## Chapter 10

# Environmental Pollution and Management

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## Abstract

Environmental pollution is one of the major problems being faced by the world posing significant health hazards. Due to their ubiquitous presence, serious health and environmental concerns, this chapter is dedicated to the commonly reported environmental pollutants. This chapter provides insights about various components of environment (biotic and abiotic), types of pollutants (inorganic as well as organic), their sources (point and non-point) in contaminated soil and water and their fate in environment that ultimately affects their persistence and toxicity. Effects of environmental pollution on human, animals and plants are also discussed, as environmental pollution is not only seriously affecting the human health but pose serious threats to animals and plants. Various concepts related to soil and water pollution are also being discussed including biological oxygen demand, chemical oxygen demand and eutrophication. This chapter also illustrates various techniques to remediate contaminated matrices including biological, physical and chemical strategies. A brief description of each remediation strategy is presented to highlight their merits and associated limitations for the removal of pollutants in contaminated soil and water. Risk assessment of environmental pollutants is an important

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component and is discussed in regard to plants, animals and humans as the last part of this chapter.

**Keywords**: Environmental pollution; Fate; Effects; Management; Remediation; Risk assessment

# 10.1. Introduction

The human population is increasing continuously by adding eight million persons per year and world's population is project to become approximately 10 billion by the year 2050. Every individual creates his demands on natural resources which continuously tend to increase with the passage of time. The demands created by the individuals are resulting in rapid agricultural and chemical industrialization. These industries are releasing different organic and inorganic chemicals into natural ecosystem which are becoming a serious threat to human beings, animals and plants because the release of these chemicals has resulted in addition of a variety of pollutants into soil, water and air . The adverse effects for humans and other organisms are the acute toxicity, changes in genetics, carcinogenicity and birth problems. Many of these toxic pollutants are not degraded by biological, chemical and physical processes and result in a meaningful threat to environment

# 10.2. Components of Environment

The environment is comprised of different components like atmosphere, hydrosphere, lithosphere and biosphere. These described in British and American literature are describes below.

## 10.2.1. Components of environment as per British literature

In the British system the environmental components have been classified on the basis of life, i.e., as abiotic or biotic. The abiotic components are further listed as edaphic (land) and climatic (air, water) and the biotic components are classified as producers, consumers and decomposers. The study of structure of ecosystem was derived from this system of classification.

### 10.2.1.1. Abiotic components

The non-living entities are included in abiotic components i.e., atmosphere, hydrosphere and lithosphere, i.e., soil, air, water and rocks. The pollution in these components causes changes in climate resulting in global warming, affecting plants, animals and human beings.

### 10.2.1.2. Biotic components

The living entities in an ecosystem are included in biotic components of environment. These biotic components effect on other living organisms like animals who consume that organism, and the living food which is consumed by them. The producers, consumers and decomposers are the subcomponents of biotic factors.

***i. Producers***

These organisms convert energy into food, i.e. autotrophs like plants which convert sunlight, water and carbon dioxide into energy through photosynthesis.

***ii. Consumers***

These are the organisms which depend on other living organisms (producers) for their food, i.e., heterotrophs like animals.

***iii. Decomposers***

These are the organisms which breakdown the chemicals produced by the producers into simpler forms which can be reused. For example the feeding process of bacteria and fungi returns the nutrients present in the waste and dead organisms to the soil.

## 10.2.2. Components of environment as per American literature

The components of environment as described in the American literature are given below (Fig. 10.1).

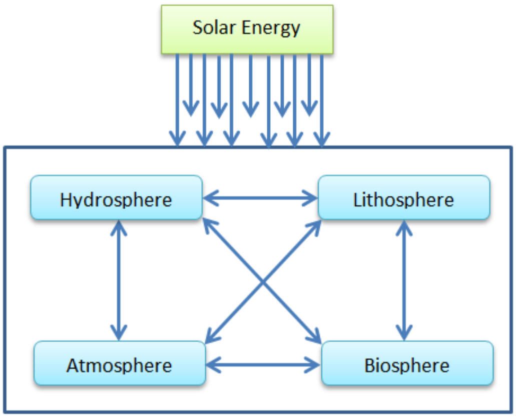


**Fig. 10.1** Components of environment as per American literature.

1) Atmosphere (Air)
2) Hydrosphere (Water)
3) Lithosphere (Land)
4) Biosphere (Flora/Fauna/Microbes)
5) Anthrosphere (man-made things)

#### 10.2.2.1. Atmosphere

The atmosphere is the gaseous envelop which surrounds our planet, Earth. The major part of the atmosphere is found close to surface of the Earth and it is most dense at sea level and rapidly decreases with increasing altitude. Major components of atmosphere are about 79% nitrogen and 21% oxygen; the remaining part consists of carbon dioxide (0.03%) and other gasses such as neon, helium, krypton, xenon, water vapours, dust particles and hydrocarbons, etc.

#### 10.2.2.2. Hydrosphere

All of the water present on or near the surface of the Earth is the part of hydrosphere. This includes the oceans, rivers, lakes, and even the moisture in the air. Almost 97% of the Earth's water is in the oceans. The remaining part of it is fresh water and about 2% of this fresh water is solid which exists as ice sheets.

#### 10.2.2.3. Lithosphere

The lithosphere consists of the solid, rocky crust which covers the entire planet. This crust is composed of minerals and it is inorganic in nature. It covers the entire surface of the Earth from the top of Mount Everest to the bottom of the Mariana Trench.

#### 10.2.2.4. Biosphere

All the living organisms which include plants, animals and microorganisms constitute the biosphere. Most of the planet's life is found from three meters below the ground to thirty meters above it and in the top 200 meters of the oceans and seas.

All spheres of earth interact with each other in a common place. For example, soil will have mineral material from the lithosphere; moisture from the hydrosphere, insects, plants and other organism from biosphere, gases in the soil pores from the atmosphere.

## 10.3. Environmental Quality

*Environmental quality* is defined as the set of characteristics and properties of the environment. The properties may be local or generalized which directly or indirectly affect human beings and different organisms. Environmental quality is a measure of the condition of an environment in relation to the requirements of one or more species and /or to any human need or purpose.

## 10.4. Soil Pollution

Soil pollution may be defined as any physical, chemical and biological adverse change in soils made by high concentrations of chemicals, which are out of their proper place and have adverse effects on organisms living on or in the soil.

# 10.5. Sources of Soil Pollution

## 10.5.1. Agricultural wastes

The agricultural wastes produced on the farms as a consequence of farming practices include a wide range of organic and inorganic contaminants. The pollutants contained in those wastes can be added into the soil through runoff or drainage ditches. The most important kinds of pollutants from agriculture are:

### 10.5.1.1. Artificial fertilizers

The increased use of fertilizers on global scale to supply nutrients to crops also pollutes the soil because of the presence of some impurities present in them. Most of these fertilizers are stable chemicals and remain as such in soil, but the nitrate plays an important role because of the possibility it's leaching into groundwater and deteriorating its quality. The nitrate leaching can happen due to application of high rate of nitrogenous chemical fertilizers couple with high rainfall and/or heavy irrigations.

