DEPOSITION OF POLLUTANTS AND THEIR IMPACTS ON FISHERIES

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Summary

Scarcity of quality water has become a pervasive threat to surface and groundwater resources in both developing and developed countries. Problems of aquatic pollution have become so severe that many local waterways are now devoid of fish. Contaminated fish also affect human health.

As fish are economically important and a source of income in many countries, fish have been extensively studied as a model for ecotoxicological research. Information available on the toxicity of xenobiotics to fish and other aquatic organisms is often based on tests of individual chemicals conducted under laboratory conditions or considered separately in field studies.

Pollutants enter aquatic environments and exert adverse effects on biota at the cellular, organism, population, and community levels, eventually altering the functioning of an aquatic ecosystem as a whole. Pollutants entering freshwaters and the oceans remain partly in solution and are partly adsorbed onto the surface of sedimentary matter.

Both dissolved and sedimentary sources of pollution affect living organisms and produce adverse effects on fish. Both persistent and nonpersistent organic pollutants accumulate in the body tissue of fish through various biotransformation processes.

Organic pollutants can bring about a change in the physicochemical characteristics of water and also cause changes in the biotic components of the ecosystem, resulting in loss of biodiversity. Organic toxicants are often in neutrally charged states, which give them greater mobility across cellular membranes; also many compounds are resistant to biodegradation.

These characteristics result in long-lasting residues and food chain magnification, which can render fish populations unsafe for human consumption. Among the most hazardous chemicals, mercury can be taken up in inorganic form by the fish through gills, skin, and/or gastrointestinal tract. Mercury is then stored in relatively high concentrations in organism tissues.

Because DDT is fat soluble but rather insoluble in water, it can be readily absorbed by organisms from water or in food, resulting in tissue concentrations much higher than ambient concentrations. Also, direct application of DDT spray has caused massive fish kills. Polychlorinated biphenyl (PCB) contamination of fisheries is important during the culture of fish, and it adversely affects the hygienic state of edible fish flesh.

Eutrophication of water bodies results in a massive algal bloom that causes a range of problems for the aquaculture. Evidence can suggest that toxins of biological origin are sometimes more detrimental than other toxicants. The negative impacts of both hypernutrification and eutrophication increase as the stocking density of cultured species increases.

A significant increase in global aquaculture production has been possible due to the increased use of antibiotics, which may cause many environmental concerns. The

presence of residues of persistent chemicals in aquaculture products is a matter of serious concern to developing nations. This chapter is an overview of the present state of the knowledge on the impact of pollution on fisheries.

It deals with concepts of pollutants, pollutant deposition, uptake mechanisms, toxic effects, key issues of sustainability, and environmental-impact assessment. It is anticipated that some insight based on the occurrence and distribution of pollutants in fisheries can be acquired to assess the potential for environmental hazards or damage to aquatic ecosystems.

1. Introduction

Water resources are an indispensable part of human society. Deterioration of the aquatic environment is associated with urbanization by human populations commencing with the industrial revolution in the eighteenth century. Scarcity of quality water poses a threat to future development in some areas of the globe, while at the same time threatening the continued economic growth in many industrialized countries.

There are approximately 1400 million cubic kilometers of water on Earth of which only 2.5% is freshwater; a mere 0.5% is readily available for human consumption from lakes, reservoirs, rivers, and surface groundwater. Adequate supplies of water of good quality must be maintained for the entire population of this planet. The United Nations Environmental Programme (UNEP) in its 1997 report cautioned that issues of water resources will be a major impediment to further development in many countries of the world. It is a matter of great concern that by the middle of the twenty first centurymajor international problems will be sparked by disputes over freshwater resources.

A vast array of chemical pollutants or xenobiotic contaminants, originating from industries, household wastewater, and various anthropogenic activities, has become a pervasive threat to the surface and groundwater resources of the world. Modern agriculture affects water quality through the application of fertilizers and pesticides, which run off into surface waters and leach into groundwater. The pollutants enter the aquatic environment and cause harmful effects on biota at the cellular, organism, population, and community levels, eventually altering the functioning of the aquatic ecosystem as a whole.

