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A REVIEW ON THE TYPES OF POLLUTANTS PRESENT IN FRESHWATER AQUATIC SYSTEMS

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Abstract

Freshwater aquatic systems include ponds, rivers, lakes, springs, etc., and a significant proportion of the human population depends on the freshwater ecosystems for their food. Seafood is a major portion of the diet in tropical as well as temperate countries. With increasing anthropogenic activities, water bodies are continuously getting contaminated, and every day new kinds of pollutants are being introduced into the open waters. Pollutants not only affect aquatic organisms but also enter the food web and ultimately reach human bodies. In this article, we have reviewed some of the pollutants, their production, uses, source areas, and possible impacts on aquatic organisms. These pollutants enter the water by surface runoff, spray drift, leaching, drainage, or direct application. Some pollutants only show their effect if taken in high doses, whereas even the slightest dose of some pollutants can prove lethal. The aim of this study is to shed light on the status of pollutants and provide a brief as well as systematic literature on the same.

Keywords : Pollutants; freshwater ecosystems; sea food; endocrine disruptors; carcinogens; pesticides; insecticides; drainage.

Introduction

Pollutants refer to substances that, when introduced into the environment, have undesirable effects on natural resources like water, air, soil, the atmosphere, etc. Pollutants can either form naturally (e.g., minerals) or may be due to anthropogenic activities (e.g., pesticides and insecticides). In modern society, people are prone to exposure to various kinds of pollutants during their lifetimes, starting from conception to adulthood. (Mori, C., and Todaka, E., 2017). A major challenge comes from the emerging pollutants because not enough knowledge is available to cope with their negative effects. Emerging pollutants are defined as compounds that are not currently covered by existing water-quality regulations, have not been studied before, and are thought to be potential threats to environmental ecosystems and human health and safety. (Farre et al., 2008). Generally, emerging pollutants are produced as a replacement for commonly used chemicals that are harmful to the environment. Salthammer T. (2020) For example, bisphenol A analogues, including bisphelnol AF, bisphenol F, bisphenol S, bisphenol AP, bisphenol B, and bisphenol Z, are produced as a substitute for the more harmful bisphenol A; they are also harmful

but less harmful than bisphenol A. As there are not enough safety guidelines on the production and use of these chemicals, they are produced massively and used in industries and households, but the long-term effects of these pollutants can be lethal. Our study provides comprehensive as well as structured details of some of the most hazardous and important compounds, which are as follows:

1) Gadolinium

Gadolinium-based contrast agents (GBCA) are used in magnetic resonance imaging (MRI). MRI is an important technique for the diagnosis of diseases related to the heart, brain, blood vessels, bones, breasts, kidneys, etc. Gadolinium is an important constituent of MRI. To increase the contrast of images, it is given intravenously or through the intra-articular junction into the body while doing MRI (Roberts et al., 2020). Initially, it was considered a relatively safe compound, so it gained massive popularity in the medical field, but now studies suggest that gadolinium deposits are formed in the brain, skin, kidneys, etc. while used during MRI. It can cause nephrogenic systemic fibrosis in the body (Le Fur and Caravan, 2019). Because of these side effects, gadolinium is banned in countries of the European Union, but in India, there is no stringent policy that checks the use of such a compound in MRI.

2) Fluoxetine

Fluoxetine is a kind of selective serotonin reuptake inhibitor (SSRI) drug, and it is used as an anti-depressant. Other important uses of fluoxetine include the treatment of obsessive-compulsive disorders, anxiety, and eating disorders (De Castro-Català et al., 2017). The mechanism of action of fluoxetine is that it inhibits serotonin reuptake by blocking serotonin transporters, so this drug increases the concentration of serotonin at the synaptic sites but inhibits its uptake. While WHO recommends that the use of fluoxetine is safe and effective for treating depression in humans, the presence of fluoxetine in the aquatic environment could possess serious effects on aquatic organisms, including behaviour abnormalities and reproductive dysfunction (Yamindago et al., 2021). Another side effect of this chemical is excessive serotonergic activity leading to serotonin syndrome or toxidrome, which can be potentially lethal (Haberzettl et al., 2013).