Some phosphatic fertilizers may contain varying concentrations of cadmium. Therefore, these fertilizers can contaminate soils with cadmium. The rock phosphate may contain varying levels of cadmium; therefore, the producers of phosphatic fertilizers select rock phosphate on the basis of cadmium content. The concentration of cadmium in phosphate fertilizers may vary from 0.14 mg $kg^{-1}$ to 50.9 mg $kg^{-1}$ in mono-calcium phosphate fertilizer (Lugon-Moulin et al. 2006) because the rock phosphate used can contain up to 188 mg $kg^{-1}$ cadmium.

### 10.5.1.2. Pesticides and herbicides

Indiscriminate use of pesticides to control insect pests and diseases in crops, like cotton and vegetables, is of great concern as a source of soil pollution because the residues of these pesticides, such as aldrin, dieldrin, endrin, may get sorbed onto the soil. Consequently, the crop plants grown in the contaminated soils absorb these toxic pesticides; thus, toxic pesticides may become part of the food chain. Also, we know that pesticides not only kill the living pests (i.e., insects and pathogens) present on the plants and on soil surface but through tilling and irrigation operations, pesticides may reach to greater depths of the soil and thus may kill useful living organisms there.

### 10.5.1.3. Industrial effluents

The economy of Pakistan is rapidly transferring towards industrialization. The industries such as electroplating, textile, tannery, are discharging a variety of untreated effluents into rivers and irrigation channels. The toxic heavy metals, such as arsenic (As), lead (Pb), chromium (Cr), nickel (Ni), copper (Cu), mercury (Hg), etc, are likely to be present in these effluents; thus, untreated industrial discharge is a major cause of eco-toxicological pollution in both soils and water. The fresh water resources are continuously depleting and creating acute shortage of water for agricultural sector. This situation forces the farmers to use industrial effluent as valuable source to meet the crop water requirements. The irrigational usage of these effluents pollutes the soil and water bodies.

#### 10.5.1.4. Petroleum spills

The petroleum products such as benzene, xylene and toluene can pollute the soils due to petroleum spills or leaks from fuel tanks, gas stations or some other human activities. Additionally, some underground spills may also make their way to the surface soil. Some of these chemicals, particularly volatiles, remain in the surface soil and are taken up by the plants growing in such contaminated soils. These pollutants ultimately enter into the food chain.

## 10.6. Point Source Pollution

The point source pollution is defined as "any single identifiable source of pollution from which pollutants are discharged, such as a pipe, ditch, ship or factory smoke stack (Hill 1997). Point source pollution is the pollutants released at a specific point from outfalls, pipes, conveyance channels from either wastewater treatment plants or individual waste treatment facilities. Point sources also include pollutants being contributed by tributaries to the main water stream or river.

### 10.6.1. Point sources

The sources of point source pollution include sewage treatment plants and factories. Different factories, i.e., of textile, electronics, chemicals, paper and pulp mills, discharge some specific type of pollutants in their effluents. These effluents are discharged either directly on soil or into water bodies from where these effluents are used for irrigation purposes which results in the addition of pollutants in soil.

The point source pollution can be monitored and controlled through permit system. The point source discharges can also be controlled if the factories and sewage treatment plants are bound to obtain permit from the Environmental Protection Department for the discharge of their effluents into water bodies. The point sources should also be advised to use advanced technologies for the treatment of their effluents before their discharge to minimize the amount of pollutants. The different types of pollutants discharged from different industries are given below in Table 10.1.

**Table 10.1** Types of pollutants discharged by different industries

| Type of industry | Contaminants | Reference |
|---|---|---|
| Petrochemicals and Refineries | **Metals**<br>Cd, Cr, Cu, Iron (Fe), Ni, Pb, Zn, Aluminium (Al), Barium (Ba), Molybdenum (Mo), Strontium (Sr)<br>**Organic/ inorganic matter and parameter**<br>Benzene, styrene, toluene, indene, Naphthalene, 1, 4-dioxane, Ethyl Benzene, Xylene, O&G | Ahmad et al. (2008) |
| Paper Industry | **Metals**<br>Cd, Cu, Fe, Ni, Pb, Zn<br>**Organic/ inorganic matter and parameter**<br>BOD, COD, TDS, dissolved solids (DS)<br>Chloride, sulphate, phosphate | Devi et al. (2011) |
| Cystine production industry | **Organic/ inorganic matter and parameter**<br>Sodium, chloride, calcium, COD, BOD | Srivivasa Gowd & Kotaiah et al. (2000) |
| Pharmaceutical and food industries | **Metals**<br>Fe, Zn, Cu, Ni, Pb, Cr | Radić et al. (2010) |
| Chemicals, beverage manufacturing, tanneries, oil, soap, paint production, paper, and metal processing plants | **Metals**<br>Fe, Mn, Pb, Zn, Cu, Ni, Cr, Cd , Co<br>**Organic/inorganic matter and parameter**<br>DO, COD | Jonathan et al. (2008) |
| Dyeing and printing industries | **Metals**<br>Cu, Fe, Zn and Mn<br>**Organic/inorganic matter and parameter**<br>TDS, TSS, COD, BOD, chlorides, sulfates, carbonates and sodium, calcium and magnesium | Nepal Singh et al. (2000) |

## 10.7. Non-Point Source Pollution

It is a factor, which contributes to water pollution and cannot be pointed or traced as a particular point. Non-point source pollution is contributed from urban water runoff, agricultural operations, runoff from construction sites, atmospheric deposition, rainfall, etc. It means that non-point source pollution comes from different diffused sources.

## 10.7.1. Non-point sources

### 10.7.1.1. Urban and peri-urban areas

The urban and peri-urban areas are the major contributors of nonpoint source pollution from where the huge runoff is produced from the paved roads and other surfaces. The materials asphalt and concrete used for paving the roads and surfaces do not allow the penetration of water into them. When the water comes in contact with these paved surfaces, runoff will take place and it is discharged in the surrounding areas. Thus the pollutants carried by that runoff water are easily deposited in soils of the surrounding areas. The materials are easily eroded from the construction sites by rain, snow and hail. Additionally, debris discarded from these sites can also be transported by runoff water and deposited into water reservoirs.

There are the chemicals which are typically used for lawn care in the suburban areas. These chemicals enter into the runoff water and added up in the surrounding environment through storm drains of the city. These chemicals enter into the water bodies directly because the storm water is not treated before its entrance into drains.

