental intervention can be defined as any change in the physical structures of a place that, directly or indirectly, causes an alteration in the ecosystem, the social structure, or the social interaction of the population—in other words, an environmental impact (including the natural and built environments). It may be a spontaneous or a planned action. This change might be the result of direct action on the environment and population—whether by strengthening, inhibiting, or altering forms of social relations—that in the final instance will change the forms of interaction with the ecosystem. Every intervention is managed, by action or omission. Thus, management can be conducted with awareness of the environment or by giving priority to other interests and values. *Environmental management* can be defined as the management process that incorporates the values of sustainable development in the corporate aims of the firm or mission of the government agency. EM integrates programmes and practices that respect the environment in a process that seeks to constantly improve its management. Environmental management entails educating, teaching, and motivating both the employees and the community to adopt the values of environmentalism and sustainability. It seeks the development of products and services with the smallest possible impact on the environment.

Moreover, it seeks the highest degree of eco-efficiency and applies the best and cleanest technologies available. It also seeks the reduction of energy consumption and use of raw materials and non-renewable resources, that is, an improvement in efficiency. It places a premium on minimizing waste, recycling, reusing, and eventually disposing unavoidable waste in a way that poses no threat to the environment. EM seeks transparency at all times in its undertakings, with an emphasis on dialogue, participation, and control by the social groups that are directly or indirectly affected and residents in general.

EM requires frameworks and information concerning the initial situation with which it has to deal and the acceptable range of possibilities. Concerning the physical environment, the parameters are usually fixed by specific legislation or by the carrying capacity of an ecosystem that provide guidelines such as those for acceptable levels of carbon dioxide or nitrogen oxide.. The social frameworks are typically much more fuzzy, varied, and determined by the history and the specific context of the place of intervention. Frequently, it is argued that the only valid frame of reference for evaluating a social impact is the community potentially involved.

THE ROLE OF THE ENVIRONMENTAL PSYCHOLOGIST IN EM

No environmental problem, nor any social problem, has just one solution. Such problems have several feasible solutions. The solution chosen depends on the effects sought and the framework that has been established. In this context, the role of the environmental psychologist, in common with that of any other technical expert in environmental intervention or management, is not to make decisions on his or her own. Rather his or her role is to make available to the client (policy maker, industrialist, manager, consultant, trade union, non-governmental organisation NGO, *etc.*) his or her expertise in analysing the reality and proposing actions aimed at meeting the objective proposed (whether intervention for no change or conservation).

The final decision lies with the policy maker, who must draw on the proposals of the technical expert and act in line with a previously established policy and explicit or implicit values and with a thorough technical understanding of the problem that includes a transdisciplinary analysis and construction of proposed solutions. The environmental psychologist in her or his role as a citizen can act as an environmental activist and apply her or his knowledge within this framework.

However, the most typical intervention of the psychologist in EM arises when an environmental policy has already been explicitly established (for example, the National Environmental Protection Act [NEPA] in the United States and the Environmental Action Programmes in the European Union and the legislation derived from these). This context defines various opportunities for professional action that we may classify as four types of organisations working within the field of environmental protection.

- *NGOs, green parties, residents associations, and the like.* Environmental psychologists working within EM might collaborate as experts through organisations that seek environmental change. They might apply their professional expertise in seeking a change in the environmental values, attitudes, and behaviours of residents. Also, environmental psychologists might supervise or place pressure on firms or public institutions to change their environmental policies and even the laws and regulations governing the environment.
- *Environmental consultancy:* In this framework, the psychologist (based on social and psychological background) assesses, evaluates, and proposes environmental actions and strategies linked in most cases with the prototypical tools of environmental management, including environmental impact assessments, environmental auditing, environmental certificates, and so forth. In this context, the psychologist also analyses, proposes, and assesses processes of communication and environmental participation that are always present in EM.
- *A company's environmental department:* In this case the psychologist usually forms part of the human resources management team and is concerned with environmental behaviour, internal processes of

communication, community relations, environmental training, organisational culture, management of organisational change in the introduction of environmental management systems, and so forth.

- *Government agencies:* The work of the environmental psychologist is determined by the three roles played by public administration:
- The government agency is the *responsible body* for the control of firms' environmental action (industrial permits, environmental impact assessment, environmental certificates to companies or their products, *etc.*).
- The governmental body applies *its own environmental management* in those areas over which it has jurisdiction (establishment of environmental policies at the national, regional, and local levels; regional planning; management of natural spaces; energy policy and management of waste; transport; application of a local Agenda 21, *etc.*).
- Yet at the same time, the government agencies are also *organisations* and as such can possess their own environmental management system that has the right to be recognised or accredited (via International Organisation for Standardisation [ISO] 14000, for example).

The interactions between the different levels of responsibility in the processes of intervention and management and between organisations and government agencies. Private firms applying systems of environmental management and the most common tools interact with government agencies insofar as the latter are the relevant bodies exercising control. Yet this interaction, which takes place at the same time as the carrying out of the duties that are specific to each firm or government agency, always depends on the characteristics and specific nature of the place and the culture of the community.

This gives special importance to the individual and social dimensions, areas in which environmental psychology has developed its own background. In any case, as Oskamp warns in referring to R. Miller, social scientists have to be careful not to promise too much or to make hasty recommendations for public policies that oversimplify the problem. Each intervention, each policy, interacts with countless other variables. It is the context of each intervention that allows us to assess success or failure based on the other variables and synergies that are operational.

MANAGEMENT AND ENVIRONMENTAL MANAGEMENT SYSTEMS: THE ISO 14000

An EMS, according to the definition provided by ISO 14000, is that part of the general management system of an organisation comprising the organisational structure, responsibilities, practices, procedures, processes, and resources that determine and dictate the implementation of its environmental policy. The introduction of an EMS within an organisation represents a significant change.

Optimising the technological, productive, and management processes frequently requires the restructuring of the organisation chart, changes in the places of work, a change of habits, establishment of "best practices," and, therefore, the education and training of the personnel.

There are many studies that, for example, following an analysis of environmental management in the chemical industries or the management of forests, conclude that the adoption of environmental management systems should always be based on basic changes in the organisational culture. Furthermore, EMS needs to pay particular attention to strategies of communication and the dissemination of information. EMS requires that all members of the organisation adopt and identify with the values of sustainability, explicit in the establishment of the Environmental Policy, in a public declaration. However, given the nature of these principles, this is not something that can be attained with information alone (what was called “management by instruction”); neither can it be an objective in itself, which can be attained simply by “management of objectives.”

In criticizing the ISO 14000 system, Moxen and Strachan highlight the need to convert it into a system based on wider participation and geared better to establish the objectives. The model of “management by values” would appear to be more closely in line with the proposals of EMS. Management by values is centered more on the development of principles and values than on changes of the organisation chart or on the transmission of technological knowledge. EMS requires the involvement of those responsible for different areas of the organisation as well as of all of the personnel who develop activities with environmental effects. As many of the policies of the EMS must be registered in the *Manual of EM*, they must define the *Environmental Objectives* that should include a commitment to continuous improvement.

Of these objectives, some environmental goals must be defined as detailed performance requirements that must be quantifiable and reachable. The *Environmental Programme* must specify the means to achieve the objectives and the environmental goals. It must include the schedule, the assignment of responsibilities inside the organisation, and the adopted means foreseen to reach the fixed objectives. Finally, the *Programme of Environmental Audits* will settle down to evaluate, in a systematic way, the concordance of the EMS with the environmental policy of the company. Once proved and the effectiveness of the system and the fulfilment of the requirements have settled down in the norm, the next step is to apply for an *Accreditation System*. Obtaining an accreditation implies the recognition of the EMS goodness.

In other words, it means the successful implementation of the organisational structure, operative procedures, monitoring systems to assure the success of the environmental policy and its programme. There are two ways to obtain the accreditation, which have differences between them: the ISO 14000 and the EMAS.

United States law has been in discussion since 2000. In implementing and certifying an EMS, the ISO 14000 norms are the most widely adopted because of their international, rather than regional, nature. However, certain criticisms have been raised and various limitations identified. There is a significant gap between EMS theory and practice. The main obstacles to introduce an EMS are to be encountered within the organisation itself, because it requires internal changes, in addition to the relationships with external partners.

Moreover, the typical practice in the introduction of ISO 14000, because of the dominant organisational culture, encourages risk avoidance, places a premium on tradition and precedent, and discourages originality and creativity. ISO 14000 should be revised to incorporate a real participatory and more flexible system of management. In this sense, Klaver and Jonker say that organisations lag behind society. The shortage of trained personnel and errors in the management of human resources, the high financial costs of the certification systems and the uncertainty of the market profits are some of the main problems that act as obstacles to the introduction of an EMS.

Moreover, positive attitudes towards the environment are not always appropriately transferred to management. Firms have the perception that they do not cause any major environmental impacts, and they believe that customers are indifferent to environmental performance. Customers are the key driver for the adoption of an EMS, but legislation and the regulators are more important drivers for general environmental improvements. A more far-reaching criticism considers that the private nature of some regulatory programmes generates problems for equity, laws, and democracy because of its significant reshaping of domestic and international policy institutions. Despite the obstacles and criticisms, the introduction of an EMS is a step forward compared with the previous situation.

An example of this is that the EMS, designed originally for contaminating industries and those with a high environmental risk, is being extended to other productive sectors and services, including universities. In particular, universities have an amplifying effect since the future technical experts and managers are being trained there. More and more frequently, however, we hear about *integrated management* as a new approach that has put together environmental management systems, quality management, and the management of health and risk prevention at work. This already constitutes a common practice in some leading multinational firms.

ENVIRONMENTAL IMPACT ASSESSMENT

The EIA is the oldest tool for the preventive management of the environment. An EIA is performed on an industry, infrastructure, or service project before the authorisation is given for its construction. An EIA seeks to assess the effects that an industrial plant or service project might have on the environment, human welfare, and the cultural heritage and, where they are deemed necessary, to recommend corrective or preventive measures or compensation.

An EIA is an administrative procedure with a prescriptive nature for the authorisation of any intervention. EIAs are regulated by NEPA in the United States and by Directives 85/337/EEC and 97/11/EC in the European Union. In Wathern acts from all regions and their enforcement are reviewed. A distinction should be drawn between the environmental impact study and the environmental impact assessment. An EIS is the report produced following the analysis, detection, and description of the foreseeable effects linked or potentially linked

to the installation or service project and should include proposals to minimize these effects. The study should accompany the project that is to undergo the assessment. The EIA is the global decision process that the official agencies must apply in examining the project and the study of the environmental impact. The corresponding agency will undertake to make an environmental impact statement, will grant or refuse to grant its authorisation for the construction of the project, and if necessary will increase the preventive or compensatory measures. There are many methods for conducting an environmental impact study, but relatively few are sensitive enough to detect and assess social impacts. In a review of 110 studies subjected to EIAs in the United Kingdom, Glasson and Heaney found that social and economic impacts were considered in less than half of the projects, and this despite the fact that legislation usually considers, in an explicit manner, the effects on people and communities.

The main problem impeding the integration of human and social aspects in the studies of environmental impact is that the techniques employed for so doing have been found to be lacking in efficiency for social aspects. However, many methods have been proposed to do just this. Moreno and Pol briefly outline more than 40 different methods for social impact studies. One of the main difficulties affecting the techniques and methods employed is the definition of the aspects that should be taken into consideration.

The Interorganisational Committee on Guidelines and Principles for Social Impact Assessment in the United States lays down the guidelines as to what the social component of an EIA should contain. It defines *social impact* as the consequences for human populations of any action, either public or private, that alters the way in which people live, work, behave, relate to each other, and organise themselves to satisfy their needs and in general how they behave as members of society.

It presents a series of items for inclusion as well as the steps to take in drawing up an environmental impact study. Thus, a social impact study should be concerned with: land use and the resources available to the community, the provision of essential services and how they might be affected, the impact on employment opportunities, the distribution of costs and profits, social relations, the quality of life, the subjective meanings that spaces might have, resources, and the effects that intervention might have. SISs have used *network systems and matrices*; methods of *numerical orientation*; *methods based on indicators and indices*; *checklists and questionnaires* and *methods of qualitative and participative orientation*. Another methodological revision and contribution on SIS may be found in the work of Finsterbusch and his team.

Useful tools, although complementary are the cartographic systems and computerised geographical information system that allow simulation models to be devised. Some local and national government agencies allow databases to be consulted in GIS format. For example, the Miramon project offers a large quantity of geographical information as well as data about human land uses of a small region, Catalonia, in Europe. On a larger scale, the Environmental

Information Management System of the U.S. Environmental Protection Agency offers descriptive information, databases, projects, and spatial data. Environmental psychology has recorded significant experiences in its history such as the development of the environmental simulator at the University of California, Berkeley, directed at the beginning of the 1970s by Appleyard and Craik. A multimethod approach combining various forms of recording and processing data.

Flexible in its nature and adaptable to each social reality and project, it uses checklists, qualitative methods, indicators, and indexes in a format that is compatible with the technological and ecological dimensions of the EIA. The DIS/BCN includes a manual for conducting an initial social inventory and a protocol for detecting, assessing, and systematising social, cultural, and economic aspects susceptible to the effects of an intervention. It also includes a theoretical framework for the analysis and interpretation of its parameters and categories.

LIFE CYCLE ASSESSMENTS AND ECO-LABELS

A life cycle assessment is a management tool for evaluating specific products rather than the overall activity of an organisation. Its purpose is to evaluate and reduce the environmental impacts associated actually and potentially with the product while it is still in the design phase. It seeks to reduce consumption of raw materials and the impacts associated with their extraction and transport, substituting them with the subproducts of other industrial processes or recycling used products. It seeks to reduce and optimise the consumption of energy in the phases of industrial production and use of the product. It aims to reduce the volume and toxicity of the wastes produced.

Like the various national regulations, LCAs are standardised by ISO 14040. The human and social dimension of the LCA is linked in particular to the uses (those that are foreseen in the design stage as well as those that are not) to which the consumer puts the product and the adequate and inadequate forms of disposal and/or elimination that is made of it. It should be borne in mind that there is a certain tendency towards the reuse of products (often out of a simple economic necessity and sometimes as a result of environmental awareness). The use of the product for secondary purposes not originally foreseen in its design is not always desirable and can have major environmental impacts. It is necessary to draw up a catalogue of possible secondary functions and uses and of eventual ways of disposal that should be avoided.

The role of the environmental psychologist in this case is to analyse, explain, and predict the uses and processes that intervene between the person and the product. The practical application of the LCA that follows the standards of ISO 14042 has been criticized for being biased towards the natural sciences, promoting corporate secrecy about emissions, and inhibiting or distorting innovation in LCA methods. Weidema argues for the need to understand the public's perception of a product's environmental impact and points out the uncertainties related with the product, the type of substitutions to which it will

give rise in the market, and the habits that will undergo a change with the substitution of one product for another, and so forth—none of which is not easily obtained from quantitative data. Among other aims linked to eco-efficiency, the LCA is associated with the granting of eco-labels to identify those products that are environmentally friendly. The eco-labels are regulated by ISO 14020 and the specific laws of each country.

ENVIRONMENTAL MANAGEMENT

Environmental management is not, as the phrase could suggest, the management of the *environment* as such, but rather the management of interaction by the modern human societies with, and impact upon the environment. The three main issues that affect managers are those involving politics (networking), programmes (projects), and resources (money, facilities, *etc.*). The need for environmental management can be viewed from a variety of perspectives. A more common philosophy and impetus behind environmental management is the concept of carrying capacity. Simply put, carrying capacity refers to the maximum number of organisms a particular resource can sustain.

The concept of carrying capacity, whilst understood by many cultures over history, has its roots in Malthusian theory. Environmental management is therefore not the conservation of the environment solely for the environment's sake, but rather the conservation of the environment for humankind's sake. This element of sustainable exploitation, getting the most out of natural assets, is visible in the EU Water Framework Directive. Environmental management involves the management of all components of the bio-physical environment, both living (biotic) and non-living (abiotic). This is due to the interconnected and network of relationships amongst all living species and their habitats. The environment also involves the relationships of the human environment, such as the social, cultural and economic environment with the bio-physical environment.

As with all management functions, effective management tools, standards and systems are required. An 'environmental management standard or system or protocol attempts to reduce environmental impact as measured by some objective criteria. The ISO 14001 standard is the most widely used standard for environmental risk management and is closely aligned to the European Eco-Management and Audit Scheme (EMAS). As a common auditing standard, the ISO 19011 standard explains how to combine this with quality management.

APPROACH TO STUDYING ENVIRONMENTAL MANAGEMENT

A fruitful approach to studying environmental management is the analysis of industry-government relationships. Policy is defined and translated into action in this context. We find that industrial managers legitimize government regulation of industrial water use. However, the pattern of responses suggests that some of

the support may be based on economic self-interest and industry's ability to control agency action. Managers legitimize a policy-setting role for federal agencies and an enforcement role for local and state government. Across the Asian region, natural resource exploitation is accelerating dramatically as countries, cities and small communities are ever more incorporated into the global economy.

Economic reform programmes that favour domestic and global market expansion rather than a social welfare agenda, policy responses to climate change, pressures associated with population growth and intensified geographical mobility, and urbanization and commoditization, are reconfiguring patterns of natural resource use and governance at both a national and local level and are having complex effects on peoples' lives. These processes are themselves not innocent of gendered power relations: they are inflected with gender discourses that set in motion differentiated and unjust life opportunities and exclusions.

At the same time, sustainable development policy initiatives that seek to ameliorate environmental degradation and its negative livelihood effects not only bring gendered impacts and responses, they also work through and produce particular framings of gender and gendered power relations. The impact of this is apparent in the unintended consequences associated with sustainable development initiatives that target women as a homogeneous and undifferentiated social category, at times exacerbating social and gender injustices. Related to this process of globalized marketization, natural resource management is embedded in the increasing diversification of livelihoods: a process buoyed by policies that support entrepreneurialism and appear to be producing individualized portfolio livelihood strategies across Asia.

ENVIRONMENTAL IMPACT OF SCIENCE AND TECHNOLOGY

The life support systems and non-renewable resources on the Earth are being decimated by a burgeoning population which possesses unprecedented power born of science and technology. The impact of technology on the environment has in many ways been devastating. Yet science and technology have also been the greatest forces for beneficent social change in human history and will continue to be needed to solve the economic and social problems of the future. Since the future lies in the hands of our youth we must educate them to cope with its environmental problems.

The damage already done to the environment is so great that all education and especially education in science must become imbued with an environmental ethic to reverse the present trend. It is noticed that the solution does not lie in adding environmental ethics courses to the science curriculum but in finding ways to allow ecological and environmental concerns to permeate existing courses and textbooks. This could have the added advantage of making them more relevant and interesting. The environmental ethic must guide all aspects of our lives and will also have to be taught by example outside of formal

education. “How, should the science curriculum be structured and science teaching organized so as to give insights into the ecological and environmental impact of technology in modern society and instill in young people a feeling of global responsibility?” This is the charge to which this chapter is addressed.

In response we shall consider the ecological problems that confront humanity and how they are related to science and technology. We will give some examples of how to incorporate environmental concerns into basic science courses to achieve not only an awareness of the impact of science and technology but also a motivation on the part of young people to participate in revitalizing the Earth’s environment. Introduction of the environmental dimension could, at the very least, make science courses more relevant and interesting.

The Problem: an Earth in Crisis

It has been noticed that the environment is in crisis. All around us it is suffocating and crumbling under the impact of human action. The Worldwatch Institute states: “Our generation is the first to be faced with decisions that will determine whether the Earth our children inherit will be habitable.

Recital of the major trends has become a litany: the altering of the Earth’s asphere by the burning of fossil fuels, the destruction of the protective ozone layer by man-made chemicals, the depletion of tropical rain forests, the extinction of plant and animal species, the spread of deserts, the acid poisoning of lakes and forests, the toxification of air, soil and water and the continuing nuclear threat. Concern for the Earth, which found massive expression in the first Earth Day 20 years ago, has been raised to a new level of public awareness by the media.

To cite just two examples, Time magazine recently broke from its tradition of celebrating a—Man of the Year— by choosing instead the Earth as—Planet of the Year— and—National Geographic— devoted its last issue in 1988 to the topic of mending the Earth. Its cover was a hologram showing the Earth both whole and shatred.

During the past 20 years countless individuals and organizations, large and small, have worked quietly and incessantly towards conservation and ecological sanity to bring about a heightened interest in and concern for a life-sustaining Earth.

Our task as science educators is twofold. One is to clarify the role that science and technology have had in disrupting the Earth’s ability to sustain life and the other is to motivate students to use their knowledge, including that of science and technology, to restore the Earth’s environment.

Four Related Problems

It now seems clear that the disruption of the ecological balance in the biosphere is due to the impact of—homo sapiens—the culprit species. All the trends mentioned have their origin in human activities. It is no wonder, then, that most of them are exacerbated by the explosive growth of human populations.

A child born today has 5,000 million neighbours. At age 35 they will, according to present projections, number about 10,000 million and close to 20,000 million at age 70. The burgeoning population problem is probably the most serious of the four so-called Ps:—population, pollution, poverty— and the—proliferation— of weapons of mass destruction-chemical, biological and nuclear. A not unique example of the interaction of the first three is to be found in Mexico.

The close to 20 million population of Mexico City, exceeding that of the entire continent of Australia, has a fossil fuel pollution problem that often turns day into night and poverty which belies the fact that Mexico is rich in natural resources. The proliferation of weapons of mass destruction also poses a serious threat to the biosphere. A nuclear holocaust must, of course, be avoided at all costs inasmuch as it represents the ultimate environmental catastrophe but the other weapons of mass destruction-chemical and biological-also pose massive environmental threats. It seems ironic that these weapons bear the imprint and the titles of the three basic sciences: physics, chemistry and biology.

Even preparations for conventional war leave ecological scars on the Earth. In a Sierra Club publication titled—Air, Water, Earth, Fire-The Impact of the Military on World Environmental Order—it says: “We should have been alarmed long ago.

It is a sad commentary on our powers of foresight that we did not understand sooner that the shadow of Armageddon hovers over mankind.” The list of problems could easily be extended beyond the four Ps but they give us a easily remembered combination of environmentally related global woes and their common characteristics: they are all interrelated, they all have an impact on the environment and they all tend to deteriorate the quality of life. In varying degrees they are the byproducts of technology.

