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Ecotoxicity of Emerging Pollutants in Aquatic System

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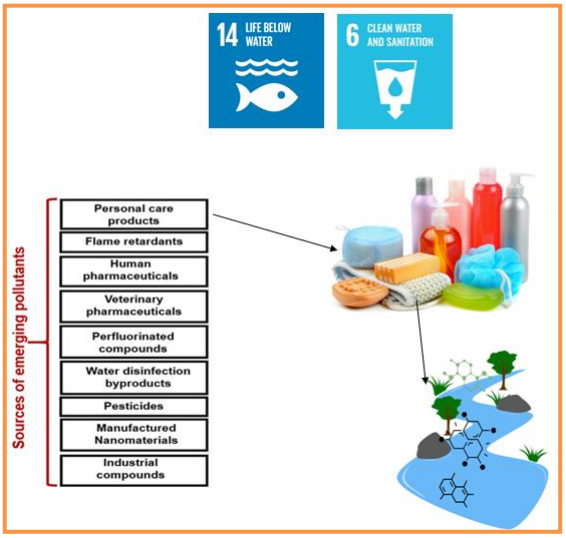
A wide variety of human activities are responsible for the introduction of newly discovered pollutants into the environment. They include a wide range of chemicals, such as medicines, drugs of abuse, personal care products, steroids and hormones, surfactants, perfluorinated compounds, flame retardants, industrial additives and agents, petrol additives, and their transformation products. In addition, they make up a diversified set of substances. Recently, other categories were included into the roster for emerging pollutants are nanomaterials, 1,4-dioxane, and by-products of swimming pool disinfection. Unfortunately, the standard waste treatment system that is already in place is not intended to remove these toxins. These contaminants come together to produce a complex or may be dissociated into other daughter compounds that may be passed on to aquatic species and people via the extended food chain leading to ecotoxicity. This can result in an increase in the concentration of pollutants that is tens of thousands of times higher than before. The complex structure of these pollutants, along with the fact that they are present in low concentrations, renders them untraceable. It is difficult to remove these pollutants using the waste treatment methods that are now in use. The health of humans and the environment are both regarded to be at risk when certain substances are present. As a result, the disposal and treatment of these chemicals that are becoming more problematic have become a primary issue in the area of water treatment and the reuse of water for human consumption or threatening aquatic life. When it comes to the treatment of these toxins that are becoming more problematic, bioremediation is an essential component.

Keywords: Emerging contaminants, pollutants, ecotoxicity, food chain, bioremediation

Background

Around 70% of wastewater is untreated, and over 40 million litres of effluent flow directly into the aquatic system every day. India ranks 120th of 122 countries in a global water quality index with nearly 70% of water being contaminated.