### 10.7.1.2. Agricultural operations

Agricultural operations contribute a major part of nonpoint source pollution because of plowing of large fields, these soils are exposed and the soil is loosened. During rainfall, these fields become more susceptible to erosion. This run off also can enhance the quantity of fertilizers and pesticides transported to the nearby water reservoirs.

### 10.7.1.3. Atmosphere

The different pollutants can enter into the atmosphere from different sources e.g. factories, transport. The factories emit different pollutants into the atmosphere through smoke. These pollutants are added into soil through rainfall. The atmospheric pollutants can also become source of water pollution when added into water bodies in the form of rain or snow.

### 10.7.1.4. Forest cutting

Forest cutting reduces the number of trees in that area which results in reduced soil stability. The plant leaves and roots are added into the soil which after decomposition produces organic substances which help in aggregation of soil particles and reduction of soil erosion. Therefore, it is likely that when the trees are cut the addition of plant leaves and roots is minimized which results in soil erosion. Further when heavy machinery is used for this purpose, the risk of soil erosion is also increased.

### 10.7.1.5. Mining

The abandoned mines are also a source of nonpoint source pollution. The runoffs from abandoned mining operations carry the pollutant with it and contribute to nonpoint source pollution. The top of the mountain is removed in strip mining operations, to expose the desired ore. The soil erosion from this area is noticed if it is not properly refilled after completion of the mining process. Moreover, some chemical reactions of air and newly exposed rock may occur resulting in runoff. The water which releases from the abandoned mines may be highly acidic in nature and discharged into the nearest water bodies and it can change the reaction of water.

# 10.8. Types of Soil Pollutants

The different types of soil pollutants are described below:

## 10.8.1. Organic pollutants

Domestic garbage, municipal sewage and industrial wastes are the major source of organic pollutants and, if not disposed off properly, these become serious threat to human health, plants and animals. The organic groups that contain carbon like polycyclic aromatic hydrocarbons (PAHs), dioxins and furans, phthalates and brominated flame retardants, detergents and pesticides are included in these pollutants.

### 10.8.1.1. Polycyclic aromatic hydrocarbons

Polycyclic aromatic hydrocarbons (PAHs) are organic compounds are found in tar materials which have been used for many centuries to preserve wooden materials in ships and buildings. Some of these compounds have the potential to be carcinogenic even when present in small quantities. The burning/combustion of coal and fossil fuels also produce PAHs. These PAHs are spread on soil in urban and peri-urban areas which contribute towards soil pollution.

### 10.8.1.2. Dioxins and furans

Dioxins and furans are toxic compounds which are prone to degrade very slowly as they contain benzene rings. Different quantities of chlorine atoms attach with these benzene rings, which results in the production of different furan and dioxin compound of different levels of toxicity. The primary source of these compounds is the incineration of organic wastes. The required temperature range for these compounds is 300 to 500 ˚C. The increase of temperature above this range causes the destruction of these compounds. The extent of spreading these compounds depends upon the wind velocity as they spread into the atmosphere through smoke.

Their sources in urban areas are incinerators, industrial and domestic fuel burning, metal industry, transport and fires.

### 10.8.1.3. Phthalates

Phthalates are organic compounds used as plasticizers in huge quantities. The sources of phthalates may be industrial processes, addition of products, recycling and disposal of products. Their presence has been reported in most of the ecosystem parts as well as food. The different concentrations of phthalates can accumulate in organisms which disintegrate at a slower rate in sediments than in water. The diethyl phthalate (DEHP) is well known compound of phthalate.

#### 10.8.1.4. Brominated flame retardants

These are characterized by the presence of organic compounds containing bromine which helps to retard flame. These compounds are emitted into soil, water and air from industrial production processes, by using different products and from waste management processes.

### 10.8.2. Inorganic pollutants

Inorganic pollutants include nitrates, phosphates, heavy metals and inorganic acids. Major toxic heavy metals are cadmium, chromium, lead, mercury, nickel, zinc, etc. The two main reasons for the transfer of heavy metals to soil are smelting and mining activities and the spreading of sewage sludge on soil. The point source emissions of large metal industries are causing large scale contamination of land. The local impact of mining activity on soils may be very high, metal concentration in soils with values of order of 1%. The other industries causing heavy metal contamination are chemical manufacturing, oil refining, metal processing and plating, tanneries and fertilizer manufactures. Major sources and toxic effects of metals on animals and human health are given in Table 9.2.

#### 10.8.2.1. Radio-active pollutants

The radio-active contaminants arise from the wastes from mining of uranium (U) and thorium (Th) (both absent in Pakistan), from wastes of hospitals, medical and other research laboratories. Such materials mainly remain on soil surface. Rock phosphate is said to contain U, Th and Ra radio-active nucleates. But locally these are not mined or processed at a scale to cause pollution.

### 10.8.3. Microbial pollutants

In Pakistan, the urban soils regularly receive refuse and organic manures e.g. FYM), the amounts of which can be visualized from large number of domesticated animals. It is expected that such refuse may contain pathogens, such as typhoid, dysentery, tuberculosis, poliomyelitis and many spp. of anaerobes. However, these microorganisms are not always found in various wastes but sanitary aspects should not be ignored. In general, metabolites of microorganisms and plants accumulating in soils as well as the established relations among the many groups of soil micro-biocenosis stabilize it to some extent and tend to eliminate foreign microorganisms, i.e. a natural control. This is precisely what determines soil's self-purification process.

## 10.9. Water Pollution

A body of water, such as a lake, stream, river, pond, ocean or even underground water can become polluted when it is contaminated by sewage leaks, agricultural runoff or chemical spills. Thus, it is unsafe for human consumption because the water contains dangerous or toxic substances and disease-causing microorganisms.

When water is polluted from point sources, this is pollution from a discrete location.