4

Elements of Environmental Education

The following is a comprehensive list of elements of the environment that are authorized by the State Environmental Policy Act for potential analysis in an environmental impact statement. The first major step in the EIS process is Scoping. The intent of Scoping is to create a concise EIS that only addresses the key environmental issues. The purpose of scoping, as outlined in the SEPA regulations, is to narrow the focus of the EIS to just address "probable significant adverse impacts and reasonable alternatives."

Preliminary review of the North/East Cities Regional Municipal Jail proposal and alternatives indicates that those environmental elements highlighted below could be considered for analysis in the Draft EIS. After reviewing comments received during Scoping, the Lead Agency will determine the final scope of the EIS.

Earth:

- Geology
- Soils
- Topography
- Unique physical features
- Erosion/enlargement of land area

Air:

- Air quality
- Odour
- Climate

Water:

- Surface water movement/quantity/quality
- Run-off/absorption

- Floods
- Groundwater movement-quantity/quality
- Public water supplies

Plants and Animals:

- Habitat for/numbers of/diversity of species
- Unique species
- Fish or wildlife migration routes

Energy and Natural Resources:

- Amount required/rate of use/efficiency
- Source/availability
- Non-renewable resources
- Conservation and renewable resources

Environmental Health:

- Noise
- Risk of explosion
- Releases or potential releases to the environment affecting public health

Land and Shoreline Use:

- Land use patterns
- Relationship to existing land use plans, policies, and regulations

Population and Housing:

- Population
- Housing

Light and Glare:

- Light
- Glare

Aesthetics:

- Aesthetics

Recreation:

- Recreation

HISTORIC AND CULTURAL PRESERVATION

- Historic resources
- Cultural resources

Agricultural Crops:

- Agricultural crops

Transportation:

- Transportation systems
- Vehicular trips
- Waterborne, rail, and air traffic
- Parking
- Movement/circulation of people or goods
- Traffic hazards

Public Services and Utilities:

- Fire
- Police

- Schools
- Parks or other recreational facilities
- Maintenance
- Communications
- Water
- Stormwater
- Sewer
- Solid waste
- Other governmental services or utilities

ATMOSPHERE

The atmosphere of Earth is a layer of gases surrounding the planet Earth that is retained by Earth's gravity. The atmosphere protects life on Earth by absorbing ultraviolet solar radiation, warming the surface through heat retention, and reducing temperature extremes between day and night. Dry air contains roughly 78.09 per cent nitrogen, 20.95 per cent oxygen, 0.93 per cent argon, 0.039 per cent carbon dioxide, and small amounts of other gases.

Air also contains a variable amount of water vapour, on average around 1 per cent. The atmosphere has a mass of about 5×10^{18} kg, three quarters of which is within about 11 km of the surface. The atmosphere becomes thinner and thinner with increasing altitude, with no definite boundary between the atmosphere and outer space. An altitude of 120 km is where atmospheric effects become noticeable during atmospheric reentry of spacecraft. The Kármán line, at 100 km also is often regarded as the boundary between atmosphere and outer space.

Composition

Air is mainly composed of nitrogen, oxygen, and argon, which together constitute the major gases of the atmosphere. The remaining gases are often referred to as trace gases, among which are the greenhouse gases such as water vapour, carbon dioxide, methane, nitrous oxide, and ozone. Filtered air includes trace amounts of many other chemical compounds. Many natural substances may be present in tiny amounts in an unfiltered air sample, including dust, pollen and spores, sea spray, and volcanic ash. Various industrial pollutants also may be present, such as chlorine, fluorine compounds, elemental mercury, and sulphur compounds such as sulphur dioxide.

Table. Composition of Dry Atmosphere, by Volume.

Gas	Volume
Nitrogen (N ₂)	780,840 ppmv (78.084%)
Oxygen (O ₂)	209,460 ppmv (20.946%)
Argon (Ar)	9,340 ppmv (0.9340%)
Carbon dioxide (CO ₂)	390 ppmv (0.039%)
Neon (Ne)	18.18 ppmv (0.001818%)

Helium (He)	5.24 ppmv (0.000524%)
Methane (CH ₄)	1.79 ppmv (0.000179%)
Krypton (Kr)	1.14 ppmv (0.000114%)
Hydrogen (H ₂)	0.55 ppmv (0.000055%)
Nitrous oxide (N ₂ O)	0.3 ppmv (0.00003%)
Carbon monoxide (CO)	0.1 ppmv (0.00001%)
Xenon (Xe)	0.09 ppmv ($9 \times 10^{-6}\%$) (0.000009%)
Ozone (O ₃)	0.0 to 0.07 ppmv (0 to $7 \times 10^{-6}\%$)
Nitrogen dioxide (NO ₂)	0.02 ppmv ($2 \times 10^{-6}\%$) (0.000002%)
Iodine (I)	0.01 ppmv ($1 \times 10^{-6}\%$) (0.000001%)
Ammonia (NH ₃)	Trace
Not included in above dry atmosphere:	
Water vapour (H ₂ O)	~0.40% over full atmosphere, typically 1%-4% at surface

STRUCTURE OF THE ATMOSPHERE

Principal Layers

Earth's atmosphere can be divided into five main layers. These layers are mainly determined by whether temperature increases or decreases with altitude.

From highest to lowest, these layers are:

- **Exosphere:** The outermost layer of Earth's atmosphere extends from the exobase upward. Here the particles are so far apart that they can travel hundreds of kilometres without colliding with one another. Since the particles rarely collide, the atmosphere no longer behaves like a fluid. These free-moving particles follow ballistic trajectories and may migrate into and out of the magnetosphere or the solar wind. The exosphere is mainly composed of hydrogen and helium.
- **Thermosphere:** Temperature increases with height in the thermosphere from the mesopause up to the thermopause, then is constant with height. The temperature of this layer can rise to 1,500 °C, though the gas molecules are so far apart that temperature in the usual sense is not well defined. The International Space Station orbits in this layer, between 320 and 380 km. The top of the thermosphere is the bottom of the exosphere, called the exobase. Its height varies with solar activity and ranges from about 350-800 km.
- **Mesosphere:** The mesosphere extends from the stratopause to 80-85 km. It is the layer where most meteors burn up upon entering the atmosphere. Temperature decreases with height in the mesosphere. The mesopause, the temperature minimum that marks the top of the mesosphere, is the coldest place on Earth and has an average temperature around -85 °C. Due to the cold temperature of the

mesosphere, water vapour is frozen, forming ice clouds. A type of lightning referred to as either sprites or ELVES, form many miles above thunderclouds in the troposphere.

- *Stratosphere*: The stratosphere extends from the tropopause to about 51 km. Temperature increases with height, which restricts turbulence and mixing. The stratopause, which is the boundary between the stratosphere and mesosphere, typically is at 50 to 55 km. The pressure here is 1/1000th sea level.
- *Troposphere*: The troposphere begins at the surface and extends to between 7 km at the poles and 17 km at the equator, with some variation due to weather. The troposphere is mostly heated by transfer of energy from the surface, so on average the lowest part of the troposphere is warmest and temperature decreases with altitude. This promotes vertical mixing. The troposphere contains roughly 80 per cent of the mass of the atmosphere. The tropopause is the boundary between the troposphere and stratosphere.

Other Layers

Within the five principal layers determined by temperature are several layers determined by other properties:

- The ozone layer is contained within the stratosphere. In this layer ozone concentrations are about 2 to 8 parts per million, which is much higher than in the lower atmosphere but still very small compared to the main components of the atmosphere. It is mainly located in the lower portion of the stratosphere from about 15-35 km, though the thickness varies seasonally and geographically. About 90 per cent of the ozone in our atmosphere is contained in the stratosphere.
- The ionosphere, the part of the atmosphere that is ionized by solar radiation, stretches from 50 to 1,000 km and typically overlaps both the exosphere and the thermosphere. It forms the inner edge of the magnetosphere. It has practical importance because it influences, for example, radio propagation on the Earth. It is responsible for auroras.
- The homosphere and heterosphere are defined by whether the atmospheric gases are well mixed. In the homosphere the chemical composition of the atmosphere does not depend on molecular weight because the gases are mixed by turbulence. The homosphere includes the troposphere, stratosphere, and mesosphere. The turbopause at about 100 km, the composition varies with altitude. This is because the distance that particles can move without colliding with one another is large compared with the size of motions that cause mixing. This allows the gases to stratify by molecular weight, with the heavier ones such as oxygen and nitrogen present only near the bottom of the heterosphere. The upper part of the heterosphere is composed almost completely of hydrogen, the lightest element.

- The planetary boundary layer is the part of the troposphere that is nearest the Earth's surface and is directly affected by it, mainly through turbulent diffusion. During the day the planetary boundary layer usually is well-mixed, while at night it becomes stably stratified with weak or intermittent mixing. The depth of the planetary boundary layer ranges from as little as about 100 m on clear, calm nights to 3000 m or more during the afternoon in dry regions.

The average temperature of the atmosphere at the surface of Earth is 14 °C or 15 °C, depending on the reference.

PHYSICAL PROPERTIES

Pressure and Thickness

The average atmospheric pressure at sea level is about 1 atmosphere (atm) = 101.3 kPa (kilopascals) = 14.7 psi (pounds per square inch) = 760 torr = 29.9 inches of mercury (symbol Hg). Total atmospheric mass is 5.1480×10^{18} kg (1.135×10^{19} lb), about 2.5 per cent less than would be inferred naively from the average sea level pressure and the Earth's area of 51007.2 megahectares, this defect having been displaced by the Earth's mountainous terrain. Atmospheric pressure is the total weight of the air above unit area at the point where the pressure is measured.

Thus air pressure varies with location and time, because the amount of air above the Earth's surface varies.

If atmospheric density were to remain constant with height the atmosphere would terminate abruptly at 8.50 km. Instead, density decreases with height, dropping by 50 per cent at an altitude of about 5.6 km. As a result the pressure decrease is approximately exponential with height, so that pressure decreases by a factor of two approximately every 5.6 km and by a factor of $e = 2.718...$ approximately every 7.64 km, the latter being the average scale height of Earth's atmosphere below 70 km.

However, because of changes in temperature, average molecular weight, and gravity throughout the atmospheric column, the dependence of atmospheric pressure on altitude is modeled by separate equations. Even in the exosphere, the atmosphere is still present. This can be seen by the effects of atmospheric drag on satellites.

However, the following published data are given for reference:

- 50 per cent of the atmosphere by mass is below an altitude of 5.6 km.
- 90 per cent of the atmosphere by mass is below an altitude of 16 km. The common altitude of commercial airliners is about 10 km and Mt. Everest's summit is 8,848 m above sea level.
- 99.99997 per cent of the atmosphere by mass is below 100 km, although in the rarefied region above this there are auroras and other atmospheric effects. The highest X-15 plane flight in 1963 reached an altitude of 108.0 km.

Density and Mass

The density of air at sea level is about 1.2 kg/m^3 . Density is not measured directly but is calculated from measurements of temperature, pressure and humidity using the equation of state for air. Atmospheric density decreases as the altitude increases. This variation can be approximately modeled using the barometric formula. More sophisticated models are used to predict orbital decay of satellites.

The average mass of the atmosphere is about 5 quadrillion tonnes or $1/1,200,000$ the mass of Earth. According to the National Centre for Atmospheric Research, "The total mean mass of the atmosphere is $5.1480 \times 10^{18} \text{ kg}$ with an annual range due to water vapour of 1.2 or $1.5 \times 10^{15} \text{ kg}$ depending on whether surface pressure or water vapour data are used; somewhat smaller than the previous estimate. The mean mass of water vapour is estimated as $1.27 \times 10^{16} \text{ kg}$ and the dry air mass as $5.1352 \pm 0.0003 \times 10^{18} \text{ kg}$."

Optical Properties

Solar radiation is the energy the Earth receives from the Sun. The Earth also emits radiation back into space, but at longer wavelengths that we cannot see. Part of the incoming and emitted radiation is absorbed or reflected by the atmosphere.

Scattering

When light passes through our atmosphere, photons interact with it through scattering. If the light does not interact with the atmosphere, it is called direct radiation and is what you see if you were to look directly at the Sun. Indirect radiation is light that has been scattered in the atmosphere. For example, on an overcast day when you cannot see your shadow there is no direct radiation reaching you, it has all been scattered. As another example, due to a phenomenon called Rayleigh scattering, shorter wavelengths scatter more easily than longer wavelengths.

This is why the sky looks blue, you are seeing scattered blue light. This is also why sunsets are red. Because the Sun is close to the horizon, the Sun's rays pass through more atmosphere than normal to reach your eye. Much of the blue light has been scattered out, leaving the red light in a sunset.

Absorption

Different molecules absorb different wavelengths of radiation. For example, O_2 and O_3 absorb almost all wavelengths shorter than 300 nanometres. Water absorbs many wavelengths above 700 nm. When a molecule absorbs a photon, it increases the energy of the molecule. We can think of this as heating the atmosphere, but the atmosphere also cools by emitting radiation. The combined absorption spectra of the gases in the atmosphere leave "windows" of low opacity, allowing the transmission of only certain bands of light. The optical window

runs from around 300 nm up into the range humans can see, the visible spectrum, at roughly 400-700 nm and continues to the infrared to around 1100 nm. There are also infrared and radio windows that transmit some infrared and radio waves at longer wavelengths. For example, the radio window runs from about one centimetre to about eleven-metre waves.

Emission

Emission is the opposite of absorption, it is when an object emits radiation. Objects tend to emit amounts and wavelengths of radiation depending on their "black body" emission curves, therefore hotter objects tend to emit more radiation, with shorter wavelengths. Colder objects emit less radiation, with longer wavelengths. For example, the Sun is approximately 6,000 K, its radiation peaks near 500 nm, and is visible to the human eye.

The Earth is approximately 290 K, so its radiation peaks near 10,000 nm, and is much too long to be visible to humans. Because of its temperature, the atmosphere emits infrared radiation. For example, on clear nights the Earth's surface cools down faster than on cloudy nights. This is because clouds are strong absorbers and emitters of infrared radiation. This is also why it becomes colder at night at higher elevations. The atmosphere acts as a "blanket" to limit the amount of radiation the Earth loses into space.

The greenhouse effect is directly related to this absorption and emission effect. Some chemicals in the atmosphere absorb and emit infrared radiation, but do not interact with sunlight in the visible spectrum. Common examples of these chemicals are CO₂ and H₂O. If there are too much of these greenhouse gases, sunlight heats the Earth's surface, but the gases block the infrared radiation from exiting back to space. This imbalance causes the Earth to warm, and thus climate change.

Refractive Index

The refractive index of air is close to, but just greater than 1. Systematic variations in refractive index can lead to the bending of light rays over long optical paths. One example is that, under some circumstances, observers onboard ships can see other vessels just over the horizon because light is refracted in the same direction as the curvature of the Earth's surface. The refractive index of air depends on temperature, giving rise to refraction effects when the temperature gradient is large. An example of such effects is the mirage.

Circulation

Atmospheric circulation is the large-scale movement of air, and the means by which heat is distributed around the Earth. The large-scale structure of the atmospheric circulation varies from year to year, but the basic structure remains fairly constant as it is determined by the Earth's rotation rate and the difference in solar radiation between the equator and poles.

ENVIRONMENTAL LITERACY

Roth (1992) noted that it was fitting that the term environmental illiteracy predated the term environmental literacy, in the same way that the term illiteracy predated the term literacy. Notably, Roth was referring to his original attempt to define environmental literacy in a 1968 issue of the *Massachusetts Audubon*, written in response to the frequent media references to “environmental illiterates,” who were accused of polluting the environment.

The widespread public awareness of and concern about environmental issues at that time is often attributed to the work of the distinguished naturalist and nature writer, Rachel Carson (e.g., Nash 1990, de Steiguer 1997, Rothman 1998). In 1960, Carson published a series of articles in *The New Yorker* concerning the effects of chemical insecticides on the balance of nature, which led to her best-selling publication, *Silent Spring*. Carson (1962) cataloged the impacts of the indiscriminate spraying of DDT in the United States and questioned the logic of releasing large amounts of chemicals into the environment without fully understanding their effects. As part of the legacy of *Silent Spring*, the public began to express their uneasiness, suspicion, and even outright hostility with respect to the nation’s unthinking allegiance to progress (Rothman 1998). Environmental illiteracy was no longer acceptable. It was in this charged atmosphere that Roth (1968) posed the question: “How shall we know the environmentally literate citizen?” Shortly thereafter, the article was reprinted in the *New York Times* (Faust 1969), yet it received relatively little more attention until a year later when the term environmental literacy appeared in several speeches by President Nixon, relating to the passage of the first National Environmental Education Act in 1970 (Roth 1992). As time passed, the term was used more and more frequently within the field of environmental education. Although the first National Environmental Education Act was not signed into law until 1970, environmental education emerged as a distinct field in the mid-1960s (Braus and Disinger 1998). With its primary antecedents in nature study, conservation education, and outdoor education, environmental education arose as a complex and vibrant field of practice and inquiry into the meanings, problems, and potentials of human-environment relationships, and the role of education in this respect.

The rise of the nature study, conservation education, and outdoor education movements largely reflected the socio-political environment of their time (Braus and Disinger 1998). Beginning in the late 1800s, nature study emerged as a means of providing opportunities for the appreciation and discovery of nature in response to the shift from a mainly agrarian to a more industrial society in which students were no longer spending their childhood in natural settings. In the 1930s, conservation education grew out of concerns about poor natural resource management, as reflected by the Great Dust Bowl, and focused on the importance of conserving soil, water, and other natural resources. In the 1950s, outdoor education emerged out of concern that urban youth were not experiencing direct contact with the outdoor environment; it encouraged the

teaching of all subjects outdoors, often using residential camps. By the late 1960s, public awareness of environmental issues had become widespread, and environmental education, with a focus on the social aspects of environmental problems, emerged.

Numerous scholarly reviews have highlighted the fact that, despite a common concern for the environment and human-environment relationships and a shared recognition of the role of education in this respect, the field of environmental education continues to be advanced via widely differing theoretical, pedagogical, and research perspectives (*e.g.*, Robottom and Hart 1993, Disinger 1998, Hart and Nolan 1999, Sauvé 1999, Rickinson 2001, Ramsey and Hungerford 2002, Russel and Hart 2003, Disinger 2005, Robottom 2005, Sauvé 2005, Smyth 2006). While originally focused on increasing public awareness of the environmental damage caused by humans, particularly in terms of pollution, environmental education has since evolved into a rich, complex and vast pedagogical landscape, encompassing numerous distinct currents of intervention, each with different objectives, teaching approaches, and strategies (Sauvé 2005).

While developing a consensus set of goals for environmental education continues to be a topic of spirited discourse and debate, many previous and current leaders in the field have identified environmental literacy as the primary goal of environmental education. The goal of environmental literacy was advanced in the *Belgrade Charter* by the United Nations Educational, Scientific, and Cultural Organization and the United Nations Environment Programme (UNESCO-UNEP 1976) and the *Tbilisi Declaration* (UNESCO 1978), which are considered the official founding documents of the environmental education field. The *Belgrade Charter*, the product of the first international conference on environmental education held in former Yugoslavia in 1975, outlined some of the basic structure and aims of environmental education worldwide, and provided a widely accepted goal statement for environmental education:

“The goal of environmental education is to develop a world population that is aware of and concerned about, the environment and its associated problems, and which has the knowledge, skills, attitudes, motivations, and commitment to work individually and collectively towards solutions of current problems and the prevention of new ones (UNESCO 1976: 1).

In 1977, the *Belgrade Charter* was further refined at the Intergovernmental Conference on Environmental Education, held in Tbilisi, Republic of Georgia. The *Tbilisi Declaration* defined three goals as the basis for environmental education (UNESCO 1978: 2): (1) to foster a clear awareness of, and concern about, economic, social, political and ecological interdependence in urban and rural areas; (2) to provide every person with opportunities to acquire the knowledge, values, attitudes, commitment and skills needed to protect and improve the environment; and (3) to create new patterns of behaviour of individuals, groups, and society as a whole towards the environment.

In 1987, ten years after the *Tbilisi Declaration*, an international congress on environmental education was convened in Moscow, USSR, resulting in the

International Strategy for Action on EE and Training for the 1990s. The action strategy focused on environmental problems and the essential principles of and guidelines for environmental education (UNESCO-UNEP 1988). Soon after, UNESCO-UNEP (1989) published *Environmental Literacy for All*, which positioned environmental literacy as the fundamental goal of environmental education and reviewed the numerous environmental education initiatives that were taking place around the world at that time. Yet, efforts to explicitly define and delineate the essential components of environmental literacy, in the form of frameworks, occurred mainly in the United States.

Identifying the *Belgrade Charter* and the *Tblisi Declaration* as its guiding documents, The North American Association for Environmental Education (NAAEE) continues to identify cultivating environmental literacy as the primary goal of environmental education (NAAEE 2004). Like the field of environmental education itself, the term environmental literacy has undergone a lengthy metamorphosis. A driving purpose in the field has been to create a complete and broadly applicable conceptual framework for environmental literacy (*i.e.*, what an environmentally literate person should know and be able to do), allowing for the establishment of guidelines and tools for assessing educational achievement. Since the 1970s, a multitude of new and adapted frameworks, guidelines, and plans for environmental literacy have been put forward by individuals, consortiums, organizations, and states with the primary goal of providing environmental education. Since the 1990s, tremendous efforts have been made across all of these entities to establish a consensus framework to guide educators at the front lines of cultivating environmental literacy in both formal and informal settings (*e.g.*, Simmons 1995, NAAEE 2004).

In 1993, The National Project for Excellence in Environmental Education, sponsored by the NAAEE, was initiated to develop a set of guidelines for high-quality environmental education across the U.S., with the primary purpose of articulating knowledge and skills they viewed as essential for environmental literacy (NAAEE 2004: 1). As part of its goal of reflecting a broadly shared understanding of environmental literacy, NAAEE's *Guidelines for Learning* were developed using the extensive body of existing scholarship in environmental education as its foundation.

NEED FOR PUBLIC AWARENESS

Since our environment is getting degraded due to human activities, we need to do something about it to sustain the quality. We often feel that government should take proper measuring steps. But all of us are equally responsible to protect our environment. Hence public awareness needs to be created. Both print media and electronic media can strongly influence public opinion. Politicians should respond positively to a strong publicly supported activity. NGOs can take active role in creating awareness from grass root levels to the top-most policy decision makers.

Environment is an integration of both living and non-living organisms. Water, air, soil, minerals, wild life, grass lands, forests, oceans, agriculture are all life supporting systems. Since these natural resources are limited, and human activities are the causative factors for environmental degradation, each one of us need to feel responsible to protect the environment.