Aquatic pollution is acute at certain locations leaving many waterways devoid of fish. Although some progress is being made in many postindustrial countries, the problem is worldwide and especially problematic in Far East, Asia, and Africa, where human health has suffered much. For example, the Minamato disease in Japan was caused by the ingestion of shellfish contaminated with methyl mercury.

Animal and plant communities in aquatic environment are dynamic and often react to changes in their environment. The interactions between anthropogenic activities and their effects on different components of the aquatic ecosystem are depicted in Figure 1. Changes in land use and several socioeconomic factors contribute to stresses on aquatic ecosystems.

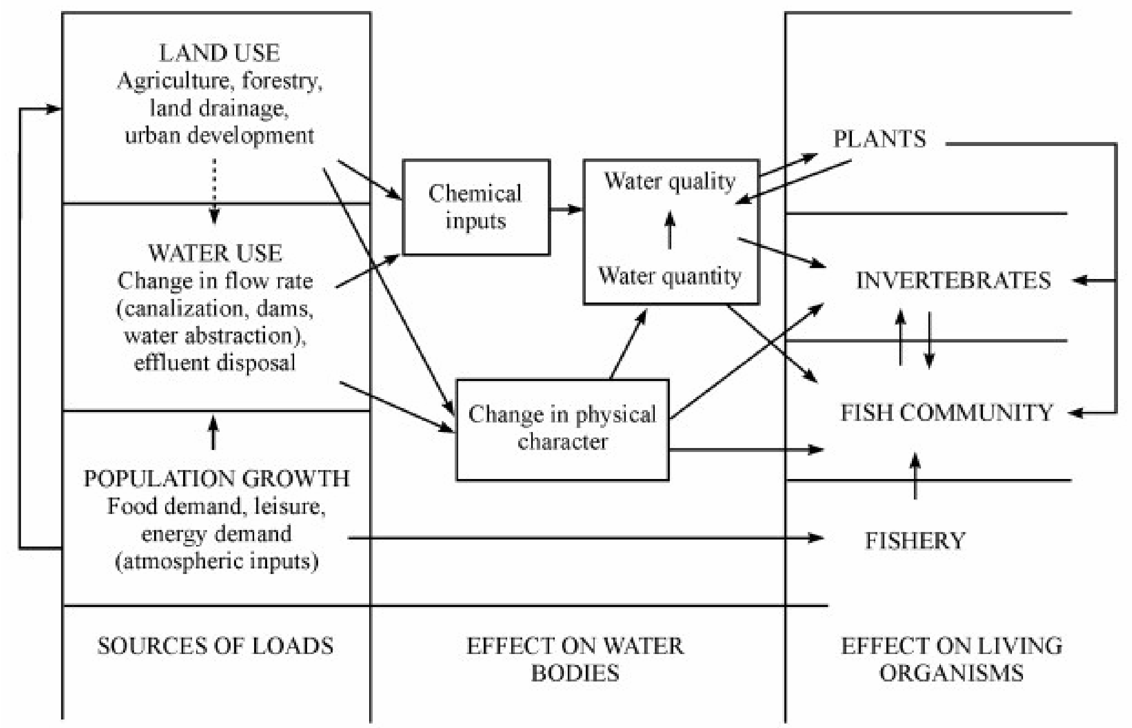

Figure 1. Interelationship between the major environmental factors that can affect a fish community

Fish are economically important as a source of income in many countries. Fish have also been the subject of extensive ecotoxicological research during the last few decades of twentieth century. For a full understanding of the nature of the problem of aquatic pollution and conservation of inland water resources, it is necessary to examine the nature and extent of pollutants and the mechanisms of the actions of these pollutants on biota. This chapter highlights the knowledge regarding the fate of inorganic and organic xenobiotics in aquatic in aquatic environments and their impact on fisheries impact and water resources.