**Table 10.2** Major sources and toxic effects of metals on animals and human health

| Metal | Source | Toxic effects of metals |
|---|---|---|
| Ni, Mo, Pb, As, Hg | Industry | Sb: Shortening of life in rats.<br>Be: Most toxic, accumulates in lungs to cause beryliosis – a fetal disease. |
| Cr, Na, Cl | Waste gases, water, residues, metal industry | Bi: Damages kidney and liver if taken in large doses.<br>Cd: Cardiovascular disease and hypertension, |
| Pb, Cr, Hg, As | Tanneries, POL burning | interferes with Zn and Cu metabolism, severe nausea, salivation, vomiting, diarrhea, lipid |
| Cd, Pb, Ni, Cu, Cr, Sb | Dust from coal and petroleum combustion | deposition in the arteries of heart, abdominal pain.<br>Pb: Brain damage, convulsions, behavioral |
| Hg, Pb, Cd | Waste water from electro-plating units | disorder, fatal, anemia, headache, dizziness, loss of memory.<br>Hg: Nerve damage, fatal. |
| Pb | Waste water from plastic and battery industry and autovehicle exhaust | Cu: Nausea, epigastric burning, diarrhea, gastrointestinal bleeding.<br>Ni: Carcinogenic for animals and human beings, particularly if inhaled as carbonyl [$Ni(CO)_4$], abdominal discomfort, vomiting, |
| Cu, As | Exhaust gases from automobiles | nausea, diarrhea, headache, cough.<br>Sn: Low order of toxicity, decrease life span in |
| Cr, Cd, Na | Pesticides, rubber and soap industry | rats and mice.<br>As: High levels inhibit tissue oxidation and |
| I, P, Cr, Cd, Na | Textile, rubber, dye and leather industries | cholesterol, lipids and amino acids synthesis, and can cause precipitation of serum proteins.<br>Cr: Lung cancer, gastrointestinal upset, ulcer, edema, dermatitis.<br>Fe: Gastrointestinal hemorrhage, metabolic acidosis. Mn: Lethargy, increase in muscle tone tremor, mental disturbance.<br>Zn: Dehydration, electrolyte imbalance, abdominal pain, nausea, lethargy, dizziness, muscular discoordination.<br>Co: Loss of apatite, anaemia leading to death. |

*Source: Sethi and Sethi (1991)*

This discrete location could be a factory, a sewer pipe or a runoff from a single farm. The *Deepwater Horizon* oil spill in 2010 (also referred to as the BP oil spill, the BP oil disaster, the Gulf of Mexico oil spill, and the Macondo blowout) is an example of point source pollution, because the massive amount of oil leaked from a single point of origin.

The water pollution could also be from non-point sources, that is, when several points of contamination over a large area contribute to the pollution of a water body. For example, one water body may be contaminated by multiple sources like agricultural runoff, city street runoff, construction sites and residential lawns.

## 10.9.1. Surface water pollution

Surface water pollution is the pollution of aquatic systems that are above ground, such as streams, lakes and rivers. These waters become polluted when rainwater runoff carries pollutants into the water. The pollutants transported by runoff are things like salts and chemicals from city and highway roads and nutrients and fertilizers from farms and lawns.

When pollution is caused by nutrients and fertilizers, this is called nutrient pollution, and it leads to an over production of algae and other aquatic plants. This overabundance of plants and algae causes problems, because they cover the water surface and prevent sunlight from reaching the plants underwater. This then leads to less oxygen production, which causes harm to oxygen-breathing organisms in the water, like fish.

Surface water may also be polluted with pathogens and causes waterborne diseases, which is usually the result of sewage leaks and runoff from animal sheds. These viruses and bacteria that pollute the water may cause dangerous human health problems such as giardia, typhoid and hepatitis. Toxic chemicals may also lead to surface water pollution. These come from pesticides, synthetic chemicals such as petroleum products and other car fluids, mercury, lead and arsenic from mining site drainage.

## 10.9.2. Groundwater pollution

The water found underground in cracks and voids in soil, sand and rock is known as groundwater. The groundwater channels are generally formed with gravel, sand stone, sand or fractured rocks such as limestone. The groundwater table could be deep or shallow and it could increase or go-down in depth contingent on several aspects.

The regions where material above the aquifer is penetrable, contaminants could immediately leach into groundwater channels. Groundwater can be contaminated by underground gas tanks, septic tanks, landfills and due to the extensive use of pesticides and fertilizers. If groundwater is contaminated it becomes unfit for drinking.

Contamination of groundwater resources occurs when contaminated oil, gasoline, road salts and toxic chemicals are released into the groundwater and the water becomes unfit and unsafe for human use. In addition, the natural processes such as weathering of parent material, oxidation-reduction reaction of minerals can also result in the release of some toxic heavy metals and metalloids in the valuable groundwater reservoirs. For example, arsenic and fluoride are released in the groundwater systems due to weathering of minerals (containing these toxic elements), in many countries of the Southeast Asia region. The pesticides and fertilizers can leach to the groundwater supplies over time. Toxic substances released from mining sites, road salts and used motor oil from garages also may leach into the groundwater. Additionally, it is also possible that untreated waste materials from septic tanks and extremely toxic chemicals from leaked landfills and underground storage tanks may contaminate groundwater.

## 10.9.3. Biological oxygen demand

The biological oxygen demand (BOD) is defined as the amount of $O_2$ required by microorganisms for decomposition/breakdown of organic matter present in a given water sample at certain temperature over a specific time period. Biological oxygen demand is an important factor to determine the $O_2$ demand of the water coming from various sources (Yadav et al. 2013).

The organic matter can be decomposed by various microorganisms present in the water body. Aerobic microorganisms (bacteria and fungi) use oxygen and break down the organic matter and the end products are water, carbon dioxide, nitrate and phosphate. As the microorganisms ingest $O_2$, concentration of dissolved $O_2$ in the water stream starts decreasing.

The microbial species intolerant of low oxygen levels are stressed when the dissolved oxygen level drops below 5 mg $L^{-1}$. When O2 concentration in water body is below 2 $mg^{-1}$ over a few hours, the aquatic life such as fish species can die. For the $O_2$ levels below 1 mg $L^{-1}$, anaerobic bacteria (living in oxygen deficient environments) take the place of aerobic bacteria (Jordan et al. 2013). With the degradation of organic material by anaerobic bacteria, rotten egg smelling hydrogen sulfide is produced.

The biological oxygen demand can be divided into two parts: (i) the carbonaceous bio-chemical oxygen demand; and (ii) nitrogenous oxygen demand. The carbonaceous biochemical oxygen demand (CBOD) is related to the degradation of organic materials (molecules), for example, cellulose- and sugar-based compounds into $CO_2$ and water.

The nitrogenous oxygen demand (NOD) is related to the breakdown of protein-containing compounds. The nitrogen is degraded from a sugar-based compound, usually in ammonia ($NH_3$) form, which is immediately transformed to nitrate in the water environment. On the release of nutrients mainly nitrate and phosphate into the water body, the growth of plant species in the water is enhanced. The result is an increased plant decay that enhances the microbial populations, and as a result higher levels of BOD, and high demand of oxygen from the photosynthetic organisms during the dark hours. This leads to a decline in dissolved oxygen levels, particularly in the early morning times.

## 10.9.4. Chemical oxygen demand

Chemical oxygen demand (COD) is a measure of the capability of water to utilize $O_2$ during degradation of organic materials and oxidation of inorganic substances such as $NH_3$ and nitrite. It is expressed in milligrams per liter (mg/L), which indicates the mass of $O_2$ consumed per liter of solution. The chemical oxygen demand determination is usually made on samples of wastewaters or of natural waters polluted by wastes from domestic or industrial sources. It is related to BOD that is used as a standard test to assay the oxygen-consuming strength of waters. However, BOD only estimates the amount of $O_2$ required for microbial oxidation and is highly relevant to wastewaters containing high content of organic matter.