3) Fenoxycarb

Fenoxycarb is a synthetic juvenile hormone analogue. It disrupts the normal growth and development of an insect by mimicking juvenile hormones. It is sprayed in fruit orchards and vineyards to kill lepidopteran larvae and mosquitoes. Though it is an important insecticide for orchards, it eventually reaches the aquatic ecosystem by spray, drift, runoff, and drainage, and once it reaches the open waters, it could prove lethal to aquatic organisms. Fenoxycarb shows high toxicity towards crustaceans when in direct contact with them (Yu Lu et al., 2020). Negative effects of fenoxycarb on crustaceans include a reduction in the moulting process, a delay in metamorphosis, a reduction in biomass, and a reduction in reproductive potential, including a change in precopulatory behaviour and the survival rate of embryos (Hu et al., 2019; Arambourou et al., 2018). Fenoxycarb deteriorates the water quality, affecting bacterial processes like denitrification, nitrogen fixation, and sulphur oxidation (Sha et al., 2021).

4) Bisphenol A analogues

Bisphenol A is an important raw material in products like epoxy resins, baby bottles, thermal papers, pesticides, dyes, tanning agents, fibre additives, etc. (Wang et al., 2021). But because of the harmful effects

posed by BPA on living organisms, it has been banned in many countries, including the European Union, the United States, Canada, and China. So, analogues of bisphenol A found their way to the market. Many analogues of bisphenol A are available, such as bisphenol AF, bisphenol F, bisphenol S, Tetra Bromo Bisphenol A, bisphenol AP, bisphenol B, bisphenol Z, bisphenol P, etc. But these analogues are also reported to have adverse effects on the dysfunction of the endocrine system, chromosomal abnormalities, and damage to genes. (Liu et al., 2021)

5) Arsenic

Arsenic is one of the most common environmental pollutants. It occurs both through natural processes like volcanic eruptions as well as anthropogenic activities like mining operations, electroplating, smelting, pesticides, etc. (Williams et al., 2009). Inorganic arsenic is listed under the Group I carcinogen category by the International Agency for Research on Cancer. (Straif et al., 2009). Once it enters the biogeochemical cycles, it does not degrade for a long time and eventually forms more complicated forms under the water. Currently, more than 300 different species of arsenic have already been classified. (Zhang et al., 2022). Once it enters the aquatic systems, it can cause lethal effects on the aquatic organisms, and ultimately, it can easily reach humans via the food web and drinking water. Globally, around 94 to 220 million people are potentially exposed to high arsenic concentrations, of which 94% live in Asia only. (Podgorski and Berg, 2020).

6) Microplastics

Microplastics are tiny plastic granules of 5mm and more than 1 m in diameter (Barnes et al., 2009). These are of two types: primary microplastics and secondary microplastics. Primary microplastics are produced as such in industries. They are a chief component of the cosmetic as well as air blasting industries (Hartmann et al., 2019). Secondary microplastics are produced by fragmentation of larger plastic items, e.g., tyres, plastic toys, aquaculture equipment, etc. (Wang et al., 2019). Microplastics are one of the most potent emerging pollutants, as only little is known about their effects on living organisms, and there is no stringent regulation on the disposal of microplastics. They easily find their way to open waters through sewage and domestic waste. Some of the well-documented effects on aquatic organisms are blockage of the gastrointestinal system (Setla et al., 2016), reduction in the mean weight of gut content (Ramos et al., 2012), endocrine disruption (Rochman et al., 2014), and alternation in intestinal structure (Peda et al., 2017). Worldwide studies are going on to access more information about this pollutant.

7) Deltamethrin

Deltamethrin is a synthetic pyrethroid used for agricultural purposes to control insects. So, it is a common insecticide used in fields. (Zhang et al., 2019). But excessive use of deltamethrin contaminates the aquatic environment and could result in serious health issues for aquatic organisms. Initially, it was produced as a substitute for the harmful organophosphates and was considered less harmful to the environment and non-target organisms. (Li et al., 2020). But studies show that it is more harmful to aquatic animals than mammals and humans, and excessive exposure can result in behavioural changes, genotoxicity, and respiratory problems in aquatic organisms. (Dawood et al., 2020).