2. Pollutants

Pollutants are defined as undesirable substances that produce injury in living organisms. Chemical pollutants generally act on the ecosystem by three major pathways: (a) settling on the substrate and smothering life there, (b) through acute toxicity leading to death of organisms, or (c) depleting oxygen values to a threshold level causing death of organisms. Therefore, pollution causes a departure from normal functioning of the system. As a consequence, chemical pollution of the water may profusely modify the biota and affect the ecosystem.

Information available on the toxicity of substances to fish and other aquatic organisms are often based on materials tested singly under laboratory conditions, or considered separately in field studies, but information thus gleaned is not realistic, as several toxic substances often occur together in significant amounts in polluted water and are likely to interfere in their actions. It is known that the uptake of one metal may be increased or decreased according to the concentration of the other metal present. For example, the interactions among dieldrin, DDT, and methoxychlor are complicated and generally cause adverse effects when these substances occur in combination. Sometimes, the presence of other pollutants in the water may modify water quality, so standards should be set for the protection of fisheries by giving attention to the data on the nature and concentration of the toxicants present. Though such data are essential, available information in this regard is quite meager.

Recently, genetic impact of aquatic pollutants on aquatic organisms has been the subject of active research. Aquatic biota have been used to evaluate the genotoxic and mutagenic potential of physical and chemical agents in freshwater habitats. This is gaining much interest in view of the recognition of mutagenic effects of several xenobiotics and widespread genetic diseases.

2.1. Sources and Types of Pollutants

Anthropogenic activities such as mining, smelting, refining, energy production, industrial and vehicular emissions, agricultural operations, sewage discharge, and waste disposal have been responsible for a rapid increase of the environmental pollution. Pollutants may arise from point and nonpoint sources, they can be carried even to places far away from their source of origin in gaseous and particulate forms. Metallic pollutants are ultimately washed out of the air by rain onto land or on the surface of the water. As a rule, it is more difficult to manage the nonpoint source of pollution than the point source.

A wide range of pesticides and herbicides, such as atrazine, dichlorobenyl, 2,4-D, and glyphosate, are widely used in modern agriculture, and this practice has become a potential threat to fish and fisheries. Many of these toxic substances are highly persistent and can bioaccumulate in the food chain of fishes at sufficient levels to threaten aquatic ecosystems and human health.

Household wastewater containing organic compounds, detergents, trace elements, many pharmaceutical chemicals, and other materials used in modern society poses ecotoxicological risks and health hazards. The effects caused by toxicants of the industrial wastewater are more severe on fish and aquatic invertebrates and have plagued fisheries considerably. The potential spread of AIDS and other infectious diseases through discharge of health care wastes in streams and water bodies is a growing threat to modern society.

3. The Aquatic Ecosystem

Aquatic environments are complex ecosystems resulting from the interactions among physical, chemical, biological, and human-engineered factors. In essence, water, air, soil, and aquatic organisms can be viewed as overlapping compartments through their closely associated interfaces in the environment.

Bacteria, fungi, algae, many small invertebrates, and other organisms that live on the bottom of the aquatic environment are known as benthos. They serve as food sources for some aquaculture species apart from their role in nutrient dynamics through participation in the biogeochemical cycle. Burrowing and bioturbation activities of many bottom dwelling animals contribute significantly to the biogeochemical cycle and play an important role in the mud water exchange process.

The bottom sediment of the water bodies is of great significance, as it acts as sink for many toxic substances that enter into the water phase through desorption processes, and also it maintains the stability through buffering mechanisms. The dynamic balance and homeostasis of the aquatic ecosystem are often altered by various human activities, resulting in ecosystem perturbation and loss of biodiversity in general.

Organisms in the aquatic ecosystems are mutually interrelated, through their feeding activities, by allelopathic reactions induced by chemical compounds released from certain organisms, by behavior of organisms, and recycling of nutrients in a more complex manner. The grazing and detritus food chains are interconnected; the Y-shaped or two-channel energy flow model is more appropriate than a single-channel model in aquatic ecosystems. It is known that minimally 50% of the net production may pass through grazing food chain in some shallow waters, while in oceans at least 90% of unconsumed autotrophic production accumulates as particulate and dissolved organic matter in water and sediments, resulting in the operation of a detrital system.