### 10.9.5. Eutrophication

The ingression of the water body by surplus amount of phosphate and nitrate nutrients is known as *eutrophication* and it could lead to an explosive growth of algae, which probably disturb the water environment (Fig. 10.2). The algae can reduce the light penetration and when algae ultimately die, the microorganisms in water degrade them. Relying on the environment (e.g., silent bay or rough oceans/seas) and the kind of algae species (microscopic or macroscopic), the algal bloom can be found in diverse forms, e.g., foam/green tide on the beach.

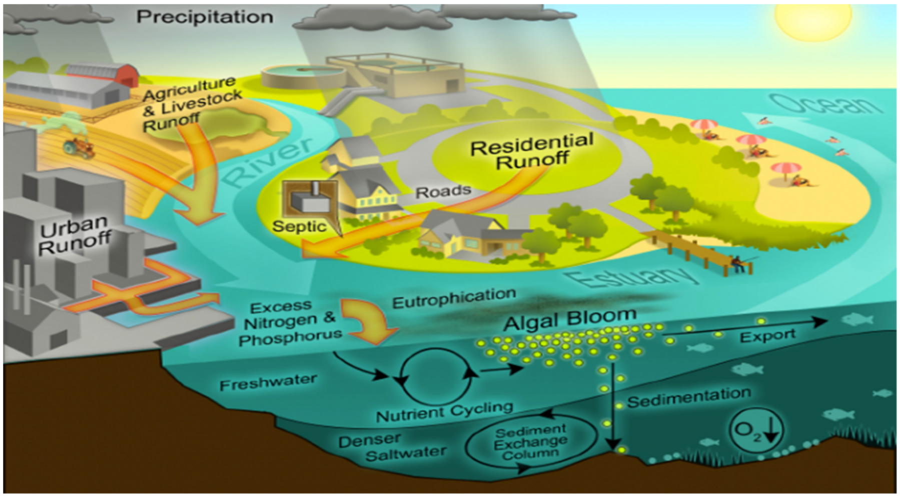


**Fig. 10.2** Schematic diagram of the different pathways of nutrient deposition into waters and ensuing processes leading to eutrophication (algal blooms) and hypoxia (Figure provided by Dr. Hans Paerl and Alan Joyner, University of North Carolina at Chapel Hill, Institute of Marine Sciences)

The major harmful effects of eutrophication are:

- Nutrient pollution in water bodies caused as a result of eutrophication can affect the aquatic life and may cause their death.
- Pollutants can negatively affect the reproductive processes, development of aquatic life and can increase their susceptibility to diseases.
- Smaller life forms may consume chemical pollutants which can become a part of food chain when they are passed to larger animals.
- Pollutants can change the metabolic activities of microbes residing in surrounding areas which can lead to the destruction of some food chain layers.

- High biomass of aquatic plants leads to algal blooms.
- Hypoxic water environment (deficiency of dissolved oxygen in water).
- Increase in fish deaths.
- Unacceptable and bad taste, color and odour of water.
- Reduction in biodiversity of species.

# 10.10. Effects of Pollution

There are of course many effects of environmental pollution which vary widely. The excessive levels of pollutants in air, soil and water are serious threat to humans, animals and plants. The various types of pollutants present in the environment affect the organisms or group of organisms. Their effects on living organisms may vary from minor disorders to serious diseases like cancer and missing limbs.

## 10.10.1. Effects of pollution on human health

Since soil and water pollution are closely linked, therefore their effects appear to be similar. Prominent problems associated with them are listed below:

- Exposure to various diseases like cancer, damage to the DNA, typhoid, hepatitis, cardiovascular diseases, stomach disorders, etc.
- Hormonal problems.
- Damage to the nervous system.
- Disruption to the reproductive and development processes.
- Damage to the body organs (liver, kidney etc.).
- Respiratory problems.
- Irritation and general illness.

## 10.10.2. Effects of pollution on trees and plants

Plants have ability to absorb pollutants from contaminated soil and water which become a part of food chain and ultimately passed to animals and human.

Pollutants have the capacity to disrupt photosynthesis in plants.

It may change the plant metabolism, growth and yield.

Pollutants can also lead to the death of plants and thus affect whole ecosystem.

# 10.11. Management of Soil and Water Pollution

## 10.11.1. Physical Management

### 10.11.1.1. Incineration

The process which is used to burn hazardous substances in an “incinerator” at temperatures high enough to degrade pollutants is called incineration. Incinerators are specially designed furnace to burn hazardous substances through combustion. Incineration can treat various hazardous materials like soil, gases, liquid and sludge by applying heat from 871–1371°C. It has the capacity to degrade various hazardous chemicals like pesticides, solvents, PAHs, PCBs, etc. but incineration is ineffective to destroy heavy metals, such as lead and chromium. It requires excavation or pumping of materials to be treated into the containers before incineration. After necessary preparations (drying to remove excess water, removal of debris and large rocks, grinding, etc.), materials are exposed to very high temperatures in combustion chambers for specified period of time. Nature of waste and contaminants present within determine the treatment length and temperature.

Lot of fuel/energy is required for incineration but there is a possibility to use generated heat for the production of electricity. Moreover, it is a rapid process that can quickly clean the contaminated materials to avoid immediate harm to the people or targeted environment. Incineration decreases the amount of material to be disposed off.

### 10.11.1.2. Thermal desorption

Thermal desorption is used to remove organic contaminants from excavated soil, sediments and sludge by applying heat which causes the pollutants to evaporate. Evaporation separates the organic pollutants from solid phase. This technique has shown strong efficiency to remove volatile organic compounds and semi-volatile organic compounds. Thermal desorption is differentiated from incineration on the basis of temperature difference, remediation strategy and time of treatment. In thermal desorption, materials are heated to evaporate the organic pollutants while incineration burns the contaminated material and thus volume of treated material is reduced at the end of treatment in incineration. Moreover, temperature varies from 93–538°C (depending upon pollutant present) in thermal desorption while incineration is characterized by higher temperature ranging from 871–1371°C. Thermal desorption usually takes longer than incineration.

Contaminated vapors are formed as a result of thermal treatment and thus gas released during treatment should be collected for further treatment. Sometimes vapors of organic pollutants are condensed to change them into liquids. These newly formed liquid chemicals may be treated by incineration or recycled for reuse. Dust particles if formed should also be removed from the vapors. Vapors can also be emitted directly to the atmosphere without treatment if dust is not a problem and the concentrations of pollutants are low enough. Thermal desorption offers a rapid cleanup solution to remediate soils highly contaminated with organic pollutants at shallow depths.