The activities help in creating awareness among public are:

- Join a group to study nature such as WWF-I or BNHS or any other organization
- Read newspaper articles and periodicals like Down to earth, WWF-I newsletter, BNHS, Hornbill, Sanctuary magazine.
- Discuss environmental issues with friends and relatives.
- Join local movements that support activities like saving trees in your locality, reducing use of plastics, going for nature treks, practicing 3 Rs *i.e.*, reduce, reuse, & recycle.
- Practice and promote good civic sense and hygiene such as enforcing no spitting or tobacco chewing, no throwing garbage on the road and no urinating in public places.
- Take part in events organized on World Environment Day, Wildlife week, *etc.*
- Visit a National park or sanctuary or spend time in whatever natural habitat you have near your home.

NEED OF PUBLIC AWARENESS ABOUT ENVIRONMENT

In today's world because of industrialization and increasing population, the natural resources has been rapidly utilised and our environment is being increasingly degraded by human activities, so we need to protect the environment. It is not only the duty of government but also the people to take active role for protecting the environment, so protecting our environment is economically more viable than cleaning it up once, it is damaged. The role of mass media such as newspapers, radio, television, etc is also very important to make people aware regarding environment.

There are various institutions, which are playing positive role towards environment to make people aware regarding environment like BSI (Botanical Survey of India, 1890), ZSI (Zoological Survey of India, 1916), WII (Wild Life Institute of India, 1982), *etc.*

THE SOCIAL MEDIUM AS EDUCATIVE

Our net result thus far is that social environment forms the mental and emotional disposition of behaviour in individuals by engaging them in activities that arouse and strengthen certain impulses, that have certain purposes and entail certain consequences. A child growing up in a family of musicians will inevitably have whatever capacities he has in music stimulated, and, relatively, stimulated more than other impulses which might have been awakened in another environment. Save as he takes an interest in music and gains a certain competency

in it, he is “out of it”; he is unable to share in the life of the group to which he belongs. Some kinds of participation in the life of those with whom the individual is connected are inevitable; with respect to them, the social environment exercises an educative or formative influence unconsciously and apart from any set purpose. In savage and barbarian communities, such direct participation furnishes almost the sole influence for rearing the young into the practices and beliefs of the group.

Even in present-day societies, it furnishes the basic nurture of even the most insistently schooled youth. In accord with the interests and occupations of the group, certain things become objects of high esteem; others of aversion. Association does not create impulses or affection and dislike, but it furnishes the objects to which they attach themselves. The way our group or class does things tends to determine the proper objects of attention, and thus to prescribe the directions and limits of observation and memory. What is strange or foreign tends to be morally forbidden and intellectually suspect. It seems almost incredible to us, for example, that things which we know very well could have escaped recognition in past ages. We incline to account for it by attributing congenital stupidity to our forerunners and by assuming superior native intelligence on our own part. But the explanation is that their modes of life did not call for attention to such facts, but held their minds riveted to other things.

Just as the senses require sensible objects to stimulate them, so our powers of observation, recollection, and imagination do not work spontaneously, but are set in motion by the demands set up by current social occupations. The main texture of disposition is formed, independently of schooling, by such influences. What conscious, deliberate teaching can do is at most to free the capacities thus formed for fuller exercise, to purge them of some of their grossness, and to furnish objects which make their activity more productive of meaning. While this “unconscious influence of the environment” is so subtle and pervasive that it affects every fibre of character and mind, it may be worth while to specify a few directions in which its effect is most marked. First, the habits of language.

Fundamental modes of speech, the bulk of the vocabulary, are formed in the ordinary intercourse of life, carried on not as a set means of instruction but as a social necessity. The babe acquires, as we well say, the mother tongue. While speech habits thus contracted may be corrected or even displaced by conscious teaching, yet, in times of excitement, intentionally acquired modes of speech often fall away, and individuals relapse into their really native tongue. Secondly, manners. Example is notoriously more potent than precept. Good manners come, as we say, from good breeding or rather are good breeding; and breeding is acquired by habitual action, in response to habitual stimuli, not by conveying information.

Despite the never ending play of conscious correction and instruction, the surrounding atmosphere and spirit is in the end the chief agent in forming manners. And manners are but minor morals. Moreover, in major morals,

conscious instruction is likely to be efficacious only in the degree in which it falls in with the general “walk and conversation” of those who constitute the child’s social environment. Thirdly, good taste and esthetic appreciation. If the eye is constantly greeted by harmonious objects, having elegance of form and colour, a standard of taste naturally grows up. The effect of a tawdry, unarranged, and over-decorated environment works for the deterioration of taste, just as meagre and barren surroundings starve out the desire for beauty.

Against such odds, conscious teaching can hardly do more than convey second-hand information as to what others think. Such taste never becomes spontaneous and personally engrained, but remains a laboured reminder of what those think to whom one has been taught to look up. To say that the deeper standards of judgements of value are framed by the situations into which a person habitually enters is not so much to mention a fourth point. We rarely recognize the extent in which our conscious estimates of what is worth while and what is not, are due to standards of which we are not conscious at all. But in general it may be said that the things which we take for granted without enquiry or reflection are just the things which determine our conscious thinking and decide our conclusions. And these habitudes which lie below the level of reflection are just those which have been formed in the constant give and take of relationship with others.

5

Environmental Science: Pollution Challenges and Implementing Control Strategie

Introduction and definition of environmental pollution–We know that, a living organism cannot live by itself. Organisms interact among themselves.

Hence, all organisms, such as plants, animals and human beings, as well as the physical surroundings with whom we interact, form a part of our environment. All these constituents of the environment are dependent upon each other. Thus, they maintain a balance in nature.

As we are the only organisms try to modify the environment to fulfill our needs; it is our responsibility to take necessary steps to control the environmental imbalances.

The environmental imbalance gives rise to various environmental problems. Some of the environmental problems are pollution, soil erosion leading to floods, salt deserts and sea recedes, desertification, landslides, change of river directions, extinction of species, and vulnerable ecosystem in place of more complex and stable ecosystems, depletion of natural resources, waste accumulation, deforestation, thinning of ozone layer and global warming.

The environmental problems are visualized in terms of pollution, growth in population, development, industrialization, unplanned urbanization, *etc.* Rapid migration and increase in population in the urban areas has also lead to traffic congestion, water shortages, solid waste, and air, water and noise pollution are common noticeable problems in almost all the urban areas since last few years.



Environmental pollution is defined as the undesirable change in physical, chemical and biological characteristics of our air, land and water. As a result of over-population, rapid industrializations, and other human activities like agriculture and deforestation *etc.*, earth became loaded with diverse pollutants that were released as by-products. Pollutants are generally grouped under two classes:

- *Biodegradable pollutants*: Biodegradable pollutants are broken down by the activity of micro-organisms and enter into the biogeochemical cycles. Examples of such pollutants are domestic waste products, urine and faecal matter, sewage, agricultural residue, paper, wood and cloth, *etc.*
- *Non- Biodegradable pollutants*: Non-biodegradable pollutants are stronger chemical bondage, do not break down into simpler and harmless products. These include various insecticides and other pesticides, mercury, lead, arsenic, aluminum, plastics, radioactive waste, *etc.*

Classification of Environmental Pollution—Pollution can be broadly classified according to the components of environment that are polluted. Major of these are: Air pollution, Water pollution, Soil pollution (land degradation) and Noise pollution. Details of these types of pollutions are discussed below with their prevention measures.

- *Air Pollution*: Air is mainly a mixture of various gases such as oxygen, carbon dioxide, nitrogen. These are present in a particular ratio. Whenever there is any imbalance in the ratio of these gases, air pollution is caused. The sources of air pollution can be grouped as under:
 - Natural; such as, forest fires, ash from smoking volcanoes, dust storm and decay of organic matters.
 - Man-made due to population explosion, deforestation, urbanization and industrializations.

Tabel. The gaseous composition of unpolluted air.

<i>The Gases</i>	<i>Parts per million (vol)</i>
Nitrogen	756,500
Oxygen	202,900
Water	31,200
Argon	9,000
Carbon Dioxide	305
Neon	17.4
Helium	5.0
Methane	0.97-1.16
Krypton	0.97
Nitrous oxide	0.49
Hydrogen	0.49
Xenon	0.08
Organic vapours	ca.0.02

Certain activities of human beings release several pollutants in air, such as carbon monoxide (CO), sulfur dioxide (SO₂), hydrocarbons (HC), oxides of nitrogen (NO_x), lead, arsenic, asbestos, radioactive matter, and dust.

The major threat comes from burning of fossil fuels, such as coal and petroleum products. Thermal power plants, automobiles and industries are major sources of air pollution as well. Due to progress in atomic energy sector, there has been an increase in radioactivity in the atmosphere. Mining activity adds to air pollution in the form of particulate matter. Progress in agriculture due to use of fertilizers and pesticides has also contributed towards air pollution.

Indiscriminate cutting of trees and clearing of forests has led to increase in the amount of carbon dioxide in atmosphere. Global warming is a consequence of green house effect caused by increased level of carbon dioxide (CO₂). Ozone (O₃) depletion has resulted in UV radiation striking our earth.

HAZARDOUS WASTE

When we think of hazardous waste, the image of industrial by-products stored in rusty barrels generally comes to mind. However, hazardous materials are also found in cleaning closets, under the sinks, and on the garage shelf in our homes.

Agricultural by-products are considered hazardous materials. These substances all pose special disposal concerns. Hazardous waste includes any toxic material whose disposal can endanger people or the environment. Although there are some naturally occurring substances that pose health risks if not properly handled, by far the greatest threat comes from three sources: synthetic chemicals, pesticides and toxic household products. We come in contact with these materials in a great variety of ways.

SOURCES

Synthetic chemicals are used to create the majority of the products in industrial societies. During the manufacture of consumer products, the possibility exists for toxic materials to enter the environment via smokestack emissions, from dumping into surface waters, from leachate lost from landfills and finally as leaked contaminants from deep disposal wells. Most modern agriculture uses a large number of pesticides and herbicides. These synthetic products get into the soil and then into the hydrosphere by runoff from the fields.

Toxic household products include cleansers, detergents, insecticides, used motor oil, and batteries of all sorts. Many people are unaware of the dangers these products pose, and unless communities have special disposal programmes for the materials, these products end up being poured down drains and dumped into municipal landfills. There they contaminate the water, because waste treatment plants are not equipped to remove contaminants, or they leak out as leachate from landfills which are not designed to contain such chemicals. In both cases the wastes become significant threats to the environment.

THREATS

Plants and animals have no natural resistance to many synthetic products, and thus their presence in soil and water upsets the balance of ecosystems. Pesticides, designed to eliminate one insect, may also kill that insect's natural predators thus increasing a problem instead of decreasing it. The insecticide may also kill or threaten a large number of other animals such as fish or birds that were never intended to be targets. Contaminants in water can produce lesions on fish or kill fish, and these are often only the very visible signs of more extensive disruption of the ecosystem.

The effects of hazardous waste contamination on humans includes a wide variety of symptoms which depend on the type of pollutant and the dose received. In extreme instances the toxins can maim or kill a person instantly, in other cases they can produce brain damage, hearing loss, behaviour problems, cancer, genetic mutations, and birth defects and miscarriages. In an attempt to avoid some of these problems, people can deal with hazardous waste in two basic ways. One method is to find safe ways to dispose of such waste. Another approach is to find ways to decrease the amount of waste produced.

DISPOSAL

Secure Landfills

One method used for the disposal of hazardous waste is to place it in secure landfills. Although some might argue that there is no such thing as a secure landfill the idea behind them is to prevent any leachate from escaping from the disposal site into local aquifers. This is achieved by using geologic barriers such as the type of rock and soil in the disposal area, and by lining the site with

an impermeable plastic sheet. Materials are placed in special compartments in the landfill to prevent any undesirable mixing of the different substances. After it is filled, the site would be capped with a layer of impermeable clay to cut down on the amount of water that will pass through. Test wells are drilled into the site to detect any leaking.

The main disadvantage to this method of disposal is its failure rate. It is very difficult to isolate the material from the groundwater, and sites which were thought to be absolutely leak-proof have leaked.

Disposal Wells

Another method to dispose of liquid hazardous waste is to pump it deep into the ground. The objective is to isolate the waste from the surface aquifers by placing it below them.

Only some areas meet the geologic requirements necessary for this type of disposal. There must be a geologic layer (usually sandstone) at depth to receive the waste, which is separated from the surface aquifers by impermeable layers (usually clay or shale). The waste is injected to the layer through special wells lined with cement. The risks associated with this method of disposal involve leaking at the well entrance, or undetected fractures in the rocks, which would allow contamination of the surface aquifer.

Incineration

A final method to dispose of hazardous waste is to incinerate the material. As long as it is carried out at a sufficiently high temperature, incineration has the advantage of destroying the hazardous nature of the material. Another advantage of this method is that it reduces the volume of the waste material. Suitable for solid and liquid waste, incineration breaks up organic compounds into harmless elements which combine with oxygen and are released into the atmosphere.

In some cases, toxic ashes, acids, or metals are the only materials left over to be handled after incineration. The associated risks of incineration are inadvertent leaking of toxic ash or gasses during the process itself. Also, CO₂ is emitted as an end-product of the process which, though not toxic, is a greenhouse gas.

MINIMIZATION

Part of the solution to the problem of hazardous waste has to be to reduce its production. One way to reduce production is to change manufacturing to utilize "cleaner" processes. Another method is participation in waste exchange programmes, where the waste from some companies is used as a resource for other companies. Many wastes can be re-processed and reused. One of the (outwardly) simplest ways to minimize waste production is to reduce demand for consumer goods. If the goods are not produced, neither will the wastes be produced.

NUCLEAR WASTE

Today there are many uses for nuclear technology which range from simple detectors to the construction of complex weapons. All applications of nuclear technology produce materials which are no longer useful, but are radioactive. These waste materials must be disposed of in a manner which will minimize human exposure to radiation until the material is no longer dangerous.

NUCLEAR ENERGY

Nuclear energy is derived from atoms when their nuclei are split to form less complex atoms, or combined to form larger ones. This change can occur spontaneously when naturally unstable atoms come apart and emit particles and energy, or it can be made to occur on command in nuclear reactors. Humans use nuclear reactions to generate electric power and for a variety of other purposes.

In most cases, the atoms created by nuclear change are radioactive, meaning that they are unstable material which will continue to emit particles and energy until it has decayed to a stable state. The energy and particles which are given off are hazardous to most living things.

The time it takes the atoms of a particular element to decay to a stable form is expressed in "half-lives". An element's half-life is the time it takes for half of the material to change to its stable form. An element can remain dangerously radioactive through many half-lives. Materials with short half-lives (measured in seconds) lose their radioactivity quickly, and those with very long half-lives (measured in millions of year) are emitting radiation very slowly. As a result, neither of these poses as much of a threat to humans as does material with an intermediate half-life which may remain dangerously radioactive to 100's or 1000's of years. These materials must be safely isolated from the environment for long periods of time.

SOURCES

The chief uses of nuclear technology include medical diagnosis and treatment, food preservation, electricity generation, weapons production, and the general research which supports those industries.

In medicine, radioactive substances are used for diagnostic purposes and for the treatment of cancer. Food irradiation can kill bacteria, insects and fungi without making the food itself radioactive. Nuclear power plants produce electricity for residential and commercial use.

The military designs and tests nuclear weapons, and uses nuclear fuel for ships and submarines. All these endeavors produce radioactive waste; some liquid, some solid, and some in the form of a gas. A certain percentage of this waste is highly radioactive and very dangerous, this is classified as high-level waste. Much of the rest of the waste is mildly radioactive and is considered low-level waste.

LOW-LEVEL WASTE

Low-level waste includes materials such as contaminated clothing, water used for cleaning, filters and some medical waste. It also includes gas emissions from nuclear plants. These may contain only small amounts of radioactivity, but this type of waste accounts for a large percentage of nuclear waste. Much of this material is taken to commercial disposal sites.

COMMERCIAL DISPOSAL SITES

For gases and liquids which contain low-levels of radiation, the main disposal objective is to dilute the material to low concentration levels so that it poses a minimal threat to the environment. The gasses are released into the atmosphere in small quantities. Liquid waste is diluted to a level which is deemed safe and then released.

WATER POLLUTION

Water pollution is any physical, chemical or biological alteration of water that is harmful to living organisms. A more human-centered definition describes pollution as "any contamination of water that makes it unsuitable for its 'highest' use". For example, silt or mud in water would not affect its use for boating or fishing, but the same silt in the same water could prevent humans from drinking or washing clothes in it. There are many types of water pollution; some have a natural origin, but most are related to human activities.

Water becomes polluted easily because it is a nearly "universal" solvent. One of the alchemists' goals was to find a "universal solvent"-a liquid into which everything could be dissolved. They were unaware that they already possessed what they were looking for-almost everything will dissolve in water, at least to some extent. This makes water an excellent cleaner, and a convenient way to dispose of waste. These initially positive uses, in turn, often lead to water pollution. There are many sources of water pollution, but a common way to categorize them is to consider point sources and non-point sources. Point sources are specific locations that are easy to identify. Less specific locations, more generalized and harder to find, are called non-point sources, and are often difficult to define and to regulate. Whatever its cause, water pollution does have many possible solutions.

Pollution in streams and lakes is often easy to see or smell, and frequently the solutions are obvious. Groundwater, though hidden below the surface, can also become polluted; and because it is harder to see and easier to forget, this pollution is more difficult to detect and to clean up.

TYPES OF WATER POLLUTION

Anything that dissolves in water, or can be suspended in water, or floats on water can be considered a pollutant. However, there are eight primary types of pollution that account for most of the problems that humans produce. These are water pollution by:

SEDIMENT

Sediment is the primary water pollutant in the United States. Sediment is undissolved solid material (sand, silt and clay) that has been eroded from the land. Such materials are washed away from all land areas during rain storms, floods and snow melts, but the volume of sediment becomes much greater if some of the land's natural protections have been removed. This is often the case on construction sites, in agricultural areas, and after forest fires. Sediment gives water a cloudy appearance, which is called "turbidity." Turbid, or muddy, water does not allow sunlight to penetrate; it can hamper the ability of aquatic animals to get oxygen out of the water; and it can bury bottom-dwelling organisms as it settles out of the water. Sediment has the additional problem-causing characteristic that many pesticides, nitrates and pathogenic organisms attach themselves to particles of silt and clay.

TOXIC MATTER

A great variety of poisonous compounds can get into water either by accident or intent. For example, humans have known for years that lead is a poison that affects the nervous system, but we realized only recently that the lead in plumbing and the lead in automobile gasoline can enter our water supply and harm us. There discovery gives us a good reason to believe that the Romans may have been harmed by lead in their water and wine over 2000 years ago.

Another example of toxic material in water occurred in the 1950s when industries around Minamata Bay in Japan discharged so much mercury into the bay that people were poisoned by mercury that had found its way into the local seafood. More recently, people have become concerned about the presence of agricultural nitrates in water. The human body converts nitrates into nitrites, and these can interfere with the blood's ability to transport oxygen. In these and many other cases, material with one purpose (plumbing, industrial production or fertilizer) ended up in the wrong place as a serious water pollutant.

PATHOGENS

Pathogens are agents that cause disease. They may be bacteria, viruses or parasites, and they can get into water from any infected organisms. Small numbers of these agents can be found in almost all bodies of water, but the numbers greatly increase when any sort of animal waste enters the water. In parts of the world where untreated sewage is allowed to enter the water supply, contaminated water is a major health hazard.

SALT

Most land plants and animals can be harmed by salt (sodium chloride and calcium chloride), and therefore any salt in the supply of fresh water can be a problem. Under certain conditions, salt water from the ocean can intrude into groundwater, and storms can blow ocean water into surface lakes and streams.

Irrigation projects can add salt to streams, and salt water is a common by-product of the oil industry. (Crude oil often comes to the surface mixed with salt water). In the northern parts of North America, salt is spread on roads and bridges to stimulate the melting of ice. Salt from storage areas as well as from the highways eventually finds its way into local streams and groundwater.

ACID

Acid mine drainage (acids given off by the weathering of ores) is a significant source of water pollution in mining areas, and acid precipitation is becoming an important problem in industrialized areas. In addition, acid can enter the water from a wide variety of industries (such as steel-making and fruit-packing) that use acids as cleaners. In all cases, the addition of acid to water lowers its pH and often kills the plants and animals that would naturally inhabit it. Acidic water also dissolves metals more easily, and thus the water may become additionally polluted by metals such as lead, copper, or mercury.

AGRICULTURAL CHEMICALS

Most agricultural chemicals are water-soluble nitrates and phosphates that are applied to fields, lawns and gardens to stimulate the growth of crops, grass and flowers. The chemicals enter streams and lakes during the run-off of rain water. Once in a body of water, these chemicals continue to promote the growth of plants, but an overgrowth of plant life can seriously damage a lake or stream. The resulting plant detritus is food for micro-organisms, and as the population of such organisms grows, the supply of oxygen in the water is depleted. Declining oxygen leads to a drop in the population of fish. In extreme cases, the plants may produce so much detritus that all oxygen is used up and all animal life disappears from the stream. Water in which this problem is occurring, is said to have a high "Biochemical Oxygen Demand", or "BOD". This means that the water is capable of supporting a large population of bacteria that will have a high demand for oxygen.

ORGANIC MATTER

Dumping untreated sewage or other organic material into a body of water has much the same effect as pollution by fertilizers. In both cases the water is supplied with an abundance of food for micro-organisms, and the rapidly expanding population of microscopic animals soon depletes the supply of oxygen making the water uninhabitable by fish and other larger organisms.

HEAT

People use a large amount of water for cooling. This water is usually returned to its source only about 10 degrees warmer than its natural temperature, but even this amount of warming can affect the water's ability to support life. The problem is known as "thermal pollution." Cold water holds more oxygen than warm water.

For example: at 32°F, fresh water can hold 14 ppm (parts per million) of oxygen. If that same water is warmed to 70°F, it can only hold 9 ppm oxygen, and at 100°F, its oxygen content decreases to 6 ppm. As the water's oxygen supply decreases, it loses its ability to support animals such as fish. The problem is made worse by the fact that warmer water encourages the growth of bacteria that may attack the fish. Thermal pollution is particularly severe during summer months when the water's natural temperature is high. During very hot weather, a body of water may hold only 50% as much oxygen as it would during the winter. Artificially warming the water at that point could easily begin to kill off the fish.