8) Aluminium

Aluminium is the most common natural metallic element on the earth's crust and the third most common mineral. It is

released into the environment naturally through the weathering of rocks and accumulates in the aquatic environment. Artificially, it is manufactured in paints, pigments, coatings, catalysts, textile dyes, etc. (Jones and Bennet, 1986). Industrial applications of aluminium include construction, appliances, packaging materials, transportation, and electrical engineering. Aluminium sulphate ($Al_2(SO_4)_3$) is used for improving water clarity, but it has harmful effects on living organisms. (Pernitsky et al., 2006). Aluminium can cause oxidative stress, cytotoxicity, genotoxicity, a pro-inflammatory effect, immunological alternations, enzymatic dysfunction, etc. (Igbokwe et al., 2019).

9) Perfluorooctane Sulphonate

Perfluorooctane sulphonate (PFOS) is a synthetic organic compound that consists of a carbon backbone and a unique sulphonate functional group. It has been used for decay in the textile, paper, pesticide, and metal industries. (Buck et al., 2011), but its production was phased out in the US around 2002 because of its resistance to hydrolysis, photolysis, microbial degradation, and metabolism, which makes it persistent in aquatic environments. (Buck et al., 2011). Reports suggest that PFOS exposure can have adverse effects on aquatic organisms (Giesy et al., 2010). Although this compound has been phased out in the US, countries like China and Brazil have increased their production to meet the increasing demand. (Wang et al., 2013)

10) Chlorothalonil

Chlorothalonil is a halogenated benzonitrile that is used as a broad-spectrum fungicide for treating pathogens of plant foliar structures; it is also used as an anti-fouling paint in watercrafts and is considered a "third generation biocide" after the banning of tributyltin (TBT) (Guardiola et al., 2012). Although it is a very effective chemical against pathogens, it also affects non-target organisms in aquatic environments, and it can be very dangerous to fish and other invertebrate organisms (Reyna et al., 2021). A high dose of chlorothalonil induces an alteration of the oxidative status of fish, resulting in a reduction in the total oxidant capacity of the gills. It is also responsible for a reduction in sperm motility and an alteration of the structure and composition of blood in fish (Lopes et al., 2020). Molluscs are most susceptible to this pollutant because they tend to bioaccumulate it in their sessile tissues a thousand times more than other animals.

11) Radiocesium

Radiocesium is one of the most abundantly found radionuclides in nature (J. C. Leaphart *et al.,* 2020). It is formed by nuclear fission and dispersed globally by activities like nuclear weapon testing and accidental nuclear waste spillage (Pravalie 2014). The Chernobyl nuclear disaster of 1986 and the Fukushima-Daiichi nuclear power plant accident of 2011 resulted in the dissemination of large concentrations of radicesium into aquatic environments (Shishkina *et al.*, 2019). Studies done by various groups of researchers indicate that radiocesium has a high potential for bioaccumulation and biomagnification across the trophic levels (Ishii *et al.,* 2017; Sakai *et al.,* 2016; Wood *et al.,* 2009).

12) Quaternary Ammonium Compounds (Quats)

Quats are very versatile products that are used in a variety of products like pesticides, insecticides, sanitizers, cleaning liquids, antimicrobial cleaning products, etc. (Bures, 2019). Other than this, quats are also used in fabric softeners, fabric sprays, and hair conditioners because of their antistatic properties (Kaj et al., 2014). Disinfectant quats are seen as effective

against the SARS-CoV virus. The United States Environmental Protection Agency identified quats among the surface disinfectants against the SARS-CoV virus, so its demand increased immensely during the COVID-19 pandemic. But significant data also shows that quats could have potential ecotoxicological effects on freshwater aquatic organisms, and their high exposure could prove lethal to aquatic organisms including algae, plants, and fish. (DeLeo et al., 2020)

13) Mercury

Methylmercury (MeHg) acts as a neurotoxic pollutant that bioaccumulates and biomagnifies in aquatic food webs, impacting the health of fish and human beings who consume those fish. Mercury is produced by the burning of coal and other fossil fuels, the weathering of rocks, and industrial emissions. Mining also promotes an increase in the level of mercury in the environment. (Sundseth et al., 2017). Some of the deleterious effects of mercury consumption are reductions in reproductive performance, growth, and survival of piscivorous birds and mammals. (Eagles-Smith et al., 2018). Exposure to MeHg in humans can cause neurological defects, impairments in foetal and infant growth, and cardiovascular disease. (Karagas et al., 2012). Because of these lethal effects, pregnant women are strongly advised not to consume fish during pregnancy. The reason is simple: sea food becomes a carrier of mercury in the human body, and it can directly cause birth defects if it reaches the baby in the womb.