#### 10.11.1.3. Soil washing

Soil washing is an ex-situ remediation technique to remove organic and inorganic pollutants by applying liquids and mechanical processes. Soil washing is used to dissolve or suspend the target contaminants by applying liquids comprising of water and/or combined with solvents. Chemical wash additives (acids, caustics, surfactants and chelating agents, etc.) are chosen on the basis of nature and extent of pollution, their ability to enhance pollutant availability and environmental impacts. Physical processes are also employed to remove pollutants. It includes the physical separation of fine-grained soil particles (clay and silt) from the rest of the soil. Physical separation of fine soil particles is employed because most of the pollutants tend to sorb and accumulate onto the fine-grained soil particles. Separation of these silt and clay particles from the rest of the soil decreases the volume of polluted soil for further treatment. Other methods can be used to treat this smaller volume of soil (chemical oxidation, incineration, thermal desorption or bioremediation) if not disposed.

### 10.11.2. Chemical Management

#### 10.11.2.1. Advanced chemical oxidation processes

Chemical oxidation is an important environmental remediation technique used to treat various organic pollutants from contaminated matrices like drinking water, wastewater and soil. Chemical oxidation involves rapid destruction or degradation of contaminants with no significant waste products. This process involves the use of chemical oxidants able to oxidize organic pollutants and to convert them into non-toxic or less toxic forms. Injection of oxidants into the aquifer or soil is followed by its mixing with polluted materials to accomplish chemical oxidation at a contaminated site. Various oxidants are used including permanganate ($MnO_4^-$), ozone ($O_3$), persulfate ($S_2O_8^{2-}$) and Fenton's reagent [hydrogen peroxide ($H_2O_2$) and ferrous iron ($Fe^{2+}$)].

The oxidants being used are readily available and length of treatment is usually in days (sometime months) instead of years and thus making chemical oxidation economically feasible. Moreover, chemical oxidation can be employed at highly contaminated sites where bioremediation seems ineffective due to extreme pollution or elevated toxicity enabling microbes to survive there. Chemical oxidation is also known for its non-selective nature and thus able to degrade variety of organic pollutants coming into contact with chemical oxidants.

The efficiency of chemical oxidation process depends upon the quantity of oxidant being used, nature of oxidant especially its residence time or stability, geological conditions and how effectively oxidants come into contact with the pollutants. Major drawback associated with chemical oxidation is natural oxidant demand caused by non-selective oxidation which degrades the non-target compounds also. Significant chemical losses occur because of non-target consumption of oxidant by soil rather than contaminants thus increasing overall cost of the remediation. Higher oxidant doses also affect the physical properties of soil e.g. clogging of soil pores which in return affect soil aeration and dissolved residual oxygen used by aerobic microorganisms to degrade contaminants. Moreover, chemical oxidation is limited by efforts to adjust contact time, temperature and pH of reaction which are important to ensure the desired extent of oxidation.

#### 10.11.2.2. Sorption

Sorption is described as the fixation of molecules from liquid phase to solid phase. Sorption includes both absorption and adsorption. Adsorption is the attachment of sorbate (pollutant) at the interface of an aqueous phase and sorbent (solid material on which pollutant is sorbed) while absorption is defined as the partitioning from the solution phase into the sorbent matrix. Contaminated matrices can be complex and heterogeneous where both adsorption and absorption may occur at the same time, and it is often impossible to differentiate between the two.

Sorption removes the pollutants from contaminated matrices by reducing their activity as well as availability and therefore sorbed molecules are less toxic to the ecosystem and human health. Moreover, due to reduced availability, biodegradation of organic pollutants is also decreased with sorption. Rate of sorption/desorption determines the efficiency of other remediation techniques like bioremediation due to its influence on bioavailability.

Sorption is an important process in contaminated environments as it controls transport, transformation and distribution of the contaminants. It is also an important process of natural attenuation for relying on natural processes to decontaminate the polluted sites. Other processes involved in natural attenuation include biodegradation, dilution, evaporation and chemical reactions with natural substances.

#### 10.11.2.3. Electrokinetic remediation

Electrokinetic remediation is an efficient technique to remediate water and soils polluted by organic, inorganic and mixed contaminants. This technique is particularly effective in fine-grained soils having large surface area and low hydraulic conductivity. However, its efficiency is limited by sorption of pollutants onto the soil particles. Moreover, hydrogen ions and hydroxide ions produced at the electrodes also affect its efficiency in a negative way. Recovery of ionic contamination from groundwater is limited by the fact that soil is a powerful ion exchange media. A direct-current (dc) electric field is imposed on the polluted soil which causes the migration of the contaminants by the combined mechanisms of electro migration, electro osmosis and/or electrophoresis.

#### 10.11.2.4. Chemical extraction

Chemical extraction is used to transfer pollutants (organic, inorganic and mixed) from contaminated matrices into an aqueous solution by using an extracting liquid containing a chemical reagent (surfactants, salts, chelating agents, redox agent or acids/bases). Chemical extraction is accomplished by using chemical solutions having ability to enhance the availability or solubility of targeted pollutant followed by their separation from contaminated matrices. Certain forms of the metal compounds are formed as a result of extractions which are more soluble (e.g., conversion to soluble metal salts by valence change). Efficiency of this process depends upon the geochemistry of polluted medium, characteristics and extent of pollution, chemistry and dosage of extraction agent and extraction conditions (pH, solid/liquid ratio, reaction time, mode of extraction etc.).

## 10.11.3. Biological Management

### 10.11.3.1. Phytoremediation

Phytoremediation is defined as the use of various plant species to eliminate, stabilize, transfer or destroy pollutants in the soil and water. Various types of phytoremediation are described below:

Phytodegradation: The plant roots secrete natural substances, which are a good source of nutrients to microbes in the soil. As a result, microbial species increase the degradation process.
Phytostabilization – the chemical compounds produced by the plants and/or plant roots immobilize and bind the contaminants, rather than degrading them.
Phytoaccumulation or phytoextraction: The plant roots extract the contaminants, mainly heavy metal (loid)s, along with other nutrients and water. This method is used primarily for remediation of soils containing heavy metal(loid)s, e.g., lead (Pb), arsenic (As).

Phytovolatilization: In this process, plants extract water contaminated with organic contaminants and then the contaminants are evaporated into the atmosphere through their leaves.

### 10.11.3.2. Applications of phytoremediation

Phytoremediation is a useful technique for the treatment of metals, pesticides, radionuclides, fuels, explosives, semi-volatile organic compounds (SVOCs) and volatile organic compounds (VOCs).

Studies on phytoremediation have shown that there are about 400 plant species which are capable for hyperaccumulation of heavy metals (Brooks 1998; Baker et al. 2000). The plant species capable of hyperaccumulation of heavy metals are either high biomass producing plant e.g. willow (Landberg and Greger 1996) or low biomass producing plants having high hyperaccumulating traits e.g. *Thlaspi* and *Arabidopsis* species.

