IMPACT OF ENVIRONMENTAL CONTAMINATION ON BIODIVERSITY

O.P. Singh

Biodiversity is the variability among living organisms and the ecological complexes of which they are part, including diversity within and between species and ecosystems. It includes the diversity of forms right from the molecular level through individual organisms, populations, ecosystems, landscapes and biosphere. It encompasses viruses, bacteria, fungi and other microorganisms as well as all plants and animals found on earth. Biodiversity can be found all around us in air, water and soil, and within or on the body of living organisms itself.

Biodiversity is the basis of human survival. It has direct consumptive value as food, fodder, fuel and medicine. It is source of clothing, building material and raw material for industry. It has aesthetic and recreative values. In addition, biodiversity maintains ecological balance and continues evolutionary process. The indirect ecosystem services provided through biodiversity are photosynthesis, pollination, transpiration, chemical cycling, nutrient cycling, maintenance of soil fertility, climate regulation, management of air and water systems, cleansing of environment and control of pests and diseases.

In the last few decades, there has been a drastic reduction in biodiversity in terms of ecosystem disruption, depletion of species abundance and diversity, and species extinction. The estimated extinction rate predicts extermination of about 30 per cent of all species in next fifty years (Wilson, 1992; Lawton and May, 1995). Habitat disturbance, fragmentation and destruction, overexploitation and illegal trade, and environmental contamination and degradation are some of the major recognized causes of biodiversity depletion (Stiassny, 2000). In this article, an overview of the impact of degradation of three important environmental components, the air, water and soil on biodiversity has been discussed.

Degradation of Air Quality and Biodiversity

Air Pollution and its General Impacts

The magnitude of degradation of ambient air quality is increasing day-by-day due to release of a large number of gases and particulate materials originating from industries, automobiles and burning of coal and other fossil fuels. Carbon dioxide (CO_2), carbon monoxide (CO), sulfur dioxide (SO_2), nitrogen oxides (NO_X), methane (CH_4), hydrogen sulfide (H_2S), volatile organic compounds, and metal fumes and particulate emissions are the major contributors of air pollution. Some of these pollutants, on wet deposition are also responsible for degradation of soil and water quality.

Air pollution is a serious threat to the diversity of life. It affects various life forms directly by causing toxicity and reducing their viability and fecundity, and indirectly by making them susceptible to pests and diseases. Some pollutants at ambient levels do not have any apparent direct effects on organisms, but they do alter the physical and chemical environment and thus affect the ability of species to survive. Lower life forms are usually more affected than the higher forms by air pollution. In general, plants are more affected than animals on land. The number of plant species affected by pollution is more than three times the number of animal species on land. But in freshwater ecosystems, on the other hand, the decline is greater among animal species than plants. According to an estimate, air pollution affects about 1,300 species, including 11 mammals, 29 birds, 10 amphibians, 398 higher plants, 305 fungi, 238 lichens and 65 invertebrates (Dudley, 1987; Tickle *et al.*, 1995).

Impact on Plant Biodiversity

The air pollution severely affects plants such as blue-green algae, lichens, bryophytes, fungi, herbaceous flowering plants, and broadleaf and coniferous trees. As a result, population of many sensitive species is declining in areas affected by air pollution. Simultaneously, a few tolerant and hardy species are becoming more prevalent. Thus, air pollution is playing a key role in changing the distribution and abundance of many plant species, and the ecology of susceptible plant communities in polluted areas. Dry and wet deposition of sulphur dioxide and oxides of nitrogen mostly affect lichens, bryophytes and herbaceous flowering plants. However, blue-green algae, fungi and soil microorganism are particularly affected by wet deposition of these acid forming gases. Further, air pollution is responsible for reduction of plant growth, defoliation, root necrosis, chlorosis in leaves, lack of seedling growth and premature tree death resulting into forest damage (Farmer, 1990).

Impact on Animal Biodiversity

The impact of air pollution on animals also appears to be wide-ranging. It varies from food loss to habitat degradation and from cell and tissue damage to direct toxicity. Impacts on higher animals are most commonly linked with food loss or loss of ability to reproduce, rather than to direct toxic effects on adults. For example, studies on mammals and birds have found the strongest links between population decline and loss of food species. Often, acidification of soil and freshwater due to wet deposition reduces the population of insects and fish, which form food for many mammals and birds. Amongst the animals of lower orders, such as amphibians and fish, impacts are mostly related to reduction and loss of reproductive ability due to metal contamination. The effect on invertebrates relates with their significant decline in population. Among the species most affected are all kinds of zooplanktons, flatworms, leeches, snails, bivalves, small crustaceans, crayfish, mayfly and stonefly larvae, earthworms, slugs and snails, and certain kinds of spiders, butterflies and moths, honeybee and beetles. Hence, air pollution is a significant contributory factor for the decline of global biodiversity. It also affects the socio-economic condition of the people by reducing the production of honey, silk, timber, agricultural and horticultural produce and adversely affecting the human health (Tickle *et al.*, 1995).