POINT SOURCES

Pollutants that are discharged at a known location through conduits such as sewers, ditches or canals, are said to be coming from a "point source." Such sources are easy to locate, and they are also easy to regulate and control. It is possible to identify the polluting material and determine its volume. It is also easy to determine the extent to which regulations are being followed.

NON-POINT SOURCES

"Non-point sources" are less distinct sites such as lawns, forests, construction sites, parking lots, or farms. Overall, agriculture is the leading source of non-point pollution in the United States. Effluent from agricultural sources produces about 65% of the total mass of pollutants entering the nation's streams and about 55% of those entering lakes. Non-point sources are much more difficult to control since it is often impossible to identify the nature and the volume of the material entering the water supply.

GROUNDWATER

All groundwater was surface water at one time, and therefore, anything that is a potential threat to surface water is also a threat to groundwater. Groundwater can become polluted, and once it does, it may take thousands of years for the contaminants to be flushed from the aquifer. Pollutants can be washed out of rivers in weeks or months, and lakes can clear themselves out in decades; but reservoirs of groundwater may remain contaminated for millennia. Since most groundwater is invisible, it may even take years just to detect a problem.

Farming and gardening use pesticides, herbicides and chemical fertilizers that may enter the ground. Leaking underground storage tanks at homes and service stations can pollute acres of groundwater with various petroleum products. Groundwater can also be contaminated by organic waste from outhouses, septic tanks, and leaking sewage lines. All such pollution must be located, and some means devised to remove it from the ground.

SOLUTIONS

At first look, solutions to water pollution seem remarkably simple. Either prevent the problem from happening, or clean up the pollution that has occurred.

Problems are handled in both of these ways, but solutions become complicated when they are put into practice. Prevention and clean-up can each be time-consuming and expensive. The source of the pollution must be located and identified; an alternative method of dealing with the waste must be determined; and often, time must pass while the pollutants are "flushed" out of the ground or the effected body of water.

PREVENTION

Legislation, such as the Safe Drinking Water Act in the U.S., is aimed at the prevention of pollution. The goal is to eliminate practices that allow pollutants to enter the water supply in the first place. Some pollutants are toxic or disease-causing materials that should not be released under any conditions. Other pollutants are only harmful in quantities that are too large to be handled by natural systems. The appropriate legislation may be as simple as regulations about dumping used motor oil onto the ground or into sewage systems, or it may be as complex as the regulations controlling the effluent from industries or municipal sewage treatment facilities. In each case, the intent is to remove toxic material from the environment, and to limit the rate that harmful materials are added to water supplies so that natural processes can absorb or destroy them.

CLEAN UP

A salt marsh may not look like a pollution control device, but it contains many physical and biological processes that work to remove polluting material from water. These natural processes allow water to be considered a "renewable resource" in that the water may serve one purpose (such as washing nutrient-rich mud into the marsh), and it may then be cleaned and re-used in another capacity (such as drinking water for a bird). Humans try to duplicate some of these natural processes in order to clean up water that we have polluted.

NATURAL PROCESSES

There are four significant natural processes that act to clean water and allow it to be reused. They are:

- *Evaporation*-When water turns from a liquid into a vapor, almost all of the material that was dissolved or suspended in the water is left behind. As a result, salt water evaporates to create a vapor of fresh water, and muddy water evaporates to create a vapor that does not contain any mud.
- *Sedimentation*-Various types of sediment are the most common agents of pollution in water. Sediment is suspended in water by turbulence, and slowly settles out of water that is allowed to sit still. The larger particles of sediment drop to the bottom first, but if a sample of water remains still for a long period of time, even the smallest particles of clay will settle to the bottom.

- *Adhesion*-Some natural materials, such as clay, adhere readily to other materials. The process is known as "adhesion," (as in adhesive tape) and results in the fact that some of the pollutants in water stick to particles of clay and fall to the bottom as the clay settles. Almost like a natural filter, this process of adhesion can remove dissolved as well as suspended pollutants from water. This process is primarily responsible for the generally correct belief that a stream will "clean itself" if it is allowed to flow far enough.
- *Biologic Activity*-Almost all of the organic waste from one organism is food for another. Dead leaves and branches are consumed by micro-organisms; the waste from the micro-organisms is then used by plants to form leaves and branches. If not disturbed, this natural cycle can operate continuously-consuming potentially polluting wastes and reusing them in the natural system. Many of these same natural processes are used by humans to clean-up our own water pollution problems.

HUMAN PROCESSES

Humans take advantage of natural cleaning processes to deal with many water pollution problems. In two of our most significant processes, we use "sedimentation and adhesion" to treat drinking water, and we take advantage of "sedimentation and biologic activity" in the treatment of sewage.

MUNICIPAL WATER TREATMENT

If a city's supply of water is drawn from lakes or rivers, the primary goal of the municipal treatment facility is to clean the water of sediment and pathogens. Sediment is removed by stimulating the small particles of clay that are suspended in the water to stick together in larger groups. Once the groups are large enough, they fall to the bottom and are removed.

This process is known as "flocculation." Flocculation is a natural process, but it is made to operate more quickly in most water treatment plants by adding "alum" (aluminum sulfate) to the water. After the flocculation process, the water passes through fine "sand filters," which often contain activated charcoal as well. This sand, or sand/charcoal combination, filters out the smallest particles and also removes small amounts of organic matter that might give the water a strange taste or smell.

Pathogens are removed in two ways. First of all, chlorine is added to the water as it enters the plant, and as it leaves. The chlorine added before treatment will kill bacteria and fungi before they enter the plant, and the chlorine added at the end of the process will protect the water as it is piped to consumers. Second of all, many pathogens and chemical impurities are removed by the natural process of adhesion to clay particles that are settling to the bottom of the treatment tanks. Once the water has been cleaned, fluoride and several other chemicals are added before it is pumped out of the plant.

MUNICIPAL WASTE WATER TREATMENT

The mission of a municipal waste water treatment plant is to clean the waste water sufficiently so that it can be returned to a river or lake without altering the natural conditions in that body of water. To do this, the plant must first remove debris that would spoil the appearance of the water. In addition, the plant must remove pathogens from the water, and it must remove organic matter that would promote the growth of plants and eventually deplete the water's supply of oxygen.

Early waste water treatment facilities were "Primary" systems that used only physical means to clean the water. Screens were used to remove large debris, and "clarifiers"(settling tanks) were employed to allow smaller suspended or floating solids to separate from the water. The cleaner water was then chlorinated and released. Today, most major U.S., cities operate "Secondary" systems that use both physical and biological processes to clean the water. In addition to the primary treatment described above, these plants also have "aeration basins" in which oxygen is added to the waste water to encourage bacteria to consume suspended and dissolved organic matter. Good secondary systems can significantly reduce the waste water's BOD. In places where waste water contains many chemical impurities, or where it must be cleaned to a very high standard, various types of "Tertiary," or chemical, treatment are used. This type of treatment is often expensive and its use is limited.

GAS POLLUTION

Any change in the atmosphere's natural mixture of gases has the potential to be significant air pollution. Most gases are invisible, and thus this type of pollution is less obvious. Since it is out-of-sight, it was for many years out of mind. Today, however, gas pollution is a familiar and important problem. Exotic gases can enter the atmosphere from natural as well as human sources. Once in the atmosphere, the gases may cause problems alone or they may form troublesome compounds by combining with particles or other gases.

NATURAL SOURCES

Several important air pollutants have natural sources. One is methane (CH_4). Methane is produced by the bacteria that break down organic matter in the absence of oxygen. This process can occur in swamps, on the sea floor, and inside the bodies of animals. The methane which escapes to the atmosphere adds to the "Greenhouse Effect". Natural fires produce carbon dioxide (CO_2) which is also a green house gas, and volcanoes produce a great deal of Chlorine gas which may have an effect on the Ozone Layer.

HUMAN SOURCES

In industry, domestic heating and many varieties of transportation, humans produce gases that are released into the atmosphere. In most cases these gases affect the Lower Atmosphere into which they are released, but in some cases they can affect the Upper Atmosphere.

LOWER ATMOSPHERE

The most prominent air pollutants are: Sulfur Dioxide (SO_2), Nitrogen Oxides (NO_x), Carbon Monoxide (CO), Carbon Dioxide (CO_2) and Chlorofluorocarbons (CFCs).

SULFUR DIOXIDE

Sulfur dioxide (SO_2) is a colourless gas that is produced when the element sulfur is burned. This can happen intentionally during the purification of ores which contain sulfur. In a process known as "smelting", the ore is heated to a high temperature and the sulfur is burned off. Sulfur is burned unintentionally when coal or other fuels containing a large amount of sulfur are used by industries and public utility companies. Whatever its source, once the sulfur enters the atmosphere it combines with water to form sulfuric acid (H_2SO_4) and becomes an important component of acid rain. For more information on the effects of acid rain.

NITROGEN OXIDES

Nitrogen oxides are produced when a mixture of nitrogen and oxygen is subjected to high temperatures and high pressures. These conditions occur continuously inside the internal combustion engines that operate automobiles, trucks, trains and small airplanes. These two primary atmospheric gases are drawn into the engines, some of the oxygen is used up as the fuel burns, but the remainder is heated and compressed inside each cylinder as it fires. The resulting nitrogen oxides are responsible for three important air pollution problems.

EFFECTS OF LOWER ATMOSPHERE GAS POLLUTION

There are several biologic and/or non-biologic effects of lower atmosphere gas pollution. Included among these are the following:

- (1) *Acid precipitation has its source in the combustion of fossil fuels:* When both sulfur and nitrous oxides are emitted into the atmosphere, both can react with water vapor to produce sulfuric acid (H_2SO_4) and nitric acid (HNO_3), respectively. Both have both biologic and non-biologic effects. Biologic effects include acidification of soils, plants and surface and ground water. Acidification can stunt or even kill the growth of plants by acting on the plant's leaves or by ingestion through the root system. An excellent example of the detrimental effects can be seen in the destruction of entire stands of fir and spruce trees in the Blue Ridge and Great Smoky Mountains of North Carolina and Tennessee. Acidification of soils can result in the alteration of soil chemistry by leaching acid-soluble chemicals and effectively increasing the levels of certain other non-acid-soluble chemicals. Runoff of acidic soils in upstate New York in the 1950's led to the acidification of Lake Erie and the near death of that Great Lake. In recent years, Lake Erie has

been brought back to life as a result of practices designed to reduce soil acidification. Acid precipitation has even been linked to human respiratory diseases such as asthma and bronchitis.

Non-biologic effects of acid precipitation include the dissolution and destruction of many statues and buildings, especially those made of limestone and marble, and the "pitting" of many metal and painted surfaces.

- (2) *Ozone*: In the presence of sunlight, one of the atoms of oxygen is often driven off of nitrogen dioxide (NO_2) and is free to combine with an oxygen molecule (O_2) to form ozone (O_3). Ozone is beneficial to humans when in the upper atmosphere, but in the lower atmosphere ozone is an irritant making throats sore, eyes red, and noses run.
- (3) *Photochemical Smog*: In the presence of sunlight, nitrogen oxides can combine with unburned hydrocarbons (gasoline and oil) to form chemicals such as formaldehyde and peroxyacetyl nitrate (PAN) which are some the primary components of the brownish haze which often forms over Los Angeles and other sun belt cities during the summer time. Since this new type of "smog" is formed by chemical reactions that are driven by sun light, it is known as Photochemical Smog to distinguish it from the earlier type of smog.

CARBON MONOXIDE

Carbon monoxide is produced when a compound containing carbon is burned at a very high temperature, or burned without a sufficient supply of oxygen. This occurs in internal combustion engines (cars, trucks and buses), in trash piles, and in many types of domestic heaters. Carbon monoxide is poisonous because it is absorbed by the blood in place of oxygen. If we breath too much carbon monoxide, we can die from a lack of oxygen.

CARBON DIOXIDE

Carbon dioxide (CO_2) is produced when any material containing carbon is burned. Whether the material is wood, oil, garbage, paper or natural gas, as it burns oxygen combines with carbon to make heat and give off CO_2 . Carbon dioxide is also produced by all living things when they obtain energy from carbon-based food by combining it with oxygen and giving off CO_2 as a waste product. Carbon dioxide is a natural, though quite small, component of the atmosphere, and for this reason, it was not considered an air pollutant for many years.

Environmentalists became concerned about carbon dioxide when it became apparent that the atmosphere's average temperature was increasing worldwide. Since carbon dioxide absorbs infra-red radiation (heat), this increase in temperature could be explained by an increase in the amount of CO_2 in the atmosphere. This situation, known as the "greenhouse" effect, is the source of increasing concern.

First of all, because a number of gases which we have released into the atmosphere have the same effect as carbon dioxide in that they absorb infra-red radiation. Called "greenhouse Gases" they include nitrogen oxides, chlorofluorocarbons, methane (natural gas), water and carbon dioxide. Second of all, a general warming of the atmosphere can lead to a great variety of environmental problems.

GLOBAL CHANGE

The term "Global Change" refers to all of the many ways that the earth appears to have changed or be changing during the time that humans are here. Some of the changes are the direct result of human activity, some clearly are not, and some are not well enough understood to attribute to any cause.

This section will look at the global change issue, some of its causes, some of its effects on the Earth's sub-systems, and some of the actions that are being taken or could be taken to address the issue. The global change issues to be examined include:

GLOBAL WARMING

One can hardly escape the reports in the media about global warming and the greenhouse effect. To understand the concept of global warming, it is necessary to remember that throughout geologic history, the global climate has warmed and cooled several times, resulting in Ice Ages when the global climate was significantly colder than present, and Interglacial Stages, when the global climate was significantly warmer than present. In fact, during the last 2 million years, there is now evidence of at least 20 glacial ages.

To understand the effect that human activities have had on global climate, we must understand where we are in the glacial/interglacial time-frame. The consensus among earth scientists is that we are in a global warming period that was not initiated by human activity. Because we are concerned with the possibility that human activity might further warm the global climate, we must attempt to separate the human-induced and the non-human-induced components of global warming. As shown in Figure 1, that is more difficult than one might imagine.

UPPER ATMOSPHERE OZONE LAYER

The stratosphere is that layer of the atmosphere that extends from 17 km to 48 km above sea level. Within the lower parts of the stratosphere there exists a "layer" rich in ozone gas. Ozone, whose chemical formula is O_3 , is important because it absorbs ultraviolet radiation from the sun, and thus limits the amount of that radiation which reaches the earth's surface. Recent atmospheric studies show that the amount of ozone in the upper atmosphere varies from one location to another, and from one time to the next. This means that the amount of ultraviolet radiation reaching the earth also varies. This is important because ultraviolet radiation is known to be harmful to many living things, including humans.

Any reduction in the amount of ozone in the upper atmosphere can have detrimental effects. It has been well documented in the past few decades that there is a roughly circular area in the ozone layer where the ozone concentration is dangerously low. This hole in the ozone layer is not constant in size or location, but it appears to be most problematic in the Southern Hemisphere, over Antarctica, Australia and New Zealand. Unlike many environmental issues, where we do not know for sure the causes and effects of the problem, in this case we do. One of the primary causes for the reduction of ozone in the upper atmosphere is an increase in a series of man-made chlorine-and fluorine-compounds known as chlorofluorocarbons.

DEFORESTATION

While forests are being cleared permanently in nearly all parts of the world, the issue of deforestation generally focuses on the loss of tropical forests. Tropical forests, including rain forests, are confined to equatorial areas, especially Latin America, Africa and Southern and Southeastern Asia. Tropical forests currently cover slightly over 5% of the earth's land area, but are rapidly being permanently altered-it is reliably estimated that we have already lost or damaged over 50% of the world's tropical forest resources. The problem is most severe in the less developed nations-Haiti and the Philippines have already lost more than 95% of their tropical forests. Why is this a problem? After all, trees can be replanted. And any way, how does this affect us in the more developed nations? In fact, deforestation is a global environmental issue, one which affects all of us, whether we live in an area being deforested or in an area in which people are trying to protect their forests, especially tropical and rain forests. As with so many other environmental issues, this one too often pits less developed nations on one side of the issue and developed nations on the other. To understand why deforestation is taking place, at an alarming rate, we need first to identify why the forests are being cut. Most of these reasons can be grouped together as the perceived and real different needs for forested land.

POLLUTION PREVENTION

Pollution prevention is reducing or eliminating waste at the source by modifying production processes, promoting the use of non-toxic or less-toxic substances, implementing conservation techniques, and re-using materials rather than putting them into the waste stream. Pollution prevention means "source reduction," as defined under the Pollution Prevention Act, and other practices that reduce or eliminate the creation of pollutants through:

- Increased efficiency in the use of raw materials, energy, water, or other resources, or
- Protection of natural resources by conservation. The Pollution Prevention Act defines "source reduction" to mean any practice which
- Reduces the amount of any hazardous substance, pollutant, or contaminant entering any waste stream or otherwise released into the environment prior to recycling, treatment, or disposal; and

- Reduces the hazards to public health and the environment associated with the release of such substances, pollutants, or contaminants. The term includes: equipment or technology modifications, process or procedure modifications, reformulation or redesign of products, substitution of raw materials, and improvements in housekeeping, maintenance, training, or inventory control.

Specific Pollution Prevention Approaches

Pollution prevention approaches can be applied to all pollution-generating activities, including those found in the energy, agriculture, Federal, consumer, as well as industrial sectors. The impairment of wetlands, ground water sources, and other critical resources constitutes pollution, and prevention practices may be essential for preserving these resources.

These practices may include conservation techniques and changes in management practices to prevent harm to sensitive ecosystems. Pollution prevention does not include practices that create new risks of concern. In the agricultural sector, pollution prevention approaches include:

- Reducing the use of water and chemical inputs;
- Adoption of less environmentally harmful pesticides or cultivation of crop strains with natural resistance to pests; and
- Protection of sensitive areas. In the energy sector, pollution prevention can reduce environmental damages from extraction, processing, transport, and combustion of fuels. Pollution prevention approaches include:
 - Increasing efficiency in energy use;
 - Substituting environmentally benign fuel sources; and
 - Design changes that reduce the demand for energy. Some Types of Pollution are: Air, Water and thermal, Radioactive.

HARMFUL EFFECTS OF AIR POLLUTION

- It affects respiratory system of living organisms and causes bronchitis, asthma, lung cancer, pneumonia, *etc.* Carbon monoxide (CO) emitted from motor vehicles and cigarette smoke affects the central nervous system.
- Due to depletion of ozone layer, UV radiation reaches the earth. UV radiation causes skin cancer, damage to eyes and immune system.
- Acid rain is also a result of air pollution. This is caused by presence of oxides of nitrogen and sulfur in the air. These oxides dissolve in rain water to form nitric acid and sulfuric acid respectively. Various monuments, buildings, and statues are damaged due to corrosion by acid present in the rain. The soil also becomes acidic. The cumulative effect is the gradual degradation of soil and a decline in forest and agricultural productivity.
- The green house gases, such as carbon dioxide (CO₂) and methane (CH₄) trap the heat radiated from earth. This leads to an increase in earth's temperature.
- Some toxic metals and pesticides also cause air pollution.

Water Pollution

Water is one of the prime necessities of life. With increasing number of people depend on this resource; water has become a scarce commodity. Pollution makes even the limited available water unfit for use. Water is said to be polluted when there is any physical, biological or chemical change in water quality that adversely affects living organisms or makes water unsuitable for use. Sources of water pollution are mainly factories, power plants, coal mines and oil wells situated either close to water source or away from sources. They discharge pollutants directly or indirectly into the water sources like river, lakes, water streams, *etc.* The harmful effects of water pollution are:

- Human beings become victims of various water borne diseases, such as typhoid, cholera, dysentery, hepatitis, jaundice, *etc.*
- The presence of acids/alkalies in water destroys the microorganisms, thereby hindering the self-purification process in the rivers or water bodies. Agriculture is affected badly due to polluted water. Marine ecosystems are affected adversely.
- The sewage waste promotes growth of phytoplankton in water bodies; causing reduction of dissolved oxygen.
- Poisonous industrial wastes present in water bodies affect the fish population and deprives us of one of our sources of food. It also kills other animals living in fresh water.
- The quality of underground water is also affected due to toxicity and pollutant content of surface water.

Water Pollution by Industries and its Effects

A change in the chemical, physical, biological, and radiological quality of water that is injurious to its uses. The term “water pollution” generally refers to human-induced changes to water quality. Thus, the discharge of toxic chemicals from industries or the release of human or livestock waste into a nearby water body is considered pollution. The contamination of ground water of water bodies like rivers, lakes, wetlands, estuaries, and oceans can threaten the health of humans and aquatic life. Sources of water pollution may be divided into two categories.

- Point-source pollution, in which contaminants are discharged from a discrete location. Sewage outfalls and oil spills are examples of point-source pollution.
- Non-point-source or diffuse pollution, referring to all of the other discharges that deliver contaminants to water bodies. Acid rain and unconfined runoff from agricultural or urban areas falls under this category.

The principal contaminants of water include toxic chemicals, nutrients, biodegradable organics, and bacterial & viral pathogens. Water pollution can affect human health when pollutants enter the body either via skin exposure or through the direct consumption of contaminated drinking water and

contaminated food. Prime pollutants, including DDT and polychlorinated biphenyls (PCBs), persist in the natural environment and bioaccumulation occurs in the tissues of aquatic organisms. These prolonged and persistent organic pollutants are transferred up the food chain and they can reach levels of concern in fish species that are eaten by humans. Moreover, bacteria and viral pathogens can pose a public health risk for those who drink contaminated water or eat raw shellfish from polluted water bodies.

Contaminants have a significant impact on aquatic ecosystems. Enrichment of water bodies with nutrients (principally nitrogen and phosphorus) can result in the growth of algae and other aquatic plants that shade or clog streams. If wastewater containing biodegradable organic matter is discharged into a stream with inadequate dissolved oxygen, the water downstream of the point of discharge will become anaerobic and will be turbid and dark. Settleable solids will be deposited on the streambed, and anaerobic decomposition will occur. Over the reach of stream where the dissolved-oxygen concentration is zero, a zone of putrefaction will occur with the production of hydrogen sulfide (H_2S), ammonia (NH_3), and other odorous gases. Because many fish species require a minimum of 4–5 mg of dissolved oxygen per liter of water, they will be unable to survive in this portion of the stream.