Further research is being conducted to enhance our understanding about the role of phytoremediation in remediating perchlorate, which is present in surface and groundwater bodies and is reported to have high persistent in the environment. For radioactive pollutants and heavy metals, use of chelating agents is very important to increase the uptake of contaminants by plants.

## 10.11.4. Bioremediation process and its types

Bioremediation is the process of using microorganisms, plants, or enzymes produced by microorganisms, plants or both to degrade or transform the contaminants in soil or other environmental matrices. Generally, bacteria are considered as vital for bioremediation because they degrade dead organic matter and also use the organic matrix as source of nutrients for their nourishment. Special type of contaminants like chlorinated pesticides can easily be digested by bacteria. Similarly oil spills can also be cleaned by bacteria. However, bioremediation cannot destroy all kinds of contaminants; e.g., heavy metals such as arsenic, cadmium and lead cannot be decomposed by the action of microorganisms.

#### 10.11.4.1. Strategies for bioremediation

A number of bioremediation strategies can restore the quality of degraded soils and the environment. For a given contaminant, one or more of the following strategies may be needed to ensure successful bioremediation.

***i. Passive bioremediation***

It is a natural bioremediation process of contaminated sites by indigenous microorganisms. The contaminated soils can be remediated through this process but the rate of degradation (breakdown) may be too slow for some situation. The challenge with this type of bioremediation is that it is very difficult to monitor and therefore it is very difficult to predict the degradation rate of the contaminants.

***ii. Biostimulation***

It is the process of bioremediation in which the indigenous microorganisms are supplied with nutrients, such as nitrogen and phosphorus, to stimulate their activity. The small quantities of the contaminant or an analogue can be added as stimulants which encourage the production of enzymes responsible for degradation.

***iii. Bioventing***

It is the process of biostimulation in which gaseous stimulants, such as oxygen (to improve aerobic conditions) and methane (as energy and carbon source to enhance cometabolism), are added in the soil to stimulate microbial activity. These stimulants are added into soil by pumping process.

***iv. Bioaugmentation***

It is the inoculation of a contaminated site with microorganisms that enhance the contaminants biodegradation process. The bacteria are the most common organisms which are usually used for bioaugmentation. A single species or consortium (group) of organisms can be used for biodegradation of contaminants. The inoculants may contain genetically changed or wild type of microorganisms as a single species or consortium of many species. In most of the cases the selected organisms having high potential for degradation of the contaminants are used.

## 10.12. Remediation of Contaminated Water

### 10.12.1. Rhizofiltration

It is similar to phytoaccumulation, but the plant species are grown in greenhouse having their roots submerged in water. This process can be applied for *ex-situ* treatment of groundwater in which, groundwater is brought to the surface by pumping to give water to the plants. As the roots become saturated with contaminants, they are harvested.

### 10.12.2. Biosorption

It is a physico-chemical process in which contaminants bind and accumulate gradually onto the cellular structure of certain biomass. Biosorption is a process in which energy is not needed, and the concentration of contaminants such as heavy metals that are removed by sorbent relies on kinetic equilibrium as well as cellular structure of sorbent cellular. These contaminants become adsorbed on surface of the living material and this process is run metabolically with the energy produced by living organism and it needs respiration. Use of biomass for environmental remediation has been practiced since many years, researchers are trying to make this process as an economical alternative to remove toxic heavy metals from contaminated industrial water and help in environmental cleanup.

### 10.12.3. Bioaccumulation

Bioaccumulation happens when contaminants are adsorbed and transferred onto the surface and move towards the interior of the cellular surface. As compared to biosorption in the remediation of environment, bioaccumulation is much preferable due to its faster rate and ability to concentrate higher quantities of contaminants. Since heavy metals are adsorbed onto the surface of sorbents, biosorption is potentially a reversible phenomenon than the partially reversible process of bioaccumulation.

## 10.13. Environmental Risk Assessment

Environmental risk assessment (ERA) is important to understand the concept of hazard and risk prior to proceed to environmental risk assessmet. Hazard is the ability, nature or property of a substance or situation which has the potential to cause harm in terms of human injury, ill health or damage to property or the environment. The term risk in everyday language means "chance of harm" but when it is used in risk assessment process, it has specific definitions, the most commonly agreed "The combination of the probability, or frequency, of occurrence of a defined hazard and the magnitude of the consequences of the occurrence" (Royal Society 1992) whereas Aldenberg and Jaworska (2000) defined it as a structured process to estimate the likelihood and severity of risk with attendant uncertainty.

Hazard and risk can be differentiated with an example. Most of the chemicals are hazardous. Acids can cause corrosion or irritate to human beings. However, these acids can cause risk to humans only if they are exposed to them. The extent of harm will depend on the situation of exposure. If this contact occurs after heavy dilution of acids, there will be minimum harm to human beings but the hazardous property will not be changed. Therefore, it is clear that these terms have different meanings and may not be exchanged with each other.

Risk assessment is a process which estimates the risks qualitatively or quantitatively caused by potential hazards. If we take the example of chemicals, the risks can arise during their manufacturing, distribution, or disposal. The identification of inherent hazardous and risks caused by those hazardous are estimated during the process of risk assessment. Risk is measured by incorporating the measurement of the likelihood of the hazard which causes harm and an estimation of the extent of harm in terms of consequences on environment and human beings. The term environmental risk assessment does not normally cover the risks to individuals or the general public at large from consumer products or from exposure in the work place, where other specific legislation applies. In other words environmental risk assessment is the qualitative and quantitative evaluation of environmental status. ERA is comprised of human health risk assessment as well as ecological risk assessment (Cowan et al. 1995).

### 10.13.1. Stages in carrying out an environmental risk assessment

The environmental risk assessment can be conducted by different methods; however, the particular methodology and responsibility may vary to carry out the assessment. The major rules and important stages of these methods are basically the same in every case (Lindenschmidt et al. 2008). It is important to clearly identify the problem which is being addressed and the limits to make the decisions on environment be fixed prior to carry out the risk assessment. This phenomenon is called problem formulation and particularly can define the cause of risk, environmental part to be harmed, location and time (Lee-Steere, 2009). All that can also help to select the level and types of assessment methodology which are going to be used in environmental risk assessment itself.

The following stages may be followed for environmental risk assessment;

1) Identification of hazard: It is the identification of situation or property that can cause harm.
2) If the hazard occurred what were its consequences.
3) Evaluation of the extent of consequences in which temporal and spatial scale of consequences which occurred over the period of time.
4) Probability estimation of the consequences based on the following three components (Lee-Steere, 2009); a) hazard to be there, b) exposure probability of the receiving organism which was exposed to hazard, and (c) harm probability resulting from exposure to hazard.