3.1. Assimilative Capacity

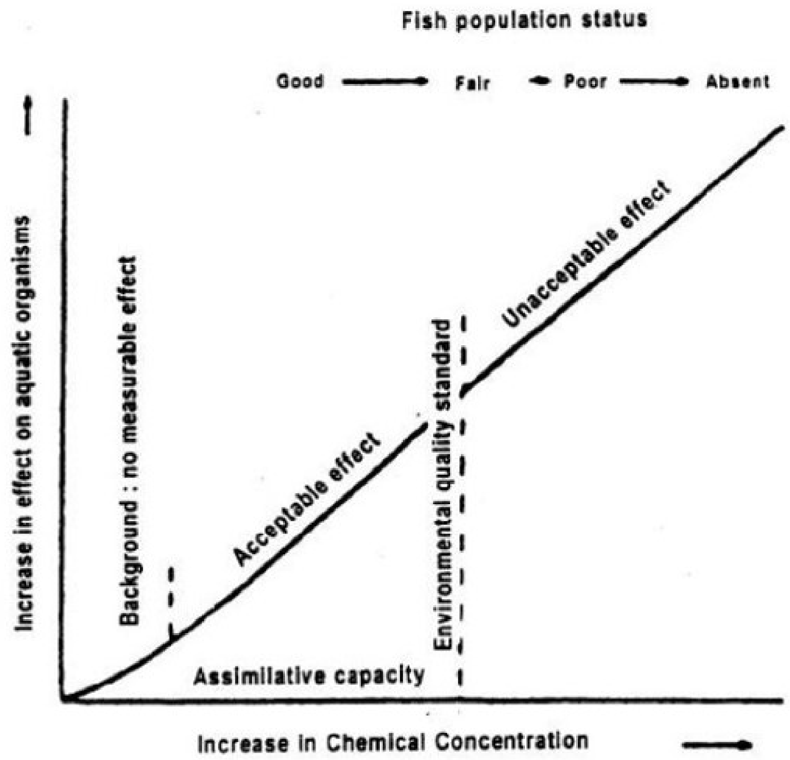

Figure 2. Relationship between increase in chemical inputs and effects on aquatic life

Loading of pollutants above the natural load may have an additional effect. The ability of the resource to withstand a small increase in loading is known as the assimilative capacity. Within this zone, some pollution-sensitive species are either reduced in numbers or disappear and are replaced by more resistant species with similar functions. Clearly, species that are valued for recreational, commercial, or scientific purposes should remain unaffected by this small loading, so as to keep these resources unimpaired, whereas additional inputs may have an adverse effects on biota. The relationship between additional loading and its effects on aquatic life is shown in Figure 2.

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Biographical Sketch

B. B. Jana is a senior professor at the Department of Zoology and Coordinator in the International Centre of Ecological Engineering, University of Kalyani, West Bengal, India. He has carried out different aspects of research on Aquaculture, Wastewater aquaculture, Aquatic Microbiology, Eco-reclamation, Eco-village, Cryopreservation, etc. His research interests include wastewater- fed aquaculture, reclamation of eutrophic wetlands using biological agents, fertilizer-microbial interaction in carp culture system, water quality management, integrated fish farming, cryopreservation of fish embryo, ecosanitation as well as development of socio-economic status of the backward tribal people though community senitization. Professor B. B. Jana and his school in the International centre of Ecological Engineering, University of Kalyani, West Bengal, India have been working on fertilizer value of human and bovine urine in aquaculture system. He has developed a protocol for using rock phosphate as alternative P fertilizer in aquaculture. He has also devoted much time to develop low cost Eco-techs for reclamation of eutrophic water bodies for rational use of water resources. He is the elected International Board Member of the International Ecological Engineering Society, Switzerland and the founder member of Asian Fisheries Society, Philippines. He is a Fellow of National Academy of Agricultural Sciences, West Bengal Academy of Science and Technology, Zoological Society, Calcutta, etc. He is the author or co-author of over 180 scientific publications including 3 books.