Direct exposures to toxic chemicals are also a health concern for individual aquatic plants and animals. Chemicals such as pesticides are frequently transported to lakes and rivers via runoff, and they can have harmful effects on aquatic life. Toxic chemicals have been shown to reduce the growth, survival, reproductive output, and disease resistance of exposed organisms. These effects can have important consequences for the viability of aquatic populations and communities.

Wastewater discharges are most commonly controlled through effluent standards and discharge permits. Under this system, discharge permits are issued with limits on the quantity and quality of effluents. Water-quality standards are sets of qualitative and quantitative criteria designed to maintain or enhance the quality of receiving waters. Criteria can be developed and implemented to protect aquatic life against acute and chronic effects and to safeguard humans against deleterious health effects, including cancer.

Soil Pollution (Land Degradation)

Land pollution is due to:

- Deforestation and
- Dumping of solid wastes.

Deforestation increases soil erosion; thus valuable agricultural land is lost. Solid wastes from household and industries also pollute land and enhance land degradation. Solid wastes include things from household waste and of industrial wastes. They include ash, glass, peelings of fruit and vegetables, paper, clothes, plastics, rubber, leather, brick, sand, metal, waste from cattle shed, night soil and cow dung. Chemicals discharged into air, such as compounds of sulfur and

lead, eventually come to soil and pollute it. The heaps of solid waste destroy the natural beauty and surroundings become dirty. Pigs, dogs, rats, flies, mosquitoes visit the dumped waste and foul smell comes from the waste. The waste may block the flow of water in the drain, which then becomes the breeding place for mosquitoes. Mosquitoes are carriers of parasites of malaria and dengue. Consumption of polluted water causes many diseases, such as cholera, diarrhea and dysentery.

Noise Pollution

High level noise is a disturbance to the human environment. Because of urbanization, noise in all areas in a city has increased considerably. One of the most pervasive sources of noise in our environment today is those associated with transportation. People reside adjacent to highways, are subjected to high level of noise produced by trucks and vehicles pass on the highways. Prolonged exposure to high level of noise is very much harmful to the health of mankind. In industry and in mines the main sources of noise pollution are blasting, movement of heavy earth moving machines, drilling, crusher and coal handling plants, *etc.* The critical value for the development of hearing problems is at 80 decibels. Chronic exposure to noise may cause noise-induced hearing loss. High noise levels can contribute to cardiovascular effects. Moreover, noise can be a causal factor in workplace accidents.

AIR POLLUTION

Air is a vast renewable resource used by all living things. Unfortunately, the air has also long been a dumping site for tons of unwanted material. Since the air is usually mixed rapidly and thoroughly, whatever is put into it is soon distributed over a wide area. To a certain extent this has always been a part of the "solution"; to disperse pollutants broadly and quickly so that they are no longer a problem. More significantly, however, the fact that the air easily carries pollutants from one area to the next means that one person's "solution" becomes everyone's problem. Air is a rather stable mixture of nitrogen, oxygen, and water vapor, with much smaller amounts of carbon dioxide and several inert gases such as argon and helium. Any changes to this mixture could be considered pollution. Most types of air pollution can be divided into two major categories: pollution by the addition of particles, Particulate Pollution, and pollution by the addition of gases, Gas Pollution.

PARTICULATE POLLUTION

All but the very cleanest air contains small particles of liquid and solid material. By definition, air is composed solely of gases, and thus these particles can be considered pollutants. Some particles have a natural origin, and other are produced by humans. Whatever their origin, particles in the atmosphere can cause problems. The most obvious problem is appearance. Soot and dust in the

air look bad, and the particles eventually settle out of the air and accumulate on leaves, automobiles, and window sills. For many people, particulate pollution is also a significant health problem. Pollen can produce allergic reactions, and prolonged exposure to coal dust and finely powdered rock can produce lung diseases such as black lung and silicosis. On a much larger scale, particles in the atmosphere can lead to the atmospheric condition for which the word "smog" was first coined almost 100 years ago.

SMOG

As most people know, the word "smog" comes from a combination of the words "smoke" and "fog". What might be less familiar is the origin of this term about a century ago in London. At that time, soft coal was the city's primary fuel in factories and homes. Burning soft coal can make a great deal of smoke. London's climate, particularly in the winter, is cold and damp. When moisture-laden air is cooled (as it might be on a bathroom window) the moisture condenses on any available surface. That surface might be a window pane, a water pipe or a cold drink can. Particles suspended in the air also provide surfaces for condensation, and when moisture condenses on particles, they get larger, creating a fog. Thus, smoke can produce fog. Smoke was the primary cause of the famous London fogs, and when the burning of soft coal was curtailed, the fogs began to disappear.

NATURAL CAUSES

Many particles are placed into the atmosphere by natural processes which are unrelated to human activity. Pollen enters the air from flowers and salt crystals form when ocean spray dries. Dust storms and volcanic eruptions put dust into the atmosphere, and forest fires create smoke which is composed predominantly of small particles of ash and minute pieces of unburned carbon.

HUMAN CAUSES

Smoke contains most of the particles which enter the atmosphere as the result of human actions. Visible smoke can be composed of a variety of particles such as soot, unburned fuel and minute pieces of ash. For example, coal-fired electric power stations usually grind coal into a fine powder before burning it. When the powdered coal burns, it makes minute particles of ash which might be carried up the smoke stack and create a gray smoke. Automobiles which are not operating properly often discharge small particles of oil which make a blue smoke, or small amounts of unburned gasoline making a black smoke. Diesel engines often discharge a black smoke composed of particles of soot.

SOLUTIONS

People have developed a variety of means to deal with air pollution. Since particulate pollution was the first and most obvious problem, its solutions came first. There are four common ways to combat particulate pollution:

- (1) *Bag Filters*: Much like giant vacuum cleaner bags, bag filters are suspended inside chimneys and smoke stacks. The smoke or other waste gas is forced to pass through the bag, and the majority of the associated particles are trapped. Some industries collect the particles in truck loads and sell them for use in construction materials such as concrete blocks.
- (2) *Cyclones*: As the name suggests, a cyclone is a mechanism to spin waste gases, forcing the denser particles to the outside and into a collecting device. Textile mills often use this system to remove lint from the air in manufacturing areas.
- (3) *Scrubbers*: These devices use a mist of water to "wash" pollution out of the air. As the polluted air passes through the mist, water droplets stick to the particles and make them heavy enough to fall out of the air. The air is cleaned in much the same way that a rain storm can clean pollen out of the atmosphere. Scrubbers are one of the systems which are effective against both types of pollution. They can also wash some types of gas pollution out of the air. For example, sulfur dioxide (SO₂) will dissolve in water creating an acid rain inside the scrubber rather than outside in a forest.
- (4) *Electro-static Precipitators*: The electro-static precipitator uses static electricity to give the polluting particles a strong electric charge. After receiving their charge the particles pass through a screen with the opposite electric charge, they are attracted to the screen and attach themselves to it. The screen must be washed periodically to remove the particles.

SOIL POLLUTION

Soil pollution is any chemical or biological alteration of soil that is harmful to living organisms. Virtually all soil pollution is the direct result of sources of pollution on the ground surface. These percolation of these surface pollutants through the soil cause soil degradation, but also acts as a natural cleansing process for ground water. However, solutions, through regulations, are feasible.

SOURCES OF SOIL POLLUTION

Pollution on the ground surface is the cause of most soil pollution. This surface pollution comes from many sources, but these can be grouped into three categories:

WASTE DISPOSAL PRACTICES

The disposal of three sources and types of wastes are one of the primary sources of pollution on or near the ground surface. The disposal of these wastes are discussed in these sections:

6

Chemical Substance in Environment

A chemical substance is a material with a specific chemical composition. It is a concept that became firmly established in the late eighteenth century after work by the chemist Joseph Proust on the composition of some pure chemical compounds such as basic copper carbonate. He deduced that, “All samples of a compound have the same composition; that is, all samples have the same proportions, by mass, of the elements present in the compound.” This is now known as the law of constant composition.

Later with the advancement of methods for chemical synthesis particularly in the realm of organic chemistry; the discovery of many more chemical elements and new techniques in the realm of analytical chemistry used for isolation and purification of elements and compounds from chemicals that led to the establishment of modern chemistry, the concept was defined as is found in most chemistry textbooks. However, there are some controversies regarding this definition mainly because the large number of chemical substances reported in chemistry literature need to be indexed.

A common example of a chemical substance is pure water; it has the same properties and the same ratio of hydrogen to oxygen whether it is isolated from a river or made in a laboratory. Some typical chemical substances are diamond, gold, salt (sodium chloride) and sugar (sucrose). Generally, chemical substances exist as a solid, liquid, or gas, and may change between these phases of matter with changes in temperature or pressure. Chemical reactions convert one chemical substance into another.

Forms of energy, such as light and heat, are not considered to be matter, and thus they are not “substances” in this regard. Chemical substances (also

sometimes referred to as a pure substances) are often defined as “any material with a definite chemical composition” in most introductory general chemistry textbooks. A chemical substance can either be a pure chemical element or a pure chemical compound. However, there are exceptions to this definition; a pure substance can also be defined as a form of matter that has both definite composition and distinct properties. The chemical substance index published by CAS also includes several alloys of uncertain composition. Non-stoichiometric compounds are a special case (in inorganic chemistry) that violates the law of constant composition, and for them, it is sometimes difficult to draw the line between a mixture and a compound, as in the case of palladium hydride.

CHEMICAL ELEMENTS

An element is a chemical substance that is made up of a particular kind of atoms and hence cannot be broken down or transformed by a chemical reaction into a different element, though it can be transmuted into another element through a nuclear reaction. This is so, because all of the atoms in a sample of an element have the same number of protons, though they may be different isotopes, with differing numbers of neutrons.

There are about 120 known elements, about 80 of which are stable - that is, they do not change by radioactive decay into other elements. However, the number of chemical substances that are elements can be more than 120, because some elements can occur as more than a single chemical substance (allotropes). For instance, oxygen exists as both diatomic oxygen (O_2) and ozone (O_3).

The majority of elements are classified as metals. These are elements with a characteristic lustre such as iron, copper, and gold. Metals typically conduct electricity and heat well, and they are malleable and ductile. Around a dozen elements, such as carbon, nitrogen, and oxygen, are classified as non-metals. They also have a high electronegativity and a tendency to form negative ions. Certain elements such as silicon sometimes resemble metals and sometimes resemble non-metals, and are known as metalloids.

CHEMICAL COMPOUNDS

A pure chemical compound is a chemical substance that is composed of a particular set of molecules or ions. Two or more elements combined into one substance, through a chemical reaction, form what is called a chemical compound. All compounds are substances, but not all substances are compounds.

A chemical compound can be either atoms bonded together in molecules or crystals in which atoms, molecules or ions form a crystalline lattice. Compounds based primarily on carbon and hydrogen atoms are called organic compounds, and all others are called inorganic compounds. Compounds containing bonds between carbon and a metal are called organometallic compounds. Compounds in which components share electrons are known as covalent compounds. Compounds consisting of oppositely charged ions are known as ionic compounds, or salts. In organic chemistry, there can be more than one chemical

compound with the same composition and molecular weight. Generally, these are called isomers. Isomers usually have substantially different chemical properties, may be isolated and do not spontaneously convert to each other. A common example is glucose vs. fructose. The former is an aldehyde, the latter is a ketone. Their interconversion requires either enzymatic or acid-base catalysis. However, there are also tautomers, where isomerization occurs spontaneously, such that a pure substance cannot be isolated into its tautomers. A common example is glucose, which has open-chain and ring forms. One cannot manufacture pure open-chain glucose because glucose spontaneously cyclizes to the hemiacetal form.

SUBSTANCES VERSUS MIXTURES

All matter consists of various elements and chemical compounds, but these are often intimately mixed together. Mixtures contain more than one chemical substance, and they do not have a fixed composition. In principle, they can be separated into the component substances by purely mechanical processes. Butter, soil and wood are common examples of mixtures.

Grey iron metal and yellow sulfur are both chemical elements, and they can be mixed together in any ratio to form a yellow-grey mixture. No chemical process occurs, and the material can be identified as a mixture by the fact that the sulfur and the iron can be separated by a mechanical process, such as using a magnet to attract the iron away from the sulfur.

In contrast, if iron and sulfur are heated together in a certain ratio (56 grams (1 mol) of iron to 32 grams (1 mol) of sulfur), a chemical reaction takes place and a new substance is formed, the compound iron(II) sulfide, with chemical formula FeS . The resulting compound has all the properties of a chemical substance and is not a mixture. Iron(II) sulfide has its own distinct properties such as melting point and solubility, and the two elements cannot be separated using normal mechanical processes; a magnet will be unable to recover the iron, since there is no metallic iron present in the compound.

Chemicals Versus Chemical Substances

While the term *chemical substance* is a somewhat technical term used most often by professional chemists, the word *chemical* is more widely used in the pharmaceutical industry, government and society in general. Thus the word *chemical* includes a much wider class of substances that includes many mixtures of chemical substances that often find application in many vocations; and is most commonly used only for artificial or processed substances, such as the products of the chemical industry.

Naming and Indexing

Every chemical substance has one or more systematic names, usually named according to the IUPAC rules for naming. An alternative system is used by the Chemical Abstracts Service (CAS). Many compounds are also known by their

more common, simpler names, many of which predate the systematic name.

For example, the long-known sugar glucose is now systematically named 6-(hydroxymethyl)oxane-2,3,4,5-tetrol. Natural products and pharmaceuticals are also given simpler names, for example the mild pain-killer Naproxen is the more common name for the chemical compound (S)-6-methoxy- α -methyl-2-naphthaleneacetic acid.

Chemists frequently refer to chemical compounds using chemical formulae or molecular structure of the compound. There has been a phenomenal growth in the number of chemical compounds being synthesized (or isolated), and then reported in the scientific literature by professional chemists around the world. An enormous number of chemical compounds are possible through the chemical combination of the known chemical elements.

At the last count, about thirty million chemical compounds are known. The names of many of these compounds are often nontrivial and hence not very easy to remember or cite accurately. Also it is difficult to keep the track of them in the literature. Several international organizations like IUPAC and CAS have initiated steps to make such tasks easier.

CAS provides the abstracting services of the chemical literature, and provides a numerical identifier, known as CAS registry number to each chemical substance that has been reported in the chemical literature.

Table. Identification of a Typical Chemical Substance

Common Name	Systematic Name	Chemical Formula	Chemical Structure	CAS Registry Number	InChI
Alcohol, or ethyl alcohol	Ethanol	C ₂ H ₅ OH		[64–17–5]	1/C ₂ H ₆ O/c1–2–3/h3H, ² H ₂ , ¹ H ₃

CADMIUM

Cadmium is a chemical element with the symbol Cd and atomic number 48. The soft, bluish-white transition metal is chemically similar to the two other metals in group 12, zinc and mercury.

Similar to zinc it prefers oxidation state +2 in most of its compounds and similar to mercury it shows a low melting point for a transition metal. Cadmium is a relatively abundant element. Cadmium was discovered in 1817 by Friedrich Strohmeyer as an impurity in zinc carbonate.

Cadmium occurs as minor component in most zinc ores and therefore is a by-product of zinc production. Cadmium was for a long time used as pigment and for corrosion resistant plating on steel. Cadmium compounds were used to stabilize plastic. With the exception of its use in nickel-cadmium batteries, the use of cadmium is generally decreasing in all other applications.

This decrease is due to the high toxicity and carcinogenicity of cadmium and the associated health and environmental concerns. Although cadmium is toxic, one enzyme, a carbonic anhydrase with a cadmium as reactive centre has been discovered.

CHARACTERISTICS

Cadmium is a soft, malleable, ductile, toxic, bluish-white bivalent metal. It is similar in many respects to zinc but forms more complex compounds.

Chemical

The most common oxidation state of cadmium is +2, though rare examples of +1 can be found. Cadmium burns in air to form brown amorphous cadmium oxide (CdO). The crystalline form of the same compound is dark red and changes colour when heated, similar to zinc oxide. Hydrochloric acid, sulfuric acid and nitric acid dissolve cadmium by forming cadmium chloride (CdCl₂) cadmium sulfate (CdSO₄) or cadmium nitrate (Cd(NO₃)₂).

The oxidation state +1 can be reached by dissolving cadmium in a mixture of cadmium chloride and aluminium chloride, forming the Cd₂²⁺ which is similar to the Hg₂²⁺ in mercury(I) chloride.



Isotopes

Naturally occurring cadmium is composed of 8 isotopes. For two of them, natural radioactivity was observed, and three others are predicted to be radioactive but their decay is not observed, due to extremely long half-life times.

The two natural radioactive isotopes are ¹¹³Cd (beta decay, half-life is 7.7×10^{15} years) and ¹¹⁶Cd (two-neutrino double beta decay, half-life is 2.9×10^{19} years).

The other three are ¹⁰⁶Cd, ¹⁰⁸Cd (double electron capture), and ¹¹⁴Cd (double beta decay); only lower limits on their half-life times have been set.

At least three isotopes - ¹¹⁰Cd, ¹¹¹Cd, and ¹¹²Cd - are stable. Among the isotopes absent in natural cadmium, the most long-lived are ¹⁰⁹Cd with a half-life of 462.6 days, and ¹¹⁵Cd with a half-life of 53.46 hours. All of the remaining radioactive isotopes have half-lives that are less than 2.5 hours, and the majority of these have half-lives that are less than 5 minutes.

This element also has 8 known meta states, with the most stable being ^{113m}Cd (t_{1/2} 14.1 years), ^{115m}Cd (t_{1/2} 44.6 days), and ^{117m}Cd (t_{1/2} 3.36 hours). The known isotopes of cadmium range in atomic mass from 94.950 u (⁹⁵Cd) to 131.946 u (¹³²Cd). The primary decay mode before the second-most-abundant stable isotope, ¹¹²Cd, is electron capture, and the primary modes after are beta emission.

The primary decay product before ¹¹²Cd is element 47 (silver), and the primary product after is element 49 (indium). One isotope of cadmium, ¹¹³Cd, absorbs neutrons with very high probability if they have an energy below the *cadmium cut-off* and transmits them readily otherwise.

The cadmium cut-off is about 0.5 eV. Neutrons with energy below the cutoff are deemed slow neutrons, distinguishing them from intermediate and fast neutrons.

APPLICATIONS

Batteries

About three-quarters of all the cadmium used is in batteries, predominantly in rechargeable nickel-cadmium batteries. Nickel-cadmium cells have a nominal cell potential of 1.2 V.

The cell consists of a positive nickel hydroxide electrode and a negative cadmium electrode plate separated by an alkaline electrolyte (potassium hydroxide). More recent nickel-metal hydride batteries reduce the use of Ni-Cd batteries. The European Union banned the use of cadmium in electronics in 2004 with several exceptions but reduced the allowed content of cadmium in electronics to 0.002 %.

Other Uses

Most of the remaining quarter is used mainly for cadmium pigments, coatings and plating, and as stabilizers for plastics. Other uses include:

- In some of the lowest-melting alloys, for example Wood's metal.
- In bearing alloys, due to a low coefficient of friction and very good fatigue resistance.
- In electroplating (6% cadmium). Cadmium electroplating is widely used in aircraft industry due to the excellent corrosion resistance of cadmium-plated steel components. Cadmium provides cathodic protection to low-alloyed steels, since it is positioned lower in the galvanic series. The coating is usually passivated by chromate salts. A significant limitation of cadmium plating is hydrogen embrittlement of high-strength steels caused by the electroplating process. Therefore, steel parts heat-treated to tensile strength above 1300 MPa (200 ksi) should be coated by an alternative method (such as special low-embrittlement cadmium electroplating processes or physical vapour deposition).
- In many kinds of solder
- As a barrier to control neutrons in nuclear fission
- The pressurized water reactor designed by Westinghouse Electric Company used an alloy consisting of 80% Ag, 15% In, and 5% Cd.
- Cadmium oxide in black and white television phosphors and in the blue and green phosphors for colour television picture tubes.
- Cadmium sulfide (CdS) as a photoconductive surface coating for photocopier drums.
- In paint pigments, cadmium forms various salts, with CdS being the most common. This sulfide is used as a yellow pigment. Cadmium selenide can be used as red pigment, commonly called *cadmium red*. To painters who work with the pigment, cadmium yellows, oranges, and reds are the most potent colours to use. In fact, during production, these colours are significantly toned down before they are ground with oils and binders, or blended into watercolours, gouaches, acrylics, and

other paint and pigment formulations. These pigments are toxic, and it is recommended to use a barrier cream on the hands to prevent absorption through the skin when working with them.

- In some semiconductors such as cadmium sulfide, cadmium selenide, and cadmium telluride, which can be used for light detection or solar cells. HgCdTe is sensitive to infrared.
- In PVC as stabilizers.
- In molecular biology, it is used to block voltage-dependent calcium channels from fluxing calcium ions.

OCCURRENCE

Cadmium-containing ores are rare and are found to occur in small quantities. However, traces do naturally occur in phosphate, and have been shown to transmit in food through fertilizer application. Greenockite (CdS), the only cadmium mineral of importance, is nearly always associated with sphalerite (ZnS).

As a consequence, cadmium is produced mainly as a byproduct from mining, smelting, and refining sulfide ores of zinc, and, to a lesser degree, lead and copper. Small amounts of cadmium, about 10% of consumption, are produced from secondary sources, mainly from dust generated by recycling iron and steel scrap. Production in the United States began in 1907, but it was not until after World War I that cadmium came into wide use. One place where metallic cadmium can be found is the Vilyuy River basin in Siberia.

EXTRACTION

In 2001, China was the top producer of cadmium with almost one-sixth world share closely followed by South Korea and Japan, reports the British Geological Survey. Cadmium is a common impurity in zinc ores, and it is most often isolated during the production of zinc. Some zinc ores concentrates from sulfidic zinc ores contain up to 1.4 % of cadmium. In 1970s the output of cadmium was 6.5 pounds per ton of zinc. Zinc sulfide ores are roasted in the presence of oxygen, converting the zinc sulfide to the oxide. Zinc metal is produced either by smelting the oxide with carbon or by electrolysis in sulfuric acid. Cadmium is isolated from the zinc metal by vacuum distillation if the zinc is smelted, or cadmium sulfate is precipitated out of the electrolysis solution.

BIOLOGICAL ROLE

A role of cadmium in biology has been recently discovered. A cadmium-dependent carbonic anhydrase has been found in marine diatoms. Cadmium does the same job as zinc in other anhydrases, but the diatoms live in environments with very low zinc concentrations, thus biology has taken cadmium rather than zinc, and made it work. The discovery was made using X-ray absorption fluorescence spectroscopy (XAFS), and cadmium was characterized by noting the energy of the X-rays that were absorbed.