Evaluation or characterization of risk importance is obviously the result of the likelihood of the hazard which is being considered and extent of consequences. The uncertainty associated with risk and hazard may also be considered in this part (Fig. 10.3).

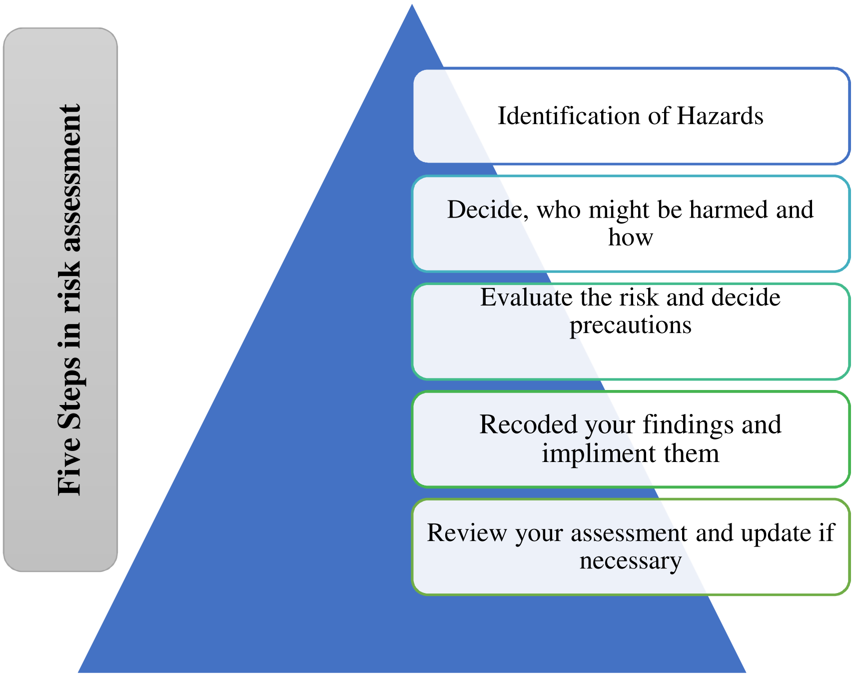


**Fig. 10.3** Steps in risk assessment

On completion of risk assessment process, the control measures in hand should be noted and additional measures may also be taken to minimize or remove the identified risks. Evaluation of significance is the final stage which involves placing it in a structure; for instance, with respect to environmental standards or other criterion defined in legislation, statutory or good guidance practice.

## 10.13.2. Qualitative risk analysis

It is the utilization of methods in order to place the identified risks with respect to their potential effect on project objectives (Sudirman and Hardjomuljadi 2011). This process prioritizes risks with respect to their potential effect on the objectives of the project. Further qualitative analysis is one way of mentioning the significance of addressing specific risks and it also guides the response of risk measures. The Probability–Impact matrix is a common and simplistic example of qualitative risk analysis. Risk probability and risk impact may be described in qualitative terms such as very high, high, moderate, low and very low. The sense of high, medium, low and very low can be mentioned in different ways; for instance, the descriptive or numerical scales used are usually based on the judgment of experts. On identification of risks, the matrix permits to easily determine the relative significance, so that the risk can be prioritized and appropriate strategy or program can be executed as shown in Fig. 10.4.

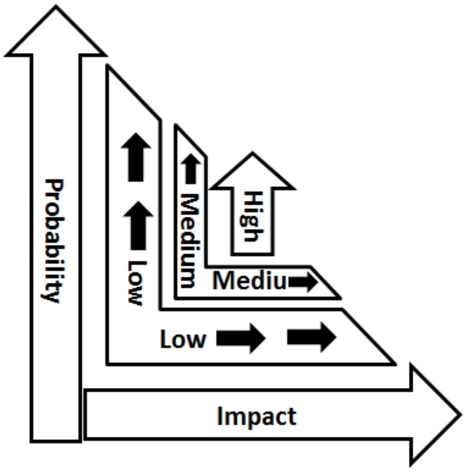


**Fig. 10.4** Risk management strategy

The use of quantitative risk assessment approaches may be more suitable in relatively more complicated cases. Further the pathway and consequences can be defined though these approaches by using modeling techniques. These modeling techniques also allow determining the extent of exposure of any receptor, consequences to the receptor in a better way. The probabilistic models can be used in order to evaluate the real probability of the occurring risk in some cases.

#### 10.13.2.1. Human health risk assessment

Human health risk assessment (HHRA) involves the followings:

- hazard identification,
- dose-response assessment,
- exposure assessment, and
- risk characterization.

#### 10.13.2.2. Ecological risk assessment

The ecological risk assessment determines the likelihood of the occurrence/non-occurrence of adverse ecological effects as a result of exposure to some stress factors.

### 10.13.3. Quantitative risk assessment

The quantitative risk assessment deals with the following:

- The quantity of toxic material in the inventory is hazardous.
- Over pressure in the storage tank (with failure of the relief valve) may lead to tank rupture.

- The combination of wind speed and atmospheric stability may lead to an estimated spatial and temporal distribution of toxic material concentration over time and space.
- The distribution of population based on night-time occurrence.
- The vulnerability of quantitative risk assessment models has been postulated.
- These have been based almost exclusively on animal test data. For example, the equation is:

$$Pr = At + Bt \ln (Cnt)$$

where $Pr$ = probability function, $At$, $Bt$, and $n$ are constants, $C$ is the concentration of pollutant to which exposure is made (in ppm v/v), and $t$ is the duration of exposure to the pollutant (measured in minutes). These types of models have been derived from dose relationships and the probability of affecting a certain proportion of the exposed population.

## 10.14. Conclusion

The rapid industrialization and urbanization is causing increased environmental pollution which is resulting in deterioration of natural resources like soil and water. Ultimately this environmental pollution is imposing great stress to humans, animals and plants.

The activities carried out by humans e.g. agriculture, industrialization, health care, road transport and generation of energy are the major causes of pollution. It has been observed that the industries like petroleum, paper, textile, sugar, food, cement and chemical pollute soil, water and air.

The use of pesticides, fertilizers and industrial waste water pollute our fo od. The pesticides enter into food chain and accumulate in plants, human and animal bodies. These accumulated poisons cause health issues which range from simple headache to brain tumors.

Soil ecosystem has been imbalanced along with various ecological hazards in urban and rural areas due to soil pollution caused by different solid and liquid pollutants.

Transport is the major source of air pollution in urban areas. The vehicles release greenhouse gases like CO, $SO_2$, $NO_2$ which pollute air in urban areas.

Human health problems e.g. breathing, throat/lung cancer are caused are the result of air pollution in urban areas. The polluted water cases the human health problems like gastric, ulcer and formation of tumors.

Environmental pollution control has become imperative to save human health and natural resources. But the fast growing population has become a serious challenge for the control of environmental pollution.

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