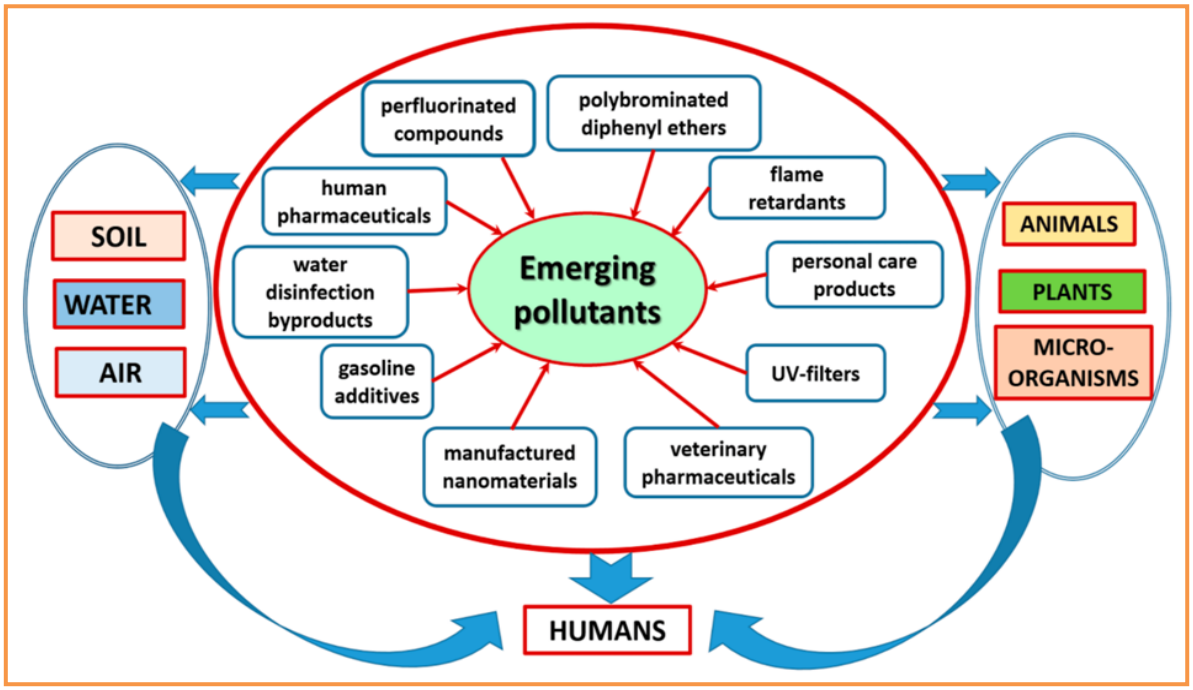
Recently, personal care products (PCPs) have emerged as ECs, and these contaminants were recorded in almost all water resources and identified as endocrine-disrupting compounds and have potential environmental and public health risks (Ramaswamy *et al*., 2011)

The 6th of 17 Sustainable Development Goals floated by the United Nations Development Program focuses on ensuring availability and sustainable management of water and sanitation as a key action point towards ending poverty by 2030.

Emerging pollutants

The growing population and industrial/agricultural activities release large amounts of wastewater into aquatic system.This wastewater contains various organic and inorganic contaminants. Some trace organic compounds with new sources or effects are called "emerging pollutants" (US EPA, 1999). These chemicals, both natural and synthetic, are found worldwide but are not yet regularly monitored. They have the potential to harm ecosystems and human health. Emerging pollutants are newly identified harmful chemicals that raise environmental concerns (US EPA, 1999)."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" (Geissen et al., 2015).

Types of Emerging pollutants



1. **Pharmaceuticals and Personal Care Products (PPCPs)** - Antibiotics, painkillers, hormones, cosmetics, and sunscreens.
2. **Endocrine-Disrupting Chemicals (EDCs)** - Synthetic hormones, pesticides, and industrial chemicals that affect hormonal balance.
3. **Persistent Organic Pollutants (POPs)** - Pesticides (DDT), industrial chemicals (PCBs), and dioxins that persist in the environment.
4. **Per- and Polyfluoroalkyl Substances (PFASs)** - Found in non-stick cookware, firefighting foams, and waterproof materials.
5. **Microplastics and Nanoplastics** - Tiny plastic particles from cosmetics, synthetic fibers, and plastic waste.
6. **Industrial Chemicals and By-products** - Surfactants, flame retardants, and heavy metals from manufacturing processes.
7. **Antibiotic-Resistant Bacteria and Genes** - Result from overuse of antibiotics in medicine and agriculture.

Priority pollutants in aquatic environment

Priority pollutants constitute a classification of hazardous chemicals recognized for their substantial role in aquatic pollution. These toxic substances pose serious threats to aquatic ecosystems, affecting both marine life and human health. The framework for identifying priority pollutants was established by the U.S. Environmental Protection Agency (EPA),

encompassing a diverse array of chemical categories that warrant stringent regulatory oversight to mitigate their adverse environmental impacts.