TOXICITY

Cadmium poisoning is an occupational hazard associated with industrial processes such as metal plating and the production of nickel-cadmium batteries, pigments, plastics, and other synthetics. The primary route of exposure in industrial settings is inhalation. Inhalation of cadmium-containing fumes can result initially in metal fume fever but may progress to chemical pneumonitis, pulmonary edema, and death. Cadmium is also a potential environmental hazard.

Human exposures to environmental cadmium are primarily the result of the burning of fossil fuels and municipal wastes. However, there have been notable instances of toxicity as the result of long-term exposure to cadmium in contaminated food and water. In the decades leading up to World War II, Japanese mining operations contaminated the Jinzu River with cadmium and traces of other toxic metals. As a consequence, cadmium accumulated in the rice crops growing along the riverbanks downstream of the mines.

The local agricultural communities consuming the contaminated rice developed Itai-itai disease and renal abnormalities, including proteinuria and glucosuria. Cadmium is one of six substances banned by the European Union's Restriction on Hazardous Substances (RoHS) directive, which bans certain hazardous substances in electronics. Cadmium and several cadmium-containing compounds are known carcinogens and can induce many types of cancer.

Research has found that cadmium toxicity may be carried into the body by zinc binding proteins; in particular, proteins that contain zinc finger protein structures. Zinc and cadmium are in the same group on the periodic table, contain the same common oxidation state (+2), and when ionized are almost the same size. Due to these similarities, cadmium can replace zinc in many biological systems, in particular, systems that contain softer ligands such as sulfur. Cadmium can bind up to ten times more strongly than zinc in certain biological systems, and is notoriously difficult to remove. In addition, cadmium can replace magnesium and calcium in certain biological systems, although these replacements are rare.

Tobacco smoking is the most important single source of cadmium exposure in the general population. It has been estimated that about 10% of the cadmium content of a cigarette is inhaled through smoking. The absorption of cadmium from the lungs is much more effective than that from the gut, and as much as 50% of the cadmium inhaled via cigarette smoke may be absorbed.

On average, smokers have 4-5 times higher blood cadmium concentrations and 2-3 times higher kidney cadmium concentrations than non-smokers. Despite the high cadmium content in cigarette smoke, there seems to be little exposure to cadmium from passive smoking. No significant effect on blood cadmium concentrations could be detected in children exposed to environmental tobacco smoke.

CHROMIUM

Chromium is a chemical element which has the symbol Cr and atomic number 24. It is a steely-gray, lustrous, hard metal that takes a high polish and has a

high melting point. It is also odourless, tasteless, and malleable. The name of the element is derived from the Greek word “chrōma”, meaning colour, because many of its compounds are intensely coloured. It was discovered by Louis Nicolas Vauquelin in the mineral crocoite in 1797. Crocoite was used as a pigment, and after the discovery that the mineral chromite also contains chromium this latter mineral was used to produce pigments as well.

Chromium was regarded with great interest because of its high corrosion resistance and hardness. A major development was the discovery that steel could be made highly resistant to corrosion and discolouration by adding chromium and nickel to form stainless steel. This application, along with chrome plating (electroplating with chromium) are currently the highest-volume uses of the metal. Chromium and ferrochromium are produced from the single commercially viable ore, chromite, by silicothermic or aluminothermic reaction or by roasting and leaching processes. Although trivalent chromium (Cr(III)) is required in trace amounts for sugar and lipid metabolism in humans and its deficiency may cause a disease called chromium deficiency, hexavalent chromium (Cr(VI)) is a toxin and a carcinogen, so that abandoned chromium production sites need environmental cleanup.

CHARACTERISTICS

Occurrence

Chromium is the 21st most abundant element in Earth's crust with an average concentration of 100 ppm. Chromium compounds are found in the environment, due to erosion of chromium-containing rocks and can be distributed by volcanic eruptions. The concentrations range in soil is between 1 and 3000 mg/kg, in sea water 5 to 800 µg/litre, and in rivers and lakes 26 µg/litre to 5.2 mg/litre. The relation between Cr(III) and Cr(VI) strongly depends on pH and oxidative properties of the location, but in most cases, the Cr(III) is the dominating species, although in some areas the ground water can contain up to 39 µg of total chromium of which 30 µg is present as Cr(VI).

Chromium is mined as chromite (FeCr_2O_4) ore. About two-fifths of the chromite ores and concentrates in the world are produced in South Africa, while Kazakhstan, India, Russia, and Turkey are also substantial producers. Untapped chromite deposits are plentiful, but geographically concentrated in Kazakhstan and southern Africa.

Though native chromium deposits are rare, some native chromium metal has been discovered. The Udachnaya Pipe in Russia produces samples of the native metal. This mine is a kimberlite pipe rich in diamonds, and the reducing environment helped produce both elemental chromium and diamond.

Isotopes

Naturally occurring chromium is composed of three stable isotopes; ^{52}Cr , ^{53}Cr , and ^{54}Cr with ^{52}Cr being the most abundant (83.789% natural abundance).

Nineteen radioisotopes have been characterized with the most stable being ^{50}Cr with a half-life of (more than) 1.8×10^{17} years, and ^{51}Cr with a half-life of 27.7 days. All of the remaining radioactive isotopes have half-lives that are less than 24 hours and the majority of these have half-lives that are less than 1 minute. This element also has 2 meta states.

^{53}Cr is the radiogenic decay product of ^{53}Mn . Chromium isotopic contents are typically combined with manganese isotopic contents and have found application in isotope geology. Mn-Cr isotope ratios reinforce the evidence from ^{26}Al and ^{107}Pd for the early history of the solar system. Variations in $^{53}\text{Cr}/^{52}\text{Cr}$ and Mn/Cr ratios from several meteorites indicate an initial $^{53}\text{Mn}/^{55}\text{Mn}$ ratio that suggests Mn-Cr isotopic composition must result from in-situ decay of ^{53}Mn in differentiated planetary bodies. Hence ^{53}Cr provides additional evidence for nucleosynthetic processes immediately before coalescence of the solar system.

The isotopes of chromium range in atomic mass from 43 u (^{43}Cr) to 67 u (^{67}Cr). The primary decay mode before the most abundant stable isotope, ^{52}Cr , is electron capture and the primary mode after is beta decay.

Chemistry

Oxidation States of Chromium	
-2	$\text{Na}_2[\text{Cr}(\text{CO})_5]$
-1	$\text{Na}_2[\text{Cr}_2(\text{CO})_{10}]$
0	$\text{Cr}(\text{C}_6\text{H}_6)_2$
+1	$\text{K}_3[\text{Cr}(\text{CN})_5\text{NO}]$
+2	CrCl_2
+3	CrCl_3
+4	K_2CrF_6
+5	K_3CrO_8
+6	K_2CrO_4

Chromium is a member of the transition metals, in group 6. Chromium(0) has an electronic configuration of $4s^1 3d^5$, due to the lower energy of the high spin configuration. Chromium exhibits a wide range of possible oxidation states. The most common oxidation states of chromium are +2, +3, and +6, with +3 being the most stable. +1, +4 and +5 are rare.

Chromium compounds of oxidation state +6 are powerful oxidants. All (except the hexafluoride and chromium hexacarbonyl) stable chromium compounds of the oxidation state +6 contain oxygen as ligand, for example the chromate (CrO_4^{2-}) and Chromyl chloride (CrO_2Cl_2).

Chemistry and Compounds

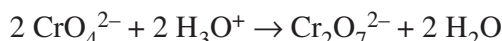
The oxidation state 3+ is the most stable one and therefore a large number of chromium(III) compounds is known. Chromium(III) can be obtained by dissolving chromium in acids like hydrochloric acid or sulfuric acid. The

aluminium(III) (ion radius 0.50 Å) and chromium(III) (ion radius 0.63 Å) can replace each other in some compounds, for example chrome alum and alum. Another example is aluminium oxide (corundum, Al_2O_3) where by replacement, the red coloured ruby is formed. Chromium tends to form complexes, for example with water molecules (hydrates); the chromium ions in water are usually octahedrally coordinated. The commercially available chromium(III) chloride hydrate is the dark green complex $[\text{CrCl}_2(\text{H}_2\text{O})_4]\text{Cl}$, but two other forms are known, *viz.*, pale green $[\text{CrCl}(\text{H}_2\text{O})_5]\text{Cl}_2$ and violet $[\text{Cr}(\text{H}_2\text{O})_6]\text{Cl}_3$.

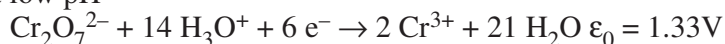
If water-free green chromium(III) chloride is dissolved in water then the green solution turn violet after some time. This colour change is due to the substitution of water for chloride in the inner coordination sphere. This kind of reactions is also observed in chrome alum solutions and some other water soluble chromium(III) salts, and the reverse reaction can be induced by heating the solution.

The chromium(III) hydroxide $\text{Cr}(\text{OH})_3$ shows amphoteric reactions and dissolves in acid water by forming $[\text{Cr}(\text{H}_2\text{O})_6]^{3+}$ and in basic water by forming $[\text{Cr}(\text{OH})_6]^{3-}$. By heating the chromium(III) hydroxide it is transformed into the green chromium(III) oxide (Cr_2O_3), which is the stable oxide (melting point of 2275 °C) with the crystal structure identical to that of corundum.

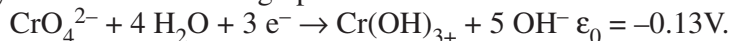
The second stable oxidation state is 6+, for example the chromate, which is produced in large scale by oxidative roasting of chromite ore with calcium or sodium carbonate. Chromate and dichromate are in an equilibrium, which is influenced in that case by the law of mass action and therefore by the pH of the solution.



The change in equilibrium is also visible by a change from yellow (chromate) to orange (dichromate) if an acid is added to a neutral solution of potassium chromate. At lower pH, further condensation to more complex oxyanions of chromium is possible. The chromate and dichromate are strong oxidizing reagents at low pH



but only moderate ones at high pH



Chromium(VI) compounds in solution can be detected by adding acidic hydrogen peroxide solution. A dark blue unstable chromium(VI) peroxide (CrO_5) is formed which can be stabilized as an ether adduct $\text{CrO}_5 \cdot \text{OR}_2$. Chromic acid has the hypothetical structure H_2CrO_4 . Neither chromic nor dichromic acid is found in nature, but their anions are found in a variety of compounds, the chromates and dichromates. chromium(VI) oxide CrO_3 , the acid anhydride of chromic acid, is sold industrially as “chromic acid”. The dark red chromium(VI) oxide can be produced by mixing sulfuric acid with dichromate, and is an extremely strong oxidizing agent. The oxidation state 5+ is only realized in few compounds. The only binary compound is the highly volatile chromium(V) fluoride (CrF_5). This red solid with a melting point of 30°C and a boiling point

of 117°C can be synthesized by reacting fluorine with chromium at 400°C and 200 bar pressure. The peroxochromate(V) is another example of the oxidation state 5+. The potassium peroxochromate ($K_3[Cr(O_2)_4]$) is made by reacting potassium chromate with hydrogen peroxide at low temperatures.

This red brown compound is stable at room temperature but decomposes spontaneously at 150–170°C. The chromium(IV) compounds (4+) are slightly more stable than the chromium(V) compounds, and the halogen compounds CrF_4 , $CrCl_4$ and $CrBr_4$ can be produced by the reaction of the trihalogens with additional elementary halogens at elevated temperatures.

Most of the compounds are susceptible to disproportionation reactions and therefore are not stable in water. An example for a Chromium(II) compounds (2+) is the water stable chromium(II) chloride which can be produced by reduction of chromium(III) chloride with zinc. The resulting light blue solutions are only stable at neutral pH when the solution is very pure.

PASSIVATION

Chromium is passivated by oxygen, forming a thin protective oxide surface layer. This layer is a spinel structure only a few atoms thick. It is very dense, preventing diffusion of oxygen into the underlying material. (In iron or plain carbon steels the oxygen migrates into the underlying material.) Chromium is usually plated on top of a nickel layer which may first have been copper plated. Chromium, unlike metals such as iron and nickel, does not suffer from hydrogen embrittlement. It does suffer from nitrogen embrittlement - chromium reacts with nitrogen from air and forms brittle nitrides at temperatures necessary to work the metal parts. The passivation can be increased by short contact with oxidizing acids like nitric acid. The passivated chromium is stable against acids. The contrary effect can be achieved if a strong reducing reactant destroys the oxide protection layer on the metal, a metal treated in this way readily dissolves in weak acids.

QUINTUPLE BOND

Chromium is notable for its ability to form quintuple covalent bonds. The synthesis of a compound of chromium(I) and a hydrocarbon radical was shown via X-ray diffraction to contain a quintuple bond of length 183.51(4) pm (1.835 angstroms) joining the two central chromium atoms. Extremely bulky monodentate ligands prevent that bonds to other atoms can be formed and therefore stabilizes this compound.

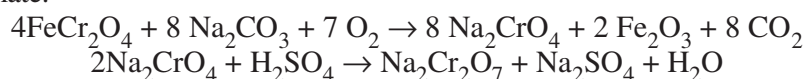
Physical Properties

Chromium is remarkable by its magnetic properties: it is the only elemental solid which shows antiferromagnetic ordering at room temperature. Above 38 °C, it transforms into a paramagnetic state.

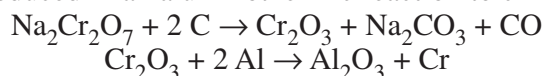
Production

Approximately 4.4 million metric tons of marketable chromite ore were produced in 2000, and converted into ~3.3 million tons of ferro-chrome with an approximate

market value of 2.5 billion United States dollars. The largest producers of chromium ore have been South Africa (44%) India (18%), Kazakhstan (16%) Zimbabwe (5%), Finland (4%) Iran (4%) and Brazil (2%) with several other countries producing the rest of less than 10% of the world production. The two main products of chromium ore refining are ferrochromium and metallic chromium. For those products the ore smelter process differs considerably. For the production of ferrochromium, the chromite ore (FeCr_2O_4) is reduced in large scale in electric arc furnace or in smaller smelters with either aluminium or silicon in an aluminothermic reaction. For the production of pure chromium, the iron has to be separated from the chromium in a two step roasting and leaching process. The chromite ore is heated with a mixture of calcium carbonate and sodium carbonate in the presence of air. The chromium is oxidized to the hexavalent form, while the iron forms the stable Fe_2O_3 . The subsequent leaching at higher elevated temperatures dissolves the chromates and leaves the insoluble iron oxide. The chromate is converted by sulfuric acid into the dichromate.



The dichromate is converted to the chromium(III) oxide by reduction with carbon and then reduced in an aluminothermic reaction to chromium.



APPLICATIONS

Metallurgy

The strengthening effect on steel by forming stable carbide grains at the grain boundaries and the strong increase in corrosion resistance made chromium an important alloying material for steel. The high speed tool steels contain between 3 and 5% chromium. An important stainless steel is 18/10 *stainless*, made from iron with 10% nickel and 18% chromium, is widely used for cookware and cutlery. For these applications, ferrochromium is added to the molten iron. Also nickel-based alloys increase in strength due to the formation of stable carbide grains at the grain boundaries. For example, Inconel 718 contains 18.6% chromium. Because of the excellent heat stability of these nickel superalloys, they are used in jet engines and gas turbines in large quantities.

The relative high hardness and corrosion resistance of unalloyed chromium makes it a good surface coating. A thin layer of chromium is deposited on pretreated metallic surfaces by electroplating techniques. There are two deposition methods: Thin, below 1 μm thickness, layers are deposited by chrome plating, and are used for decorative surfaces. If wear-resistant surfaces are needed then thicker chromium layers of up to mm thickness are deposited. Both methods normally use acidic chromate or dichromate solutions. To prevent the energy consuming change in oxidation state, the use of Chromium(III) sulfate is under development, but for most applications, the established process is used.

In the chromate conversion coating process, the strong oxidative properties of chromates are used to deposit a protective oxide layer on metals like aluminium, zinc and cadmium. This passivation and the self healing properties by the chromate stored in the chromate conversion coating, which is capable to migrate to local defects, are the benefits of this coating method. Because of environmental and health regulations on chromates, alternative coating method are under development.

Anodizing of aluminium is another electrochemical process, which does not lead to the deposition of chromium, but uses chromic acid as electrolyte in the solution. During anodization, an oxide layer is formed on the aluminium. The use of chromic acid, instead of the normally used sulfuric acid, leads to a slight difference of these oxide layers. The high toxicity of Cr(VI) compounds, used in the established chromium electroplating process, and the strengthening of safety and environmental regulations demand a search for substitutes for chromium or at least a change to less toxic chromium(III) compounds.

Dye and Pigment

The mineral crocoite was used as a yellow pigment recently after its discovery. After a synthesis method became available starting from the more abundant chromite, Chrome yellow was, together with cadmium yellow, one of the most used yellow pigments. The pigment does not degrade in the light and has a strong colour. The signaling effect of yellow was used for school buses in the United States and for Postal Service in Europe. The use of chrome yellow declined due to environmental and safety concerns and was substituted by organic pigments or other lead-free alternatives. Other pigments based on chromium are, for example, the bright red pigment Chrome red, which is a basic lead chromate ($\text{PbCrO}_4 \cdot \text{Pb}(\text{OH})_2$). Chrome green is a mixture of Prussian blue and chrome yellow, while the Chrome oxide green is Chromium(III) oxide.

Glass is coloured green by the addition of chromium(III) oxide. This is similar to emerald, which is also coloured by chromium. A red colour is achieved by doping chromium(III) into the crystals of corundum, which are then called ruby. Therefore, chromium is used in producing synthetic rubies. The toxicity of chromium(VI) salts is used in the preservation of wood. For example, chromated copper arsenate (CCA) is used in timber treatment to prevent wood from decay fungi, wood attacking insects, including termites, and marine borers. The formulations contain chromium based on the oxide CrO_3 between 35.3% and 65.5%. In the United States, 65,300 metric tons of CCA solution have been used in 1996.

Tanning

Chromium(III) salts, especially chrome alum and chromium(III) sulfate, are used in the tanning of leather. The chromium(III) stabilizes the leather by cross linking the collagen fibres within the leather. Chromium tanned leather can contains between 4 and 5% of chromium, which is tightly bound to the proteins.

Refractory Material

The high heat resistivity and high melting point makes chromite and chromium(III) oxide a material for high temperature refractory applications, like blast furnaces, cement kilns, molds for the firing of bricks and as foundry sands for the casting of metals. In these applications, the refractory materials are made from mixtures of chromite and magnesite. The use is declining because of the environmental regulations due to the possibility of the formation of chromium(VI).

Other Use

Several chromium compounds are used as catalyst. For example the Phillips catalysts for the production polyethylene are mixtures of chromium and silicon dioxide or mixtures of chromium and titanium and aluminium oxide. Chromium(IV) oxide (CrO_2) is a magnetic compound. Its ideal shape anisotropy, which imparted high coercivity and remanent magnetization, made it a compound superior to the $\alpha\text{-Fe}_2\text{O}_3$.

Chromium(IV) oxide is used to manufacture magnetic tape used in high performance audio tape and standard audio cassette. Chromates can prevent corrosion of steel under wet conditions, and therefore chromates are added to the drilling muds.

The long known influence of chromium uptake on diabetes conditions suggested the positive influence of dietary supplement containing chromium(III) also on healthy persons. For this reason, dietary supplement or slimming aid usually contain chromium(III) chloride, chromium(III) picolinate, chromium(III) polynicotinate or amino acid chelate, such as chromium(III) D-phenylalanine.

The benefit of those supplements is still under investigation and is questioned by some studies:

- Chromium hexacarbonyl $\text{Cr}(\text{CO})_6$ is used as a gasoline additive.
- Chromium(III) oxide is a metal polish known as green rouge.
- Chromic acid is a powerful oxidizing agent and is a useful compound for cleaning laboratory glassware of any trace of organic compounds. It is prepared *in situ* by dissolving potassium dichromate in concentrated sulfuric acid, which is then used to wash the apparatus. Sodium dichromate is sometimes used because of its higher solubility (5 g/100 ml vs. 20 g/100 ml respectively). Potassium dichromate is a chemical reagent, used in cleaning laboratory glassware and as a titrating agent. It is also used as a mordant (*i.e.*, a fixing agent) for dyes in fabric.

ARSENIC

Arsenic is the chemical element that has the symbol As and atomic number 33. Arsenic was first documented by Albertus Magnus in 1250. Its atomic mass is 74.92. This is a notoriously poisonous metalloid that has many allotropic forms: yellow (molecular non-metallic) and several black and grey forms (metalloids) are a few that are seen. Three metalloidal forms of arsenic with different crystal structures are found free in nature (the minerals arsenic *sensu*

stricto and the much rarer arsenolamprite and pararsenolamprite), but it is more commonly found as arsenide and arsenate compounds. Several hundred such mineral species are known. Arsenic and its compounds are used as pesticides, herbicides, insecticides and various alloys.

CHARACTERISTICS

Isotopes

Naturally occurring arsenic is composed of one stable isotope. As of 2003, at least 33 radioisotopes have also been synthesized, ranging in atomic mass from 60 to 92. The most stable of these is ^{73}As with a half-life of 80.3 days. Isotopes that are lighter than the stable ^{75}As tend to decay by β^+ decay, and those that are heavier tend to decay by β^- decay, with some exceptions. At least 10 nuclear isomers have been described, ranging in atomic mass from 66 to 84. The most stable of arsenic's isomers is $^{68\text{m}}\text{As}$ with a half-life of 111 seconds.

Allotropes

Like phosphorus, arsenic is an excellent example of an element that exhibits allotropy, as its various allotropes have strikingly different properties. The three most common allotropes are *metallic grey*, *yellow* and *black arsenic*. The most common allotrope of arsenic is *grey arsenic*. It has a similar structure to black phosphorus (β -metallic phosphorus) and has a layered crystal structure somewhat resembling that of graphite.

It consists of many six-membered rings which are interlinked. Each atom is bound to three other atoms in the layer and is coordinated by each 3 arsenic atoms in the upper and lower layer. This relatively close packing leads to a high density of 5.73 g/cm^3 .