Degradation of Water Quality and Aquatic Biodiversity

Degradation of Water Quality

Many different processes and materials pollute ground and surface water bodies and cause degradation of water quality. Major sources of water pollution include runoff from agriculture fields, urban and industrial areas, leakage from septic tanks and disposal sites, accidental spills and air fallouts. These sources contaminate water bodies with organic matters, pathogens, inorganic and organic chemicals, acids, toxic and hazardous chemicals and sediments. A great deal of information is now available on adverse impacts of water degradation on human health, agriculture and aquaculture and industrial productivity, and also on biodiversity in and around the contaminated water bodies. A brief account of negative impacts of degradation of water quality on freshwater biodiversity is given below.

Aquatic Biodiversity

The organisms living in freshwater include a variety of microflora such as bacteria, algae, fungi and aquatic plants, and a large number of benthic animal species. Among aquatic animals, group of benthic macroinvertebrates (bottom living invertebrates that are visible by naked eye) is the largest, and constitutes of extremely diverse assemblage, containing representatives of major invertebrate groups. It includes more than 500,000 different species of insects, snails, leeches, aquatic worms, water bugs, crayfish, sponges, coelenterates, hydrocarina, oligichaetes etc. The most diverse group is of aquatic insects, which account for about 70 per cent of the species diversity of benthic invertebrates (Allan, 1995).

Impact on Aquatic Biodiversity

Different species groups have different sensitivity and tolerance to water quality degradation. As a matter of fact, less sensitive species can tolerate the pollution to some extent and thrive. In contrast, highly sensitive species die and disappear from the community on exposure to pollution. Thus, their abundance, composition and diversity depend on quality of water that they inhabit. In clean and unpolluted water the diversity of macroinvertebrates species is found very high, including pollution sensitive species such as stonefly (*Plecoptera*), mayfly nymph (*Ephemeroptera*), alderfly (*Megaloptera*), snipefly (*Diptera*), caddisfly (*Trichoptera*), dobsonfly, water penny beetle (*Coleoptera*), riffle beetle (*Coleoptera*), gilled snail (*Gastropoda*) and freshwater mussels (*Gastropoda*). However, in polluted water the diversity of benthic macroinvertebrates is significantly low, lacking most of the pollution sensitive species, mentioned above. Polluted water is dominated by only a few pollution tolerant species, such as midge larvae (*Diptera*), blackfly larvae (*Diptera*), leech (*Hirudinea*), aquatic worms (*Oligochaeta*), pouch snail (*Gastropoda*), etc.

Disposal of organic matter such as sewage and domestic wastes into aquatic systems is undoubtedly one of the oldest forms of water contamination. Although intermediate levels of organic enrichment may favour certain suspension- or deposit-feeding macroinvertebrate groups such as blackfly and midge larvae, but high levels of organic enrichment results in the disappearance of intolerant taxa due to change in substratum and low dissolved oxygen concentration. In long run, organic and nutrient enrichment leads to eutrofication of water body and disappearance of sensitive aquatic flora and fauna.

Anthropogenic acidification of freshwater ecosystems is a serious environmental problem particularly in mining areas due to acid mine drainage (AMD). AMD originates from exposed rocks and minerals containing sulphur, which continuously reacts with air and water forming sulphuric acid. The water mixed with sulphuric acid drains out of the mining areas and contaminates water bodies bringing down the pH. Acidification affects aquatic organisms by influencing their physiological processes, decreased availability of food due to low productivity, and toxicity due to increased trace metal concentration. Several benthic macroinvertebrate groups or species are known to be sensitive to acidification. The Crustacea (particularly crayfish) and Mollusca are sensitive to low pH (Balustein and Wake, 1995; Fryer, 1980). Conversely, certain taxa of Coleoptera, Megaloptera, Odonata, Hemiptera and Chaoboridae are relatively tolerant to acidification and often increase in slightly acidified aquatic ecosystems. Further, AMD facilitates the release of trace metals from the rocks increasing the concentration of several undesirable metal elements in water bodies. Reduced total abundance and species richness and changes in macroinvertebrate dominance often occur in aquatic systems polluted with heavy metals. Generally, insects appear to be less sensitive than Gastropods and Crustaceans to metal exposure. Most of the macroinvertebrate species contribute to secondary production. Hence, any change in their abundance and diversity leads to alteration in food chain of the aquatic ecosystems (Haines and Baker, 1986; Havens and Health, 1989).