Key Categories

1. Personal Care Products (PPCPs): Personal care products are manufactured from variety of active and inert substances which includes both prescribed as well as non-prescribed pharmaceuticals that are used by human for personal care purposes and animals for veterinary purposes (Sharma etal.,2013). The diverse range of products encompasses synthetic hormones, sunscreens, analgesics, cosmetics, insect repellents, shampoos, toiletries, preservatives, fragrances, lipid regulators, and steroids. Each of these items serves a distinct purpose, contributing to both personal care and therapeutic applications. The integration of such products reflects advancements in science and technology, catering to various consumer needs in health, beauty, and wellness. In recent decades, the persistent use of personal care products (PCPs) has resulted in significant quantities of these substances, whether in their original or transformed states, entering aquatic systems and being detected in wastewater treatment facilities. Within these plants, some metabolites undergo conversion to benign compounds, such as carbon dioxide and water, primarily inorganic in nature. Conversely, certain metabolites, owing to their lipophilic characteristics and resistance to biodegradation, adhere to hydrophilic compounds and become partially adsorbed onto sedimentation sludge, highlighting the complex interplay between environmental contaminants and wastewater management (Jiangetal.,2023). We all know the ill effect of PCPs on our environment and water system but still, there discharge is unregulated and they are carelessly thrown in our immediate environment. The condition further deteriorates in developing countries due to improper regulations and lack of strict supervision as there is no regulatory frame work.

2. **Endocrine-Disrupting Chemicals (EDCs):** Endocrine glands, hormones, and receptors are the main part of Endocrine systems which help in regulating the physiological activities of body like reproductive processes (Markle etal.,2012). Endocrine-disrupting compounds (EDCs), also known as endocrine disruptors or modulators, are substances that interfere with the normal secretion and function of hormones produced by endocrine glands. These compounds, which can be natural or synthetic, have the ability to interact with hormone receptors, such as oestrogenic receptors, thereby enhancing or inhibiting the proper functioning of hormones (Jackson.,etal 2008). EDCs are found in various environmental sources, including certain plastics, pesticides, and industrial chemicals, and can have detrimental effects on human health and ecosystems. Their ability to alter endocrine function raises concerns about their potential impact on reproductive, developmental, and metabolic processes.

3**. Persistent Organic Pollutants (POPs):** Persistent Organic Pollutants (POPs) are a group of toxic chemical substances that persist in the environment, resist degradation, and accumulate in living organisms, leading to long-term adverse effects on human health and the environment. They are known for their ability to bioaccumulate and biomagnify, posing significant risks to ecosystems and human health. POPs include substances like DDT, dioxins, and PCBs.(Lallas., etal 2001).

4. Perfluorinated compounds (PFCs): Perfluorinated compounds (PFCs) are synthetic organic substances characterized by the complete fluorination of their hydrocarbon backbones, resulting in exceptionally stable carbon-fluorine bonds. This structural feature imparts remarkable thermal and chemical resilience to PFCs. However, their persistence and tendency to bioaccumulate raise significant environmental concerns. These fluorine compounds are commonly used in consumer products as stain/water/ grease repellents in carpets and clothing or in cooking utensils as nonstick coatings found in synthetic fibers, cosmetics, and plastic waste (Fricke etal.,2005). The bioaccumulation of perfluorinated compounds (PFCs) in fish represents a significant pathway for human internal contamination. Recent exposure assessments, notably by the German BfR, indicate that fish consumption, encompassing both freshwater and saltwater varieties, accounts for approximately 90% of total dietary exposure to perfluorooctanesulfonic acid (PFOS). This highlights the critical role

of fish as a vector for PFC transmission to humans (für etal., 2009). The German Federal Institute for Risk Assessment (BfR) has established a preliminary tolerable daily intake (TDI) of 0.1µg of perfluorooctanesulfonic acid (PFOS) per kilogram of body weight. Consequently, adhering to this recommendation, an adult weighing 70 kg should limit their daily PFOS consumption to a maximum of 7 µg to mitigate potential health risks (Ackmann etal .,2007)