Yellow arsenic (As_4) is soft and waxy, not unlike P_4 . Both have four atoms arranged in a tetrahedral structure in which each atom is bound to the other three atoms by a single bond, resulting in very high ring strain and instability. This form of the elements are the least stable, most reactive, more volatile, less dense, and more toxic than the other allotropes. Yellow arsenic is produced by rapid cooling of arsenic vapour with liquid nitrogen. It is rapidly transformed into the grey arsenic by light. The yellow form has a density of 1.97 g/cm^3 .

Chemical

The most common oxidation states for arsenic are -3 (arsenides: usually alloy-like intermetallic compounds), $+3$ (arsenates(III) or arsenites, and most organoarsenic compounds), and $+5$ (arsenates: the most stable inorganic arsenic oxycompounds). Arsenic also bonds readily to itself, forming square As_3-4 ions in the arsenide skutterudite. In the $+3$ oxidation state, the stereochemistry of arsenic is affected by possession of a lone pair of electrons.

Arsenic is very similar chemically to its predecessor in the Periodic Table, phosphorus. Like phosphorus, it forms colourless, odourless, crystalline oxides As_2O_3 and As_2O_5 which are hygroscopic and readily soluble in water to form

acidic solutions. Arsenic(V) acid is a weak acid. Like phosphorus, arsenic forms an unstable, gaseous hydride: arsine (AsH_3). The similarity is so great that arsenic will partly substitute for phosphorus in biochemical reactions and is thus poisonous. However, in subtoxic doses, soluble arsenic compounds act as stimulants, and were once popular in small doses as medicinals by people in the mid 18th century.

When heated in air, arsenic oxidizes to arsenic trioxide; the fumes from this reaction have an odour resembling garlic. This odour can be detected on striking arsenide minerals such as arsenopyrite with a hammer. Arsenic (and some arsenic compounds) sublimes upon heating at atmospheric pressure, converting directly to a gaseous form without an intervening liquid state. The liquid state appears at 20 atmospheres and above, which explains why the melting point is higher than the boiling point.

Compounds

Arsenic compounds resemble in many respects those of phosphorus as both arsenic and phosphorus occur in the same group (column) of the periodic table. The most important compounds of arsenic are arsenic(III) oxide, As_2O_3 , ("white arsenic"), the yellow sulfide orpiment (As_2S_3) and red realgar (As_4S_4), Paris Green, calcium arsenate, and lead hydrogen arsenate. The latter three have been used as agricultural insecticides and poisons.

Whilst arsenic trioxide forms during oxidation of arsenic, arsenic pentoxide is formed by the dehydration of arsenic acid. Both oxides dissolve in strong alkaline solution, with the formation of arsenite AsO_3^{-3} and arsenate AsO_3^{-4} respectively. The protonation steps between the arsenate and arsenic acid are similar to those between phosphate and phosphoric acid.

However, arsenite and arsenous acid contain arsenic bonded to three oxygens and not hydrogen, in contrast to phosphite and phosphorous acid (more accurately termed 'phosphonic acid'), which contain non-acidic P-H bonds. Arsenous acid is genuinely tribasic, whereas phosphonic acid is not.

A broad variety of sulfur compounds of arsenic are known, As_4S_3 , As_4S_4 , As_2S_3 and As_4S_{10} . All arsenic(III) halogen compounds (except with astatine) are known and stable. For the arsenic(V) compounds the situation is different: only the arsenic pentafluoride is stable at room temperature. Arsenic pentachloride is only stable at temperatures below -50°C and the pentabromide and pentaiodide are unknown.

Arsenic is used as group 5 element as part of the III-V semiconducting compounds. Gallium arsenide, indium arsenide and aluminium arsenide are used as semiconductor material when the properties of silicon are not suitable for the application and the higher price of the compounds is acceptable.

- Arsenic acid (H_3AsO_4)
- Arsenous acid (H_3AsO_3)
- Arsenic trioxide (As_2O_3)
- Arsine (Arsenic Trihydride AsH_3)

- Cadmium arsenide (Cd_3As_2)
- Gallium arsenide (GaAs)
- Lead hydrogen arsenate (PbHAsO_4)

Arsenic also has a formal oxidation state of +2 in As_4S_4 , realgar. This is achieved by pairing As atoms to produce dimeric cations $[\text{As}-\text{As}]^{2+}$, so the total covalency of As is still in fact three.

Occurrence

Arsenopyrite, also unofficially called mispickel, (FeAsS) is the most common arsenic-bearing mineral. In the lithosphere the minerals of the formula M(II)AsS , with M(II) being mostly Fe, Ni and Co, are the dominant arsenic minerals.

Orpiment and realgar were formerly used as painting pigments, though they have fallen out of use due to their toxicity and reactivity. Although arsenic is sometimes found native in nature, it is also found in arsenides of metals such as silver, cobalt (cobaltite: CoAsS and skutterudite: CoAs_3) and nickel, as sulfides, and when oxidised as arsenate minerals such as mimetite, $\text{Pb}_5(\text{AsO}_4)_3\text{Cl}$ and erythrite, $\text{Co}_3(\text{AsO}_4)_2 \cdot 8\text{H}_2\text{O}$, and more rarely arsenites ('arsenite' = arsenate(III), AsO_3^{3-} as opposed to arsenate (V), AsO_4^{3-}). Arsenic also occurs in various organic forms in the environment.

Production

In 2005, China was the top producer of white arsenic with almost 50% world share, followed by Chile, Peru and Morocco, reports the British Geological Survey and the United States Geological Survey. The arsenic was recovered mostly during mining operations, for example the production from Peru comes mostly from copper mining and the production in China is due to gold mining.

Arsenic is part of the smelter dust from copper, gold, and lead smelters. On roasting in air of arsenopyrite, arsenic sublimes as arsenic (III) oxide leaving iron oxides, while roasting without air results in the production of metallic arsenic.

For further purification of the arsenic from sulfur and other chalcogenes is sublimed in vacuum or in a hydrogen atmosphere or by distilling it from molten lead-arsenic mixture.

APPLICATIONS

Wood Preservation

The toxicity of arsenic to insects, bacteria and fungi makes it an ideal component for the preservation of wood. The worldwide treatment with chromated copper arsenate, also known as CCA or Tanalith was the largest consumer of arsenic since the introduction of the process in the 1950s. Due to the environmental problems caused by the arsenic most countries banned the use of chromated copper arsenate on consumer products. The ban began in the European Union and in the United States in 2004.

In 2002 in the United States 90% of the 19,600 metric tons of arsenic compounds were used to preserve wood, in 2007 still 50% of the 5,280 metric tons of consumption was used for this purpose. In the European Union the use of arsenic in consumer products The USEPA's website, CCA lumber was discontinued for residential and general consumer construction on December 31, 2003 and alternative methods are now used like ACQ, Borates, Copper Azole, Cyproconazole, and Propiconazole.

Although discontinued, this application is also one of the most concern to the general public. The vast majority of older pressure-treated wood was treated with CCA. CCA lumber is still in widespread use in many countries, and was heavily used during the latter half of the 20th century as a structural and outdoor building material. The direct or indirect ingestion of wood ash from burnt CCA lumber has caused fatalities in animals and serious poisonings in humans; the lethal human dose is approximately 20 grams of ash.

Scrap CCA lumber from construction and demolition sites may be inadvertently used in commercial and domestic fires. Protocols for safe disposal of CCA lumber do not exist evenly throughout the world; there is also concern in some quarters about the widespread landfill disposal of such timber.

Medical

During the 18th, 19th, and 20th centuries, a number of arsenic compounds have been used as medicines, including arsphenamine and arsenic trioxide. Arsphenamine as well as Neosalvarsan was indicated for syphilis and trypanosomiasis, but has been superseded by modern antibiotics. Arsenic trioxide has been used in a variety of ways over the past 500 years, but most commonly in the treatment of cancer. The US Food and Drug Administration in 2000 approved this compound for the treatment of patients with acute promyelocytic leukemia that is resistant to ATRA. It was also used as Fowler's solution in psoriasis. Recently new research has been done in locating tumours using arsenic-74 (a positron emitter).

The advantages of using this isotope instead of the previously used iodine-124 is that the signal in the PET scan is clearer as the iodine tends to transport iodine to the thyroid gland producing a lot of noise.

Pigments

Copper acetoarsenite was used as a green pigment known under many different names, including 'Paris Green' and 'Emerald Green'. It caused numerous arsenic poisonings. Scheele's Green, a copper arsenate, was used in the 19th century as a colouring agent in sweets.

Military

After World War I the United States built up a stockpile of 20,000 tons of Lewisite; a chemical weapon, acting as a vesicant (blister agent) and lung irritant. The stockpile was neutralized with bleach and dumped into the Gulf of Mexico

after the 1950s. During the Vietnam War the United States used Agent Blue (a mixture of sodium cacodylate) and dimethyl arsinic acid (cacodylic acid) as one of the rainbow herbicides to deprive the Vietnamese of valuable crops.

Other Uses

- Various agricultural insecticides, termination and poisons. For example Lead hydrogen arsenate was used well into the 20th century as an insecticide on fruit trees. Its use sometimes resulted in brain damage to those working the sprayers. In the last half century, monosodium methyl arsenate (MSMA) and disodium methyl arsenate (DSMA), a less toxic organic form of arsenic, has replaced lead arsenate's role in agriculture.
- Used in animal feed, particularly in the US as a method of disease prevention and growth stimulation. One example is roxarsone which was used by 69.8 and 73.9% of the broiler starter and growers between 1995 to 2000.
- Gallium arsenide is an important semiconductor material, used in integrated circuits. Circuits made using the compound are much faster (but also much more expensive) than those made in silicon. Unlike silicon it is direct bandgap, and so can be used in laser diodes and LEDs to directly convert electricity into light.
- Also used in bronzing and pyrotechnics.
- Up to 2% of arsenic is used in lead alloys for lead shots and bullets.
- Arsenic is added in small quantities to brass to make it Dezincification resistant. This grade of brass is used to make plumbing fittings.

BIOLOGICAL ROLE

Inorganic arsenic and its compounds, upon entering the food chain, are progressively metabolised to less toxic forms of arsenic through a process of methylation. For example, the mold *Scopulariopsis brevicaulis* produce significant amounts of trimethylarsine if inorganic arsenic is present.

The organic compound arsenobetaine is found in some marine foods such as fish and algae, and also in mushrooms in larger concentrations. The average person's intake is about 10–50 µg/day. Values about 1000 µg are not unusual following consumption of fish or mushrooms. But there is little danger in eating fish because this arsenic compound is nearly non-toxic.

Some species of bacteria obtain their energy by oxidizing various fuels while reducing arsenate to arsenite. The enzymes involved are known as arsenate reductases (Arr). In 2008, bacteria were discovered that employ a version of photosynthesis in the absence of oxygen with arsenites as electron donors, producing arsenates (just like ordinary photosynthesis uses water as electron donor, producing molecular oxygen).

Researchers conjecture that historically these photosynthesizing organisms produced the arsenates that allowed the arsenate-reducing bacteria to thrive.

One strain PHS-1 has been isolated and is related to the γ -Proteobacterium *Ectothiorhodospira shaposhnikov*. The mechanism is unknown, but an encoded Arr enzyme may function in reverse to its known homologues.

Safety

Arsenic and many of its compounds are especially potent poisons. Arsenic disrupts ATP production through several mechanisms. At the level of the citric acid cycle, arsenic inhibits pyruvate dehydrogenase and by competing with phosphate it uncouples oxidative phosphorylation, thus inhibiting energy-linked reduction of NAD⁺, mitochondrial respiration, and ATP synthesis.

Hydrogen peroxide production is also increased, which might form reactive oxygen species and oxidative stress. These metabolic interferences lead to death from multi-system organ failure, probably from necrotic cell death, not apoptosis. A post mortem reveals brick red coloured mucosa, due to severe hemorrhage. Although arsenic causes toxicity, it can also play a protective role.

Elemental arsenic and arsenic compounds are classified as “toxic” and “dangerous for the environment” in the European Union under directive 67/548/EEC. The International Agency for Research on Cancer (IARC) recognizes arsenic and arsenic compounds as group 1 carcinogens, and the EU lists arsenic trioxide, arsenic pentoxide and arsenate salts as category 1 carcinogens.

Arsenic is known to cause arsenicosis due to its manifestation in drinking water, “the most common species being arsenate [HAsO_4^{2-} ; As(V)] and arsenite [H_3AsO_3 ; As(III)]”. The ability of arsenic to undergo redox conversion between As(III) and As(V) makes its availability in the environment more abundant. Croal, Gralnick, Malasarn, and Newman, “[the] understanding [of] what stimulates As(III) oxidation and/or limits As(V) reduction is relevant for bioremediation of contaminated sites (Croal). The study of chemolithoautotrophic As(III) oxidizers and the heterotrophic As(V) reducers can help the understanding of the oxidation and/or reduction of arsenic.

Treatment of chronic arsenic poisoning is easily accomplished. British anti-Lewisite (dimercaprol) is prescribed in dosages of 5 mg/kg up to 300 mg each 4 hours for the first day. Then administer the same dosage each 6 hours for the second day. Then prescribe this dosage each 8 hours for eight additional days.

Arsenic in Drinking Water

Arsenic contamination of groundwater has led to a massive epidemic of arsenic poisoning in Bangladesh and neighbouring countries. Presently 42 major incidents around the world have been reported on groundwater arsenic contamination. It is estimated that approximately 57 million people are drinking groundwater with arsenic concentrations elevated above the World Health Organization’s standard of 10 parts per billion.

However, a study of cancer rates in Taiwan suggested that significant increases in cancer mortality appear only at levels above 150 parts per billion. The arsenic in the groundwater is of natural origin, and is released from the sediment into

the groundwater due to the anoxic conditions of the subsurface. This groundwater began to be used after local and western NGOs and the Bangladeshi government undertook a massive shallow tube well drinking-water programme in the late twentieth century. This programme was designed to prevent drinking of bacterially contaminated surface waters, but failed to test for arsenic in the groundwater. Many other countries and districts in South East Asia, such as Vietnam, Cambodia, and China have geological environments conducive to generation of high-arsenic groundwaters. Arsenicosis was reported in Nakhon Si Thammarat, Thailand in 1987, and the dissolved arsenic in the Chao Phraya River is suspected of containing high levels of naturally occurring arsenic, but has not been a public health problem due to the use of bottled water.

The northern United States, including parts of Michigan, Wisconsin, Minnesota and the Dakotas are known to have significant concentrations of arsenic in ground water. Increased levels of skin cancer have been associated with arsenic exposure in Wisconsin, even at levels below the 10 part per billion drinking water standard. Epidemiological evidence from Chile shows a dose dependent connection between chronic arsenic exposure and various forms of cancer, particularly when other risk factors, such as cigarette smoking, are present. These effects have been demonstrated to persist below 50 parts per billion.

Analyzing multiple epidemiological studies on inorganic arsenic exposure suggests a small but measurable risk increase for bladder cancer at 10 parts per billion. Peter Ravenscroft of the Department of Geography at the University of Cambridge, roughly 80 million people worldwide consume between 10 and 50 parts per billion arsenic in their drinking water.

If they all consumed exactly 10 parts per billion arsenic in their drinking water, the previously cited multiple epidemiological study analysis would predict an additional 2,000 cases of bladder cancer alone. This represents a clear underestimate of the overall impact, since it does not include lung or skin cancer, and explicitly underestimates the exposure. Those exposed to levels of arsenic above the current WHO standard should weigh the costs and benefits of arsenic remediation.

Arsenic can be removed from drinking water through coprecipitation of iron minerals by oxidation and filtering. When this treatment fails to produce acceptable results, adsorptive arsenic removal media may be utilized.

Several adsorptive media systems have been approved for point-of-service use in a study funded by the United States Environmental Protection Agency (U.S., EPA) and the National Science Foundation (NSF). Magnetic separations of arsenic at very low magnetic field gradients have been demonstrated in point-of-use water purification with high-surface-area and monodisperse magnetite (Fe_3O_4) nanocrystals. Using the high specific surface area of Fe_3O_4 nanocrystals the mass of waste associated with arsenic removal from water has been dramatically reduced.

Epidemiological studies have suggested a correlation between chronic consumption of drinking water contaminated with arsenic and the incidence of

type 2 diabetes. However, the literature provides insufficient scientific evidence to show cause and effect between arsenic and the onset of diabetes mellitus type 2.

Occupational Exposures

Industries that use inorganic arsenic and its compounds include wood preservation, glass production, nonferrous metal alloys, and electronic semiconductor manufacturing. Inorganic arsenic is also found in coke oven emissions associated with the smelter industry. Occupational exposure and poisoning may occur in persons working in these industries.

COMMON HAZARDOUS AND TOXIC AGENTS

Many people don't realise it but there are a lot of common household items that are considered to be hazardous materials. These include medications, paint, motor oil, antifreeze, auto batteries, lawn care products, pest control products, drain cleaners, pool care products such as chlorine and acids, and household cleaners. Some household cleaners may be harmful separately or when combined such as ammonia and bleach.

The vast majority of chemical cleaners pose environmental, health and safety concerns to the air, water, animals, plants and humans. Pollution caused by chemical runoff has contaminated 40% of the nation's waterways remain too polluted for fishing and swimming.

HOUSEHOLD HAZARDOUS MATERIALS

A wide range of health effects are linked to materials used, depending on the substance, the dose, the duration of exposure, and the susceptibility of the person exposed. Many solvents affect the central nervous system and are skin and eye irritants. Most are flammable; many are linked to long-term adverse health effects such as liver damage. Several are known or suspected carcinogens such as benzene and toluene. Dusts/fibres are eye and respiratory irritants, and may aggravate asthma and provoke allergies.

Specific hazards: silica in clay dust causes lung disease over years of exposure; talc (white clays) may be contaminated with asbestos, a known carcinogen; some hardwood dusts lead to nasal and sinus cancers in woodworkers. Heavy metals are hazardous both as dusts and as fumes. Lead affects the nerves, digestive system, muscles and joints.

Arsenic, cadmium and chromium are known carcinogens. Mercury, copper, cobalt, silver, manganese, selenium and zinc are all acutely toxic. Acids are corrosive to skin and eyes.

Acid vapours are irritating to the lungs and inhalation of small amounts may damage lung tissue. Concentrated acids can react with many other materials. Gases generated from kilns, welding or sculpting with plastics are acutely toxic; some may lead to long-term lung damage with repeated exposure.

BASIC SAFETY RULES

Know the hazards of the materials you're working with. Read the labels, request material safety data sheets (MSDS) on new products, know what precautions, safety gear and clean up procedures are advised. Use the safest materials and procedures possible. Stay current on the new developments in your art or craft; safer, less-toxic alternatives are being devised for many activities. Use good ventilation at all times. Local exhaust is the best, such as a hood or spray booth that vents to the outside. Next best is to use exhaust fans that pull the contaminated air away from you and exhaust it outside (an air-conditioning system is not adequate, since it recirculates most of the air). An open window usually does not provide adequate ventilation; toxins may be blown back into your face.

Use good hygiene and housekeeping. Separate work and living areas; avoid eating, drinking or smoking in the work area; don't store materials in food containers; and wash and change clothes after working. Wet mop or vacuum for cleanup of dusts. Special precautions are needed for children's art. In general, children over the age of 12 can understand and consistently follow safety instructions for the more toxic materials; younger children cannot and should use only the safest materials.

Products Hazardous Ingredients Dangers Alternatives

- Aerosol sprays butanol, butane, propanol flammable, irritant, explosive pump-type sprays, potpourri.
- Ammonia-based cleaners ammonia, ethanol irritant, toxic, corrosive (Forms poison gas when mixed with bleach.) vinegar, salt and water for surfaces and baking soda and water for the bathroom.
- Antifreeze ethylene glycol toxic (especially to pets) unknown (use caution, take to a collection centre).
- Batteries sulfuric acid, lead corrosive, toxic unknown (use caution, recycle).
- Brake fluid glycol ethers, heavy metals flammable, toxic unknown (take to a collection centre).
- Disinfectants diethylene glycol, sodium, hypochlorite, phenols corrosive, toxic 1/2 cup borax in 1 gallon of water.
- Drain opener sodium hypochlorite, sodium/potassium hydroxide corrosive, toxic plunger, flush w/boiling water, 1/4 cup baking soda.
- Flea repellant carbamates, organophosphate, pyrethrins toxic eucalyptus leaves where pet sleeps, brewer's yeast in diet.
- Floor/furniture polishes diethylene glycol, petroleum distillates, nitrobenzene flammable, toxic 1 part lemon juice w/2 parts olive or vegetable oil.
- Furniture stripper acetone, methyl ethyl ketone, toluene xylenes flammable, toxic sandpaper.

- Latex paint resins, glycol, ethers, esters flammable lime stone based white wash or casein based paint.
- Oil based paints ethylene, aliphathydro-carbons, petroleum distillates flammable, toxic latex or water based paints.
- Oven cleaner potassium, sodium hydroxide, ammonia, lye corrosive, toxic baking soda and water, salt on spills that are still warm.
- Photographic chemicals silver, acetic acid, ferrocyanide, hydro quinone corrosive, toxic, irritant unknown (use caution, take to collection centre).
- Pool chemicals muriatic acid, sodium hypochlorite algicide corrosive, toxic unknown (use caution, use until gone take to a collection centre).
- Rat and mouse killer lead arsenate, coumarins (warfarin) strychnine toxic remove food and water sources, clear harborage, cover holes and drains rats may enter, use mechanical traps. Get a cat.
- Roach and ant killer organo-phosphates, carbamates toxic roaches: traps, boric acid. Ants: chili pepper/cream of tartar in ants' path.
- Rug and upholstery cleaners naphthalene, oxalic acid, diethylene glycol irritant, toxic, corrosive dry corn starch sprinkled on rug then vacuumed up.
- Toilet bowl cleaner muriatic or oxalic paradi-chlorobenzene calcium hypochlorite irritant, toxic, corrosive toilet brush and baking soda; mild detergent.
- Thinners and turpentine n-butyl alcohol, isobutyl keytone, petroleum distillates flammable use water with water based paints.
- Transmission fluid hydrocarbons mineral spirits flammable, toxic unknown (take to a collection centre).
- Used oil hydrocarbons, (e.g., benzene) heavy metals flammable, toxic unknown (recycle).

Note: It is illegal to dispose of oil on/in the ground.

CHLORINE (SODIUM HYPOCHLORITE)

In paper products, such as toilet paper and paper towels:

- Bleaching paper products with chlorine bleach causes the formation of dioxin, an extremely toxic and persistent chemical known to cause cancer and disrupt the endocrine system.
- Chlorine-free toilet paper and paper towels are available at many natural food stores. Additionally, newspaper can be used in place of paper towels for cleaning windows, and rags can be used for other surfaces.