Pollution is also caused when silt and other suspended solids, such as soil, wash off ploughed fields, construction and logging sites, urban areas, and eroded riverbanks reach to waterbodies. The siltation in water bodies disturbs the habitat of the benthic organisms leading to reduced abundance and diversity. It results in low dissolved oxygen content due to reduced plant productivity leading to suffocation of aquatic macroinvertebrates and fish. When level of dissolved oxygen drops below 2 to 5 ppm, it kills aquatic organisms in large numbers, which often leads to disruptions in the food chain (Dudley, 1987; Tickle *et al.*, 1995).

Land Degradation and Soil Biodiversity

Land Degradation

Unfortunately, every year millions of hectares of land through out the world is degraded due to various natural and anthropogenic activities. Soil erosion, water logging and salinization, mining activities and contamination with solid and toxic wastes contribute towards most of the land degradation. Intensive farming practices involving excessive use of water for irrigation, and increased use of agrochemicals such as inorganic fertilizers and pesticides further aggravate the problems of land degradation. In fact, agrochemicals applied by farmers to increase the crop productivity, ultimately reach soil and cause soil contamination.

Soil Biodiversity

The top soil harbours millions of living organisms belonging to different groups ranging from microorganisms, such as bacteria, algae, fungi and protozoa to tiny soil invertebrates belonging to groups of roundworm, segmented worms, mites and insects. These soil organisms play important role in rejuvenating the soil fertility and productivity by continuously making soil rich in nutrients and organic material, porous, humid and aerated. For instance, algae and blue-green bacteria capture sunlight and make new organic compounds; nitrogen-fixing bacteria fix free atmospheric nitrogen into less mobile, more useful forms; bacteria and fungi decompose organic detritus and recycle nutrients; and soil invertebrates tunnel deeper into the soil, mixing and aerating it. Hence, the land deficient in soil organisms shall lose fertility leading to diminished flora and fauna and decreased biomass production.

The soil biodiversity is so rich that one gram of healthy soil can contains over 1 billion organisms of over 10,000 different species. Bacteria are usually the most dominant group potentially making up over 500 million organisms within a gram of healthy soil. The function, shape and size of these bacteria vary enormously from the root nodule forming nitrogen fixers to *Actinomycetes* that are large filamentous bacteria responsible for the characteristic earthy smell of the healthy soil. The protozoa that feed primarily on bacteria make up around 10,000 organisms in a gram of soil. The soil fungi have been shown to perform a number of very important roles ranging from physical break down of organic matter by fungal hyphae to providing a nutrient bridge between soil and plant roots. The predominance of fungi tends to increase in soil containing perennial plants where the fungi are better suited to breaking down hard to digest organic material. Fungal dominated soils are most noticeable in established deciduous woodland ecosystems where several yards of fungal hyphae are likely in each gram of healthy soil.

The soil Nematodes also play a very significant role in biologically diverse soils. Although they are not nearly as prevalent in number as the bacteria or fungi (under 50 individuals/gram) they are nevertheless important for a diversity of roles including nutrient cycling and disease suppression. Of the more visible members of the soil, the most important organisms are the worms, which play a critical role in mixing and aggregating the soil with leaf litter on the soil surface, as well as improving soil structure and microbial decomposition of organic matter. In addition, the soil arthropods such as the insects, mites, springtails and beetles are of fundamental importance in activating the break down of organic matter. On an average up to 300 arthropods can be found in 1 square metre of healthy agricultural soil. Their number is very high in forest soil reaching to about 25,000 individuals per square metre.

Impact on Soil Biodiversity

The soil contamination adversely affects the soil microflora and fauna in terms of their abundance and diversity. Studies suggest a decreased number of species of soil organisms in soils contaminated with agrochemicals. Bacteria involved in nitrification and symbiotic nitrogen fixation are especially sensitive to disruption by pesticides, probably in part due to the small numbers of species involved in these processes. It has been found that application of pesticides can inhibit nitrification for several weeks depending on the types and concentration of the pesticides. Some degradation products of these substances may also be inhibitory (Fahlengren, 1986; Ruhling and Tyler, 1991).

Further, soil contamination is responsible for alteration of the composition of soil organisms. On contamination, many sensitive species die and disappear from the community. Subsequently, a few tolerant species multiply rapidly and become abundant in soil. Their total number becomes greater than they were originally in the soil. For example, contamination with DDT and other pesticides in low concentration initially reduces the population of Colembola in soil but after some times the population increases exponentially making them dominant group in arthropod community. As the soil fauna play an important role in removing the limiting factors for the microflora, any change in their population and composition results into decline of abundance and diversity of bacteria and fungi, and their activity in soil. Since the functioning of a biologically complex soil is dependent on interactions between different members of the soil community, any activity that impacts on one member of the community is likely to have a knock on effect on the community as a whole.

