Chapter 1

Introductory Chapter: Current Status of Freshwater Ecosystems

Didem Gökçe

Additional information is available at the end of the chapter

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1. Introduction

Limnology covers biological, chemical, and physical qualifications of lakes and other bodies of inland water as a whole ecosystem. It has become a predominant sub-branch of ecology due to aquatic limiting environmental factors, population dynamics, and community structure. Limnology is the term derived from the Greek word limne—lake and pond. Although limnology initiated with lake studies, it has expanded its field with the studies on rivers, wetlands, and estuarine ecosystems.

Wetzel [1] clearly expresses that freshwater ecosystems are biological systems, and biology controls water quality under natural conditions, and freshwaters must be evaluated and managed as biogeochemical systems. Each freshwater ecosystem maintains its balance under the current conditions (community composition and physicochemical factors) depending on its carrying capacity. Anthropogenic factors can change these conditions negatively. Therefore, engineering solutions are not sufficient alone. It is crucial to know the quality and functions of aquatic ecosystems in order to manage them successfully [1–3].

In that case, physical and chemical changes in habitat conditions lead to impairment in water quality. The physicochemical variable analysis is a classic method of controlling pollution and managing water quality. The community shows a habitat-specific distribution depending on its carrying capacity, and thus biological monitoring reflects the balance of that aquatic ecosystem within the cause-effect relationship [4]. Therefore, a water management tool has been developed by using bioindicators to evaluate the effects of the ecosystem quality on aquatic organisms [4–6]. Preserving water quality is a critical part of sustainable management of water basins. It affects the health of the hydrological system. A healthy system will provide better water quality and a more flexible ecosystem.

2. Problems of inland waters

Today, along with the advancement of technology, the property of pollutants given to the environment has started to become more destructive. The effects of combined environmental pollutants cause the ecosystem to deteriorate more rapidly. Many environmental factors can affect the community structure, distributions of organisms, and energy transfer between trophic levels in inland aquatic ecosystem. Anthropogenic activities such as agriculture, domestic and industrial wastewater discharges, and natural factors (geomorphology, hydrology, seasonal variations, and climate) change the physicochemical quality of water ecosystems.

2.1. Nanoparticles

Being used in a rapidly increasing rate in the world, the engineered nanoparticles (NPs) are widely present in many products when entering the aquatic ecosystem. Most of NPs are converted into free metal ions in solution mainly depending on the particle size, surface area, and rough degree (such as npTiO_2 and npZnO) [7]. For this reason, NP residues are present in numerous waste materials, and these nanoparticles have a potential risk for freshwater ecosystems [8, 9].

Nanoparticles TiO_2 (npTiO_2), zinc oxide (npZnO), cerium oxide (npCeO_2), copper oxide (npCuO), and silver (npAg) are the most studied metal and metal oxide nanoparticles which have toxic effects on freshwater biota and food web dynamics. Even though the NP toxicity studies on freshwater organisms (algae, zooplankton, and fish) were carried out on different experimental models, the impact of food web on NP toxicity is still not clear [8–12]. The behaviors of NPs in the aquatic system include aggregation, flocculation, redox reactions, speciation, dissolution (release of + ions like Zn^{2+}), surface modifications (interactions with other metal and pollutants), and complexation with natural organic matter.

The size of nanomaterials has a direct and critical effect on the mechanical and physiological activities in aquatic organisms [8]. Especially NPs are absorbed during filtration, hence have an impact on feeding ability in *Daphnia magna* and plays a crucial role in cellular uptake. Nanoparticles can change the community composition at the level of species that are more sensitive or tolerant to environmental contamination. Gokce et al. [8] explain that as a result of the effect of increasing NP concentrations, population growth rate reduces depending on the delay of progeny, delay of the reproduction period, and mortality rate. Taken together, these results have revealed that NPs exposure may display a negative effect on community dynamics of aquatic organisms and on food chain structures in freshwater ecosystems particularly for a long period.

2.2. Microplastics

Nowadays, plastics have a wide usage area due to increasing population. The environmental impacts first began to be noticed in the seas in the 1970s. While in terms of sea and seashore pollution the effects of plastics have been studied intensively, their effects on freshwater ecosystems and organisms have attracted the attention of researchers in recent years. Different criteria can be considered in the grouping of plastics: size (micro-, 1–5 mm; meso-, <5 mm; and macroplastics, coarse structure), primary and secondary plastics, and density, low- and high-density plastics. Plastics are suspended in water or accumulated in sediment according to these properties [13].