In Cleaning Products

Many household cleaners contain chlorine bleach. Chlorine bleach, or sodium hypochlorite, is a lung and eye irritant. If mixed with ammonia or acid-based cleaners (including vinegar), chlorine bleach releases toxic chloramine gas. Short-term exposure to this gas may cause mild asthmatic symptoms or more serious respiratory problems.

- To be on the safe side, don't mix chlorine bleach with anything — or just avoid chlorine bleach altogether. The EPA recommends using a non-chlorine bleach such as hydrogen peroxide to bleach clothes.

PHOSPHATES

Phosphates are minerals that act as water softeners. Although they are very effective cleaners, phosphates also act as fertilizers. When cleaning products go down the drain, phosphates are discharged into rivers, lakes, estuaries, and oceans. In lakes and rivers especially, phosphates cause a rapid growth of algae, resulting in pollution of the water. Many states have banned phosphates from household laundry detergents and some other cleaning products. Automatic dishwasher detergents are usually exempt from phosphate restrictions, and most major brands contain phosphates. Some phosphate-free alternatives are available and hand dishwashing liquids do not contain phosphates.

ALKYLPHENOLS AND THEIR DERIVATIVES

Alkylphenol Ethoxylates are found in some laundry detergents, disinfecting cleaners, all-purpose cleaners, spot removers, hair colours and other hair-care products, and spermicides.

- Alkylphenol Ethoxylates are endocrine disruptors.
- Alkylphenols are produced in the environmental breakdown of alkylphenol ethoxylate surfactants, are slow to bio-degrade and have been shown to disrupt the endocrine systems of fish, birds, and mammals.

VOLATILE ORGANIC COMPOUNDS

Organic chemicals are widely used as ingredients in household products. All of these products can release pollutants while you are using them, and, to some degree, when they are stored.

- EPA's Total Exposure Assessment Methodology (TEAM) studies found levels of about a dozen common organic pollutants to be 2 to 5 times higher inside homes than outside, regardless of whether the homes were located in rural or highly industrial areas.
- Additional TEAM studies indicate that while people are using products containing organic chemicals, they can expose themselves and others to very high pollutant levels, and elevated concentrations can persist in the air long after the activity is completed.
- Many organic compounds are known to cause cancer in animals; some are suspected of causing, or are known to cause, cancer in humans.
- Some of the hazardous volatile organic compounds that frequently pollute indoor air — such as toluene, styrene, xylenes, and trichloroethylene — may be emitted from aerosol products, dry-cleaned clothing, paints, varnishes, glues, art supplies, cleaners, spot removers, floor waxes and polishes and air fresheners.

High levels of toluene can put pregnant woman at risk of having babies with neurological problems, retarded growth, and developmental problems. Xylenes may also cause birth defects. Trichloroethylene is one of the chemicals suspected of causing a cluster of childhood leukemia cases due to drinking water contamination in the town of Woburn, Massachusetts, in the early 1980s. Styrene is a suspected endocrine disruptor, a chemical that can interfere, block or mimic hormones in humans or animals.

- VOCs such as xylene, ketones, and aldehydes are found in many aerosol products and air fresheners. Researchers found that babies less than six months old in homes where air fresheners are used on most days had 30 per cent more ear infections than those exposed less than once a week.
- Levels of formaldehyde in air as low as 0.1 ppm (0.1 part formaldehyde per million parts of air) can cause watery eyes, burning sensations in the eyes, nose and throat, stuffy nose, nausea, coughing, chest tightness, wheezing, skin rashes and allergic reactions.
- Babies frequently exposed to aerosols had a 22 per cent increase in diarrhea, and pregnant women frequently exposed to these products had 25 per cent more headaches and a 19 per cent increase in postnatal depression compared to those less frequently exposed.
- *Corrosive*: A chemical, (solid, liquid or gas), that can cause destructive damage to body tissues at the site of contact. It can cause severe burns to the skin and can “eat through” clothing, metal and other materials.
- *Flammable*: Can be ignited at almost any temperature. Spontaneously react with oxides.
- *Irritant*: Causes soreness or inflammation of the skin, eyes, mucous membranes or respiratory system.
- *Oxidizer*: An unstable chemical that can spontaneously react with flammables and releases oxygen.
- *Toxic*: May cause injury or death upon ingestion (eating/drinking), absorption (touching) or inhalation (breathing into lungs).

HEAVY METALS IN ENVIRONMENT

LEAD

Lead is a main-group element with symbol Pb and atomic number 82. Lead is a soft, malleable poor metal, also considered to be one of the heavy metals. Lead has a bluish-white colour when freshly cut, but tarnishes to a dull grayish colour when exposed to air. It has a shiny chrome-silver luster when melted into a liquid.

Lead is used in building construction, lead-acid batteries, bullets and shot, weights, and is part of solder, pewter, fusible alloys and radiation shields. Lead has the highest atomic number of all stable elements, although the next element, bismuth, has a half-life so long (longer than the estimated age of the universe)

it can be considered stable. Like mercury, another heavy metal, lead is a potent neurotoxin that accumulates in soft tissues and bone over time. Lead poisoning was documented in ancient Rome, Greece, and China.

CHARACTERISTICS

Lead has a dull luster and is a dense, ductile, very soft, highly malleable, bluish-white metal that has poor electrical conductivity. This true metal is highly resistant to corrosion, and because of this property, it is used to contain corrosive liquids (*e.g.*, sulfuric acid). Because lead is very malleable and resistant to corrosion it is extensively used in building construction, *e.g.*, external coverings of roofing joints. Lead can be toughened by adding a small amount of antimony or other metals to it. It is a common misconception that lead has a zero Thomson effect. All lead, except ^{204}Pb , is the end product of a complex radioactive decay. Lead is also poisonous, as are its compounds, and therefore is dangerous to human health and use as a food containment device is not recommended.

OCCURRENCE

Metallic lead does occur in nature, but it is rare. Lead is usually found in ore with zinc, silver and (most abundantly) copper, and is extracted together with these metals. The main lead mineral is galena (PbS), which contains 86.6% lead. Other common varieties are cerussite (PbCO_3) and anglesite (PbSO_4).

Ore Processing

Most ores contain less than 10% lead, and ores containing as little as 3% lead can be economically exploited. Ores are crushed and concentrated by froth flotation typically to 70% or more. Sulfide ores are roasted, producing primarily lead oxide and a mixture of sulfates and silicates of lead and other metals contained in the ore. Lead oxide from the roasting process is reduced in a coke-fired blast furnace. This converts most of the lead to its metallic form. Three additional layers separate in the process and float to the top of the metallic lead. These are slag (silicates containing 1.5% lead), matte (sulfides containing 15% lead), and speiss (arsenides of iron and copper). These wastes contain concentrations of copper, zinc, cadmium, and bismuth that can be recovered economically, as can their content of unreduced lead.

Metallic lead that results from the roasting and blast furnace processes still contains significant contaminants of arsenic, antimony, bismuth, zinc, copper, silver, and gold. The melt is treated in a reverberatory furnace with air, steam, and sulfur, which oxidizes the contaminants except silver, gold, and bismuth. The oxidized contaminants are removed by drossing, where they float to the top and are skimmed off.

Most lead ores contain significant concentrations of silver, resulting in the smelted metal also containing silver as a contaminant. Metallic silver as well as gold is removed and recovered economically by means of the Parkes process. Desilvered lead is freed of bismuth according to the Betterton-Kroll process by

treating it with metallic calcium and magnesium, which forms a bismuth dross that can be skimmed off. Very pure lead can be obtained by processing smelted lead electrolytically by means of the Betts process. The process uses anodes of impure lead and cathodes of pure lead in an electrolyte of silica fluoride.

Production and Recycling

Production and consumption of lead is increasing worldwide. Total annual production is about 8 million tonnes; about half is produced from recycled scrap. Top lead producing countries, as of 2008, are Australia, China, USA, Peru, Canada, Mexico, Sweden, Morocco, South Africa and North Korea. Australia, China and the United States account for more than half of primary production.

- 2008 mine production: 3,886,000 tonnes
- 2008 metal production: 8,725,000 tonnes
- 2008 metal consumption: 8,706,000 tonnes

At current use rates, the supply of lead is estimated to run out in 42 years. Environmental analyst, Lester Brown, however, has suggested lead could run out within 18 years based on an extrapolation of 2% growth per year. This may need to be reviewed to take account of renewed interest in recycling, and rapid progress in fuel cell technology.

Isotopes

Lead has many isotopes but 4 stable ones. The 4 stable isotopes are ^{204}Pb , ^{206}Pb , ^{207}Pb and ^{208}Pb with ^{204}Pb regarded as primordial Pb and 206, 207, 208 are formed from decay of U and Th. The one common radiogenic isotope, ^{202}Pb , has a half-life of approximately 53,000 years.

HEALTH EFFECTS

Lead is a poisonous metal that can damage nervous connections (especially in young children) and cause blood and brain disorders. Because of its low reactivity and solubility, lead poisoning usually only occurs in cases when the lead is dispersed, like when sanding lead based paint, or long term exposure in the case of pewter tableware. Long term exposure to lead or its salts (especially soluble salts or the strong oxidant PbO_2) can cause nephropathy, and colic-like abdominal pains. The effects of lead are the same whether it enters the body through breathing or swallowing.

Lead can affect almost every organ and system in the body. The main target for lead toxicity is the nervous system, both in adults and children. Long-term exposure of adults can result in decreased performance in some tests that measure functions of the nervous system. It may also cause weakness in fingers, wrists, or ankles. Lead exposure also causes small increases in blood pressure, particularly in middle-aged and older people and can cause anemia. Exposure to high lead levels can severely damage the brain and kidneys in adults or children and ultimately cause death.

In pregnant women, high levels of exposure to lead may cause miscarriage. Chronic, high-level exposure in men can damage the organs responsible for sperm production. The concern about lead's role in cognitive deficits in children has brought about widespread reduction in its use (lead exposure has been linked to learning disabilities). Most cases of adult elevated blood lead levels are workplace-related. High blood levels are associated with delayed puberty in girls. Lead has been shown many times to permanently reduce the cognitive capacity of children at extremely low levels of exposure. There appears to be no detectable lower limit. During the 20th century, the use of lead in paint pigments was sharply reduced because of the danger of lead poisoning, especially to children. By the mid-1980s, a significant shift in lead end-use patterns had taken place. Much of this shift was a result of the U.S., lead consumers' compliance with environmental regulations that significantly reduced or eliminated the use of lead in non-battery products, including gasoline, paints, solders, and water systems.

Lead use is being further curtailed by the European Union's RoHS directive. Lead may still be found in harmful quantities in stoneware, vinyl (such as that used for tubing and the insulation of electrical cords), and brass manufactured in China. Older houses may still contain substantial amounts of lead paint. White lead paint has been withdrawn from sale in industrialized countries, but the yellow lead chromate is still in use; for example, Holland Colours Holcolan Yellow. Old paint should not be stripped by sanding, as this produces inhalable dust. Lead salts used in pottery glazes have on occasion caused poisoning, when acidic drinks, such as fruit juices, have leached lead ions out of the glaze. It has been suggested that what was known as "Devon colic" arose from the use of lead-lined presses to extract apple juice in the manufacture of cider. Lead is considered to be particularly harmful for women's ability to reproduce. For that reason, many universities do not hand out lead-containing samples to women for instructional laboratory analyses. Lead(II) acetate (also known as *sugar of lead*) was used by the Roman Empire as a sweetener for wine, and some consider this to be the cause of the dementia that affected many of the Roman Emperors.

Lead as a soil contaminant is a widespread issue, since lead is present in natural deposits and may also enter soil through (leaded) gasoline leaks from underground storage tanks or through a waste stream of lead paint or lead grindings from certain industrial operations. Lead can also be found listed as a criteria pollutant in the United States Clean Air Act section 108. Lead that is emitted into the atmosphere can be inhaled, or it can be ingested after it settles out of the air. It is rapidly absorbed into the bloodstream and is believed to have adverse effects on the central nervous system, the cardiovascular system, kidneys, and the immune system.

Biochemistry of Lead Poisoning

In the human body, lead inhibits porphobilinogen synthase and ferrochelatase, preventing both porphobilinogen formation and the incorporation of iron into

protoporphyrin IX, the final step in heme synthesis. This causes ineffective heme synthesis and subsequent microcytic anemia. At lower levels, it acts as a calcium analog, interfering with ion channels during nerve conduction.

This is one of the mechanisms by which it interferes with cognition. Acute lead poisoning is treated using disodium calcium edetate: the calcium chelate of the disodium salt of ethylene-diamine-tetracetic acid (EDTA). This chelating agent has a greater affinity for lead than for calcium and so the lead chelate is formed by exchange. This is then excreted in the urine leaving behind harmless calcium.

Occupational Exposure

It is widely used in the production of batteries, metal products (solder and pipes), ammunition and devices to shield X-rays leading to its exposure to the people working in these industries. Use of lead in gasoline, paints and ceramic products, caulking, and pipe solder has been dramatically reduced in recent years because of health concerns. Ingestion of contaminated food and drinking water is the most common source of lead exposure in humans. Exposure can also occur via inadvertent ingestion of contaminated soil/dust or lead-based paint.

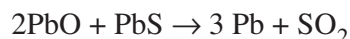
Testing

Water contamination can be tested with commercially available kits. Analysis of lead in whole blood is the most common and accurate method of assessing lead exposure in human. Erythrocyte protoporphyrin (EP) tests can also be used to measure lead exposure, but are not as sensitive at low blood lead levels (<20 µg/dL).

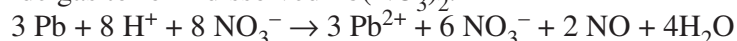
Lead in blood reflects recent exposure. Bone lead measurements are an indicator of cumulative exposure. While measurements of urinary lead levels and hair have been used to assess lead exposure, they are not reliable.

DESCRIPTIVE CHEMISTRY

Various oxidized forms of lead are easily reduced to the metal. An example is heating PbO with mild organic reducing agents such as glucose. A mixture of the oxide and the sulfide heated together without any reducing agent will also form the metal.



Metallic lead is attacked only superficially by air, forming a thin layer of oxide that protects it from further oxidation. The metal is not attacked by sulfuric or hydrochloric acids. It does, however, dissolve in nitric acid with the evolution of nitric oxide gas to form dissolved $\text{Pb}(\text{NO}_3)_2$.



When heated with nitrates of alkali metals, metallic lead oxidizes to form PbO (also known as litharge), leaving the corresponding alkali nitrite. PbO is representative of lead's II oxidation state.

It is soluble in nitric and acetic acids, from which solutions it is possible to precipitate halide, sulfate, chromate, carbonate (PbCO_3), and basic carbonate ($\text{Pb}_3(\text{OH})_2(\text{CO}_3)_2$) salts of lead. The sulfide can also be precipitated from acetate solutions.

These salts are all poorly soluble in water. Among the halides, the iodide is less soluble than the bromide, which, in turn, is less soluble than the chloride.

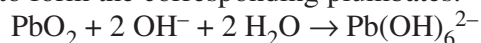
The II oxide is also soluble in alkali hydroxide solutions to form the corresponding plumbite salt.



Chlorination of plumbite solutions causes the formation of lead's IV oxidation state.



Lead dioxide is representative of the IV state, and is a powerful oxidizing agent. The chloride of this oxidation state is formed only with difficulty and decomposes readily into the II chloride and chlorine gas. The bromide and iodide of IV lead are not known to exist. Lead dioxide dissolves in alkali hydroxide solutions to form the corresponding plumbates.

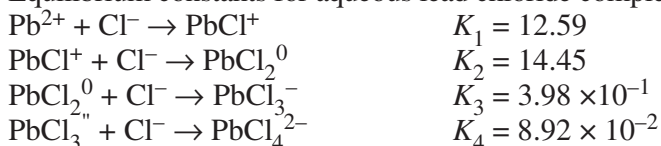


Lead also has an oxide that is a hybrid between the II and IV oxidation states. Red (also called minium) lead is Pb_3O_4 . Lead readily forms an equimolar alloy with sodium metal that reacts with alkyl halides to form organometallic compounds of lead such as tetraethyl lead.

Chloride Complexes

Lead(II) forms a series of complexes with chloride, the formation of which alters the corrosion chemistry of the lead. This will tend to limit the solubility of lead in saline media.

Equilibrium constants for aqueous lead chloride complexes at 25 °C



APPLICATIONS

Because of its high density and resistance against corrosion, lead is used for the ballast keel of sailboats. Its high weight-to-volume ratio allows it to counterbalance the heeling effect of wind on the sails while at the same time occupying a small volume and thus offering the least underwater resistance. For the same reason it is used in scuba diving weight belts to counteract the diver's natural buoyancy and that of his equipment. It does not have the weight-to-volume ratio of many heavy metals, but its low cost increases its use in these and other applications.

- Lead is a major constituent of the lead-acid battery used extensively as a car battery.
- Lead is used as a colouring element in ceramic glazes, notably in the colours red and yellow.

- Lead is used to form glazing bars for stained glass or other multi-lit windows. The practice has become less common, not for danger but for stylistic reasons.
- Lead is frequently used in polyvinyl chloride (PVC) plastic, which coats electrical cords.
- Lead is used as projectiles for firearms and fishing sinkers because of its density, low cost compared to alternative products and ease of use due to relatively low melting point.
- Lead or “sheet-lead” is used as a sound deadening layer in such areas as wall, floor and ceiling design in sound studios where levels of airborne and mechanically produced sound are targeted for reduction or virtual elimination.
- Lead is used in some candles to treat the wick to ensure a longer, more even burn. Because of the dangers, European and North American manufacturers use more expensive alternatives such as zinc.
- Lead is used as shielding from radiation, *e.g.*, in x-ray rooms.
- Molten lead is used as a coolant, *eg.* for lead cooled fast reactors.
- Lead glass is composed of 12-28% lead oxide. It changes the optical characteristics of the glass and reduces the transmission of radiation.
- Lead is the traditional base metal of organ pipes, mixed with varying amounts of tin to control the tone of the pipe.
- Lead is used as electrodes in the process of electrolysis.
- Lead is used in solder for electronics, although this usage is being phased out by some countries to reduce the amount of environmentally unfriendly waste.
- Lead is used in high voltage power cables as sheathing material to prevent water diffusion into insulation.
- Lead is added to brass to reduce machine tool wear.
- Some artists using oil-based paints continue to use lead carbonate white, citing its properties in comparison with the alternatives.
- Lead, in the form of strips or “tape” is used for the customization of tennis rackets. Tennis rackets of the past sometimes had lead added to them by the manufacturer to increase weight.
- Lead has many uses in the construction industry, *e.g.*, lead sheets are used as architectural metals in roofing material, cladding, flashings, gutters and gutter joints, and on roof parapets. Detailed lead moldings are used as decorative motifs used to fix lead sheet.
- Lead is still widely used in statues and sculptures.
- Tetra-ethyl lead is used as an anti-knock additive for aviation fuel in piston driven aircraft.
- Lead-based semiconductors, such as lead telluride, lead selenide and lead antimonide are finding applications in photovoltaic (solar energy) cells and infrared detectors.
- Lead is often used to balance the wheels of a car; this use is being phased out in favour of other materials for environmental reasons.

Former Applications

- Lead pigments were used in lead paint for white as well as yellow, orange, and red. Most have been discontinued due of the dangers of lead poisoning. However, lead chromate is still in industrial use. Lead carbonate (white) is the traditional pigment for the priming medium for oil painting, but it has been largely displaced by the zinc and titanium oxide pigments. It was also quickly replaced in water-based painting mediums.
- Lead carbonate white was used by the Japanese geisha and in the West for face-whitening make-up, which caused ill-health in the wearer.
- Lead was the hot metal used in hot metal typesetting.
- Lead was used for plumbing in Ancient Rome.
- Lead was used as a preservative for food and drink in Ancient Rome.
- Lead was used for joining cast iron water pipes and used as a material for small diameter water pipes until the early 1970s.
- Tetraethyl lead was used in leaded fuels to reduce engine knocking; however, this is no longer common practice in the Western world due to its incompatibility with catalytic converters.
 - The EPA banned the use of lead gasoline for highway transportation, beginning January 1, 1996.
- Lead has been used to make “clubs” or bats more lethal by melting it into a hole drilled into the top.
- Lead was used to make bullets for slings.
- Lead was used for shotgun pellets in the US until about 1992 when it was outlawed (for waterfowl hunting only) and replaced by “non-toxic” shot, primarily steel pellets.
- Lead was used as a component of toys. Due to toy safety regulations, this use has been stopped in the United States.
- Lead was used in car body filler, which was used in many custom cars in the 1940s–60s. Hence the term Leadsled.
- Lead is a superconductor at 7.2 K and IBM tried to make a Josephson effect computer out of lead-alloy.
- Lead was also used in pesticides before the 1950s, when fruit orchards were treated (ATSDR).

Contrary to popular belief, pencil “leads” have never been made from lead. The term comes from the Roman stylus, called the *penicillus*, which was made of lead. When the pencil originated as a wrapped graphite writing tool, the particular type of graphite being used was named *plumbago*.

ENVIRONMENTAL EDUCATION AND POLLUTION

Environmental education and pollution are intertwined issues that are critical for addressing global sustainability challenges. Environmental education aims to increase awareness, knowledge, and understanding of environmental issues among individuals and communities, fostering a sense of responsibility and stewardship towards the natural world. Central to environmental education is the recognition of the interconnectedness of human activities with the environment and the importance of sustainable practices in preserving ecosystem health and biodiversity. Pollution, on the other hand, refers to the introduction of harmful contaminants into the environment, which can have detrimental effects on ecosystems, human health, and the planet as a whole. Common sources of pollution include industrial activities, transportation, agriculture, and improper waste management. Environmental education plays a crucial role in addressing pollution by raising awareness about its causes, impacts, and solutions. By educating individuals about the consequences of pollution and promoting sustainable behaviors, environmental education empowers individuals and communities to take action to reduce pollution and mitigate its harmful effects. Through interdisciplinary approaches that integrate science, policy, ethics, and citizenship, environmental education encourages informed decision-making and collective action to create a more sustainable and resilient planet for future generations. The book on Environmental Education and Pollution provides comprehensive insights and practical strategies for fostering environmental awareness, promoting sustainable practices, and addressing pollution challenges to protect the planet for future generations.



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