Perhaps use of pesticides and soluble fertilizers in agriculture causes most directly damaging impact on soil organisms. These not only kill organisms within the soil but also affect the coating of microorganisms that is naturally present on leaf surfaces. As a result, plants become more prone to pathogen infection—leading to a greater requirement for recourse to pesticidal intervention. Furthermore, reduction of soil microbial communities has negative impact on nutrient cycling leading to less healthy plant growth. Thus a negative feedback loop develops that is difficult to break out once agrochemical contamination takes place in soil.

A wide range of pollutants originating from industries, mining and mineral processing, waste disposal sites that contaminate our soil also adversely affect the soil biodiversity and make soil less productive. Oil contamination has long-term damage to soil microbiology including adverse effects on carbon (*e.g.*, cellulose degradation) and nitrogen cycling (especially nitrification and nitrogen fixation). Contamination by heavy metals (*e.g.*, cellulose degradation) and nitrogen cycling (especially nitrification and nitrogen fixation). Contamination by heavy metals (*e.g.*, Cd, Cu, Ni, Pb, Zn) can cause long term suppression of carbon cycling, microbial biomass, nitrogen fixation, nitrification, dehydrogenase activity, and mycorrhizal incidence (Dighton and Skeffington, 1987).

In addition, various natural processes such as erosion, flooding, wildfire etc. also affect the soil biodiversity and make soil sterile. Vesicular-arbuscular mycorrhizae (VAM) can be adversely affected even by mild soil erosion. Survival of Rhizobia in eroded soils depends mostly on their tolerances to pH of deeper soil horizons.

Environmental Contamination and Biodiversity Loss in Northeast India

Similar to other parts of the country, the northeastern region of India is also facing severe problems of environmental contamination. The rate of air, water and soil contamination is increasing day-by-day due to increasing human population, increasing number of vehicles, industrialization and infrastructure development, impoundment of water bodies, mining activities, increasing use of agrochemicals in plantation crops etc. Deforestation, irrational use of natural resources, erosion of traditional values and lack of awareness add further to the problem. Though the problem of environmental contamination in the region may not be alarming, its impact on biodiversity has been felt severely due to region being ecologically fragile and extremely rich in biological diversity.

Unfortunately, very few systematic studies have been conducted to reveal the nature and extent of damage incurred on biodiversity of the region and information is fragmentary. In an investigation conducted in coal mining areas of Jaintia Hills District of Meghalaya, it has been found that the water and soil of the area are worst affected due to mining, dumping and transportation of coal. The area has become completely denuded of forest cover, soil is contaminated with coal dust and acidic water, and most of the water bodies of the area have become turbid and acidic (pH 3.6–4.8) due to contamination of seepage oozing out of coal mines and dumping sites. The sensitive species of plants have been vanished from the area, resulting into low species diversity (Pandey, 1993). The species diversity of zooplanktons and other aquatic fauna also registered declining trend in water bodies contaminated

Table 1: Major Groups of Plants and Animals affected by Environmental Contamination

Sl.No.	Groups of Plants and Animals	Responsible Factors
Plants:		
1.	Algae (Blue-green algae)	Air and water pollution
2.	Fungi (Mycorrhizal fungi)	Acidification of soil
3.	Lichens	Air pollution (SO_2)
4.	Bryophytes	Air pollution
5.	Pteridyophytes	Air pollution
6.	Herbaceous flowering plants	Air pollution (SO_2), Soil acidification
7.	Broad leaf and coniferous trees	Air pollution (SO_2), Soil acidification
Animals:		
8.	Freshwater sponges (Porifera)	Water acidification
9.	Flatworms (Platyhelminthes)	Water acidification
10.	Worms (Annelida)	Water, soil acidification
11.	Leeches (Hirudinae)	Water, soil acidification
12.	Snails, slugs and bivalves (Mollusca)	Water, soil acidification
13.	Insects, crustaceans, spiders (Arthropods)	Water, soil acidification, Air pollution
14.	Fish and amphibia	Water acidification, Metal contamination
15.	Birds and mammals	Air, water, soil pollution

by mining (Sharma and Das, 1993). The preliminary study on impact of coal mining on soil and water microorganisms (bacteria and fungi) revealed marked alteration in their species composition (Tiwari and Das Gupta, 1993).

Undoubtedly, degradation of air, water and soil quality is a major contributor for the depletion of biodiversity. In addition, drought, soil erosion and siltation, flood, depletion of forest and wetlands, wildfire, mining activities, overexploitation of natural resources, introduction of hybrid and exotic species of plants and animals and erosion of traditional beliefs and ethos are other important factors responsible for loss of global biodiversity.

Therefore, an integrated approach by taking into account all factors that adversely affect biodiversity is required to mitigate and check further depletion of biodiversity.

Acknowledgement

The author is thankful to Prof. B.K. Tiwari, Head, Centre for Environmental Studies for critically going through the manuscript and providing valuable inputs for its improvement.

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