The damage/hazard to the aquatic ecosystem varies according to the properties of plastics. Plastics indicate accumulation in organisms by feeding on water column or sediment. They have a mechanical and chemical effect on living things. They also cause organic and metal pollution.

Due to the formation of large specific areas of microplastics and their hydrophobic structure based on their small size, they cause the accumulation of organic matters and metals.

Fish is the most studied group in freshwater ecosystems. It has been defined that microplastics have accumulated in the gill, digestive system, and even muscle tissues. As a general effect, it has been found that they cause differences in the immune system and changes in leukocyte levels and oxidative stress levels [13–15]. It has also been observed in invertebrates that it accumulates in the digestive system by feeding group. Different levels of microplastic accumulation are found in benthic invertebrates according to the way of feeding. *Daphnia* species, which are widely used as experimental model organisms, have been detected in the digestive system as well as the clutch. In acute and chronic assays, it has been found that immobilization increases and survival time and reproduction decrease [16].

Different types and concentrations of microplastics have been identified in different lakes and streams. The microplastics have different sources: the primary and secondary plastics (such as private care products and the wastewater from the treatment facilities located in the vicinity). As a result, anthropogenic pollution accumulates in the water body and sediment. In addition, as a result of absorption of different chemical groups along with changing of environment conditions (temperature, pH, salinity, etc.), formation of the different pollution load depending on the microplastic nature causes the deterioration of water quality in the freshwater ecosystem. It is inevitable that this pollution load will be transported to fish, waterfowl, and human beings via the food web.

2.3. Medical wastes

The widespread emergence of resistance to pharmaceutics among pathogens has become one of the most critical issues worldwide. Hospital wastewater contains a group of organisms that cause various diseases, and it plays a major role in the spreading of drug-resistant pathogens by becoming a pollutant by improving the growth, propagation, and warming properties in the environment. Especially wastewaters that are involved in lakes and rivers cause very important problems [17]. These conditions have become a major problem for public health, particularly in developing countries as they can be transmitted directly or indirectly to human beings and animals from the aquatic food web [18].

Due to the excessive increase in the human population, the quality and quantity of pollutants in inland water ecosystems have changed. One of these contaminants is pharmaceuticals.

Pharmaceuticals are emerging as aquatic ecosystem contaminants, and their concentrations in water bodies are an increasing environmental issue [17–20]. Although their positive effect on health (human, veterinary, water culture, etc.) is significant, antibiotic-resistant bacteria and genes are found in freshwater environments, and their transfer to the food chain causes numerous negative effects. Different antibiotic pharmaceuticals are crucial environmental micro- and nano-pollutants, and their presence in freshwater is a serious environmental problem. Several antibiotics have been reported in freshwater habitats. This is parallel to the global increase in antibiotic consumption [19].

The detection of pharmaceutics in treated wastewater was first reported by Fent et al. [21] in 1976 in Kansas City, USA. Twenty-five different pharmaceutical concentrations above 1000 ng L^{-1} in the Lee River (England) were recorded in 1981. Globally, there is antibiotic contamination in freshwater habitats despite the presence of an advanced waste treatment plant in the USA and European countries. The situation is much more serious in the middle- and low-developed countries [19].

Several studies have been carried out on freshwater and sediment-receiving wastewater contaminant with pharmaceutics. In a recent study by Varol and Sünbül [20], different levels of 37 antibiotics, 10 metals, and 19 organochlorine pesticides were analyzed in 6 fish species from the Karakaya Dam Reservoir (HEPP), Turkey. Fish is one of the groups used as bioindicators for the evaluation of water quality and pollutants such as antibiotics and heavy metals and are taken directly from the water column and trophic transfer [17, 18, 20]. Therefore, for human health, it is very important to determine the levels of these pollutants in consumable fish species because the consumption of these fish species is the main way of exposure to pollutants.

Appropriate management of hospital wastewater should be implemented to reduce the problem at each healthcare facility. Therefore, the mixing of pharmaceuticals and hospital wastes with the increase in surface water, which is the receiving medium, should be prevented.