14) Azithromycin

Azithromycin is a widely used antibiotic, and it is frequently detected in aquatic ecosystems. Surface runoff, sewage, drifts, etc. result in the transfer of antibiotics like azithromycin into the water bodies. The most prominent effect of azithromycin is the inhibition of algal growth in the water. Algae are one of the primary producers in the water. If its growth is affected, it will affect the whole food web and the tropical transfer of energy. So, azithromycin indirectly affects consumers like humans and other carnivores. (Chen et al., 2020b) The ecological risk of antibiotics entering the water is increasing rapidly because they are being used continuously and their removal efficiency is very low. As a result, it is acting as one of the most potent and dangerous pollutants for aquatic organisms. (Mao et al., 2021)

15) Diclofenac

Diclofenac belongs to the class of non-steroidal anti-inflammatory drugs (NSAIDs). This is an important pharmaceutical compound that has become popular in every household, especially in tropical countries like India and China. Previously, it was not considered toxic, but recent studies reveal that diclofenac is one of the most toxic pharmaceutical compounds, which can cause oxidative stress, cytological changes, and endocrine disruption in aquatic organisms. (Godoi et al., 2020). Because of its high toxicity, the European Commission in 2012 kept diclofenac as a priority hazardous substance, and its maximum concentration was set at 100 ng per litre in freshwater. (Munoz-Penuela et al., 2021).

16) Caffeine

Caffeine is a central nervous system stimulant. It is used as a cardiac, brain, and respiratory stimulant and is commonly used in our daily food products, including coffee, tea, chocolates, and cakes. (Lee and Wang, 2015). No much information is available on the actual effects of caffeine on aquatic organisms, but a few studies show bioaccumulation of CAF in the mosquito fish *Gambusia* (Wang and Gardinali, 2012), negative effects on the development of fish embryos, and

endocrine disruption in some fish. (Godoi et al., 2020).

17) Neonicotinoids

Neonicotinoids are systemic insecticides that are widely used throughout the world. They are highly versatile and persistent, which provides all-round protection against sap-feeding insects over longer periods. (Bass et al., 2015). But studies show that neonicotinoids are harmful to pollinators, birds, mammals, and aquatic organisms (Jensen, 2019). Also, they indirectly affect large fish and humans by disrupting the food webs. (Yamamuro et al., 2019)

18) Lead

Lead is a biologically non-essential element that is widely distributed in the natural environment as one of the most toxic heavy metals. It has been included in the list of 275 priority-controlled pollutants by the United Nations Environment Protection Agency (UNEPA). Lead and its compounds enter the environment during mining, refining, bioaccumulation, or biomagnification through the food chain. Once they enter the human body, they are very difficult to remove, and they can pose a threat to living organisms (Lin, C. et al., 2021).

19) Nitrate

Nitrate is one of the nutrients responsible for the eutrophication of water bodies. Eutrophication leads to the ageing of water resources, the loss of biodiversity, and ecosystem degradation. Nitrate production and consumption cannot be fully controlled because it is an important constituent of the chemical fertilisers used by farmers. Fertilisers get mixed with the animal urine, and together they result in a high rate of nitrogen leaching into the adjacent aquatic systems, which ultimately causes harm to aquatic organisms (Davis et al., 2022).

20) Chloropyrifos

Chloropyrifos is one of the most commonly used pesticides in alpine vineyards and apple orchards. Though it is very effective against the pest of their target crop, it also causes damage to non-target species of plants as well as nearby aquatic organisms. A high dose of chloropyrifos affects the metabolism of aquatic insects and causes other metabolic disorders (Muniz-Gonzalez et al., 2021).

Conclusion

We have listed some of the regular pollutants and new emerging pollutants that are harmful to aquatic biota and ultimately to humans because we are all connected by the food web and energy exchange keeps on happening throughout the world, from a tiny microorganism to the largest mammal and reptile. An increase in the level of pollutants affects life forms in a very negative way. Although natural processes like weathering and volcanic eruptions are also responsible for introducing pollutants to the environment, the pace of these pollutants increases only due to anthropogenic activities. In today's world, when we are facing new strains of viruses, bacteria, epidemics, and pandemics, we need to be more careful with our choice of chemicals and products that we use in our daily lives. Switching towards sustainability and organic products could possibly help us encounter these problems.

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Conflict of Interest

There is no conflict of interest among the authors.

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