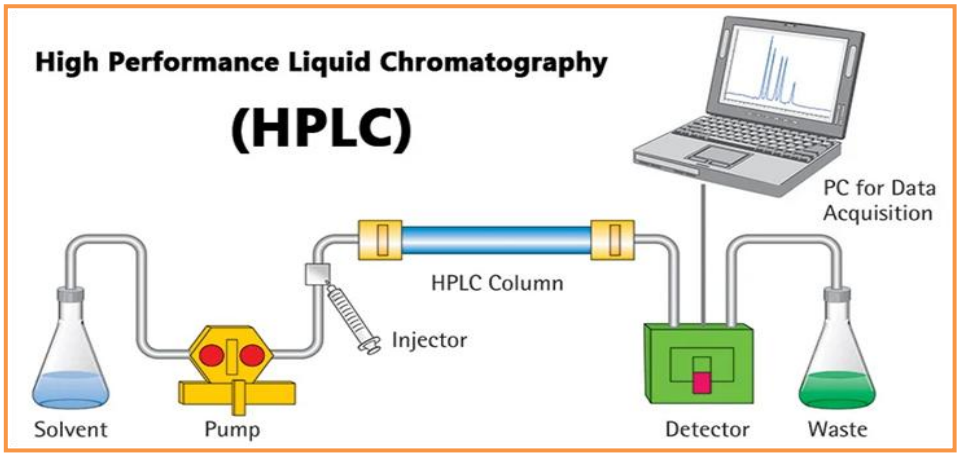
5. Heavy Metals: Heavy metals are a group of metals and metalloids characterized by their relatively high density (usually more than 5 g/cm³) and potential toxicity, especially at high levels of exposure. Common examples include lead (Pb), mercury (Hg), arsenic (As), and cadmium (Cd). While some heavy metals are essential for biological processes in trace amounts, they can become harmful when their concentrations exceed certain thresholds.(Leonard etal., 2004).

6. **Microplastics and Nanoplastics:** Plastic pollution has become one of the most pivotal environmental issues in the world today. According to statistics, the global production of plastics is close to 360 million tons (Mt) in 2018 and output is expected to double in the next 20 years. But, only 6% to 26% of these plastics are recycled, which means that up to 94% of the plastics probably be landfilled or enter the environment through various route (Farner etal.,2018). The most critical point is that the natural degradation of plastics is extremely slow. After physical, chemical and (or) biological action, large pieces of plastic will be broken into microplastics (MPs) (1 µm-5 mm) or nanoplastics (NPs < 1000 nm) (Arp etal.,2017). The majority of MPs and NPs from land sources are released straight into lakes and rivers either through surface runoff or wastewater treatment plant effluent. Typically, tiny, light plastic particles float on the top of the water whereas substantial, weighty plastic debris is left behind at the water's bottom. MP/NPs influence the growth, development, and reproduction of organisms, and can also lead to individual mortality. Because of their small size, nanoplastics have a tendency to cause oxidative stress reactions in living things, alter pigment synthesis or enzyme activity, lead to endocrine and metabolic disorders, and cause varying degrees of cytotoxicity, neurotoxicity, and/or genotoxicity. These effects are accumulated and intensified gradually from people to populations to communities and ultimately to ecosystems through the food chain, which could further degrade the delicate natural system (Liu etal., 2020).

7. Antibiotics and antibiotic resistance genes: Antibiotics and ARGs' harmful impacts on the environment have also been extensively documented in recent years. Antibiotics can produce life-threatening adverse responses due to improper metabolism or overdosing. They also have a physiological role in stress adaptation and bacterial pathogenicity (Özcengiz etal.2017). Pharmaceuticals as emerging micropollutants deteriorated the water quality, perturbation of aquatic flora and fauna and imparted a toxic effect on organisms (Solecki et al., 2017). The antibiotics erythromycin, SMX, and norfloxacin had the highest risk rankings and were more harmful to fish, algae, and invertebrates.

Technologies to detect emerging pollutants in aquatic system

Compound analysed	Method followed	Author
Triclosan, Carbamazepine and Parabens	Gas chromatography–mass spectrometry (GC–MS)	Ramaswamy *et al.* (2011)
Triclosan and Triclocarban	HPLC- High-performance liquid chromatography	Nag *et al.* (2018)
Triclosan	Spectrophotometric method	Roy and Ishtiaque, 2019
Triclosan	Reversed-phase liquid chromatographic (HPLC)	Piccoli *et al.* (2002)
Bisphenol A and Alkylphenol ethoxylates	Gas chromatography–mass spectrometry (GC–MS)	Selvaraj *et al.* (2014)
Bisphenol A	High-performance liquid chromatography system (HPLC)	Peteffi *et al.* (2018)



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