The ozonation, chlorination, and UV disinfection used independently or in combination in the disinfection of medical and pharmaceutical wastes are among the most investigated subjects and have demonstrated several performances. The use of coagulation technology to reduce antibiotic-resistant genes in wastewater treatment plants has been found to be more effective [17]. Moreover, graphene-based TiO_2 composite photocatalysts are efficient methods for the removal of antibiotics, antibiotic-resistant bacteria, and genes from wastewaters [17]. In addition, as a result of administration of TiO_2 photocatalysis under UV irradiation in combination with H_2O_2, good removal efficiencies of antibiotic-resistant bacteria and antibiotic-resistant genes (both intracellular and extracellular forms) from aquatic media were reported.

2.4. Climatic change and the related effects

Water temperature is an important environmental factor that limits survival, growth, and reproduction of plants and animals. Plant and animal populations are more likely to survive if they enter fields with climatic conditions similar to their natural habitats. The increase in water temperature and salt concentration and even pH change due to global warming cause the invasive species to spread to new habitats. The higher evaporation rates with the decrease in precipitation cause the water level to decrease, and thus most of the water ecosystems are under threat.

Climate change is a substantial factor affecting species invasion, biodiversity, and aquatic ecosystem structure in freshwater. The impact of climate change on freshwater biodiversity is increasing the speed of biological invasions [22]. Changes in climatic conditions, population dynamics of the indigenous species, and the composition and structure of communities can change the functioning of ecosystems. Similar to the observed responses of indigenous species, climate change can directly affect the possibility of invasive species entering a different aquatic ecosystem [22, 23].

Especially, salmonid fish and cold stenothermic macroinvertebrates are expected to disappear from many central and southern European river systems. In central and northern European countries, a general increase has been observed in a number of Mediterranean Odonata species, and African Odonata species are also expanding into southern Europe. However, the dispersal of Euro-Iberian species narrowed [24, 25].

The increased water temperature has caused significant changes in the European benthic invertebrate community. It is estimated that approximately 5–20% of invasive species have potent effects on receptor environments [24]. Endemic taxa will be under threat as a result of both losses of habitat and reduced connection between habitats, especially when water flow connections are broken.

Therefore, it is of great importance to reduce the anthropogenic effects of global climate change, which leads to warming and acidification of freshwater in the world. Prevention of nonindigenous species from entering into new habitats is of critical significance.

Algal bloom and eutrophication are one of the huge results of climate change. Furthermore, algal bloom cause increasing water temperature and nutrients, and deterioration of natural and/or human-induced ecosystem balance. Especially in lakes and streams, the decrease in water level and the abundance of toxic algae species are among the important problems faced by today's inland water ecosystems. Particularly, Cyanobacteria and the other harmful algae bloom cause contamination of drinking water sources and aquaculture and can harm the economy and human health.

As a result, many lakes, rivers, wetlands, and estuaries can be affected by climate change, eutrophication, water level decreases, biodiversity reduction, and invasive species. For this reason, water management plans should be prepared. An important deficiency in most of the regions investigated in limnology studies is that freshwater management plan and strong connections between the institutions should be implemented by the decision-making institutions on limnological concepts and sustainable plans. Efficient and practical adaptive measures should be taken at the local scale, both limnologically and economically.

3. Conclusions

The quality and quantity of pollutants have also changed depending on the advancing technology and industry. Considering the rapidly decreasing freshwater resources, the magnitude of the danger also arises. The accumulation of pollutants in the water ecosystem and the aquatic food web results in magnified concentrations of pollutants.

The existence of an increasing number of conflicting freshwater uses is a consequence of the increased anthropogenic pressure on the freshwater ecosystem balance and carrying capacity. At this point, the importance of limnology emerges once. Index methods developed on investigation of the community structure and dynamics of the aquatic organisms (spatial and temporal variations) and long-term monitoring allow the effects of pollutants on the ecosystem to be reliable.

It is a disastrous picture. However, it is observed that global freshwater resources are getting worse in the future. Knowledge about water, its management, and use will continue to grow and evolve in the future. The fact that limnology is a multidisciplinary science enables the determination of ecosystem questions from a wide perspective and the preparation of realistic management plans. Therefore, it is important for decision-makers to form and plan water quality standards on the basis of the principles of limnology.

Author details

Didem Gökçe

Address all correspondence to: didem.gokce@inonu.edu.tr

Department of Biology, Inonu University, Malatya, Turkey

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