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Major pollutants and their effect on Marine Ecosystem along with their Sources

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Abstract

Water bodies, including rivers, lakes, groundwater, and coastal systems, face increasing pollution from various contaminants. These pollutants threaten ecosystems, human health, and reliable water supplies. This article provides an overview of major types of contaminants in aquatic environments, their sources and impacts. This article focuses on both traditional contaminants, such as nutrients, heavy metals, pathogens, and organic pollutants, as well as emerging pollutants, which include pharmaceuticals, personal care products and microplastics. Agricultural runoff introduces nutrients like nitrates and phosphates, pesticides, and veterinary drugs, leading to algal blooms. Industrial discharges release heavy metals, such as lead, cadmium, and mercury, along with persistent organic pollutants, solvents, and chemical byproducts. Urban wastewater and landfill leachates contribute to microbial contaminants, pharmaceuticals, personal care products, and microplastics. Atmospheric deposition brings airborne pollutants, such as PAHs and mercury, into water systems. Natural processes, including rock weathering, soil erosion, and geogenic trace elements, also play a part, particularly with arsenic and fluoride. The literature review outlines documented contaminant occurrences, detection challenges, and removal strategies. In the discussion, we compare the significance of point vs. non-point sources, the fate and transport of contaminants, bioaccumulation, biomagnification, and emerging health risks. Finally, we conclude with proposed research gaps and management strategies, including improved treatment methods, source control, regulatory frameworks, and monitoring. This article aims to inform researchers, policymakers, and environmental managers about the state of contaminants in water systems and the need for integrated mitigation efforts.

Keywords: *Water contaminants, Heavy metals, Nutrients / eutrophication, Pathogens, Persistent organic pollutants (POPs), Pharmaceuticals and Microplastics.*

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Introduction

Clean water is vital for ecosystems, human health, agriculture, and industrial processes. However, both freshwater and marine systems globally are facing rising pressure from chemical, biological, and physical contaminants. In the past, water pollution research mainly focused on nutrients, oxygen-demanding organics, pathogens, and industrial toxins. Recently, the range of contaminants has expanded to include trace-level pollutants such as pharmaceuticals, endocrine disruptors, microplastics, and new synthetic chemicals. Understanding the types of contaminants, their sources, how they enter water bodies, their fate, and their effects on both human and ecological health is crucial for developing effective monitoring, regulation, and cleanup strategies. In this article, we examine the main classes of contaminants, review existing literature on their sources and prevalence, discuss management challenges, and identify gaps and suggestions for future research

Review of Literature

Excessive nitrogen (nitrate, ammonium) and phosphorus (phosphate) from agricultural fertilizer, manure, and wastewater are some of the most studied water pollutants. These nutrients lead to increase in algae, low oxygen levels, and fish die-offs in lakes, rivers, and coastal areas. Many studies have documented nutrient loading, particularly in agricultural watersheds.

Heavy Metals & Trace Elements Industrial practices such as mining, electroplating, battery production and metal finishing release metals like lead, cadmium, mercury, chromium, and arsenic which are very harmful. These metals can build up and manipulate food webs, putting aquatic organisms and humans at high risk. The review "Contaminants in the Water Environment" discusses heavy metals as traditional pollutants from industrial discharge. Arsenic contamination is common in many groundwater systems, especially in South Asia.

Pathogens / Microbial Contaminants Pathogenic bacteria, viruses, protozoa, and helminths enter water bodies through sewage, agricultural runoff, and poorly treated wastewater. Pandey et al. (2014) review pathogens in water sources and their transport methods.

Organic Pollutants & Persistent Organic Pollutants (POPs) These include pesticides (DDT, organochlorines, endosulfan), polychlorinated biphenyls (PCBs), dioxins, and polycyclic aromatic hydrocarbons (PAHs). They are persistent, do not dissolve well in water and tend to build up in various organisms. A review of the MENA region mentions finding DDT, HCB, and BPA in rivers.

Pharmaceuticals & Personal Care Products (PPCPs) These "emerging contaminants" are gaining attention as they accumulate. Drugs like antibiotics and pain killers, hormones, antiseptics, and cosmetics are found at low levels in surface water and groundwater that receive sewage or wastewater discharges. The review by Silori & Syed explores pharmaceutical compounds in treated wastewater and aquatic environments. Research highlights the presence of pharmaceuticals (diclofenac, ibuprofen, etc.) and personal care chemicals (triclosan, BPA) and their effects, including endocrine disruption and bioaccumulation.

Microplastics & Particulates Microplastics (particles smaller than 5 mm) are now a common pollutant in aquatic systems. They come from the breakdown of larger plastics, microbeads, synthetic fibers, and wear and tear. Microplastics can absorb other contaminants and when eaten by aquatic organisms, these pollutants are potentially introduced into the food web. Reviews on emerging contaminants also mention these particles.

Atmospheric Deposition & Indirect Inputs Certain contaminants, such as mercury and PAHs, travel through the air and settle in water bodies through rain. The paper "Sources of chemical contaminants and routes into the freshwater environment" discusses atmospheric sources.

Natural / Geogenic Sources Not all contamination comes from human activities. Weathering of rocks and soils can release trace metals, like arsenic and selenium, naturally. Geological sources may prevail in some aquifers.

Discussion

Point vs Non-Point Sources

Point sources (e.g. industrial effluent pipes, sewage outlets) are easier to monitor and regulate; non-point sources (diffuse runoff from agriculture, urban surfaces) are more challenging to control. In many agricultural watersheds, nutrient and pesticide runoff acts as a dominant non-point source.

Fate, Transport, and Transformations

Once in the environment, contaminants may undergo physical, chemical, or biological transformations. Some degrade or partition to sediments; others remain persistent. Hydrological transport and dilution patterns influence spatial distribution. Bioaccumulation and biomagnification are particularly critical for metals, POPs, and certain organic pollutants.

Emerging Risks

- **Antibiotic resistance**: Presence of antibiotics in water may select for resistant bacteria, which pose public health risks.
- **Endocrine disruption**: Hormones and endocrine-active compounds (e.g. BPA, triclosan) can affect reproductive systems of aquatic fauna.
- **Synergistic toxicity**: Complex mixtures of contaminants may cause non-additive effects that are difficult to predict.
- **Detection challenges**: Many contaminants occur in trace (ng/L to μg/L) concentrations requiring advanced analytical techniques.
- **Treatment constraints**: Conventional wastewater treatment is often inadequate to remove trace organic contaminants or microplastics. Advanced methods (activated carbon, ozonation, advanced oxidation, membrane processes) are being studied.

Table: Major pollutants in water bodies and their sources

Pollutants	Type	Primary Sources	Effects on Water/Ecosystem
Nitrates & Phosphates	Nutrients	Agricultural runoff (fertilizers), sewage and detergents	Eutrophication, algal blooms and oxygen depletion
Heavy Metals	Inorganic Chemicals	Industrial discharge, mining and landfill leachate	Toxic to aquatic life and humans (e.g., lead, mercury poisoning)
Pathogens	Biological	Untreated sewage, animal waste and stormwater runoff	Waterborne diseases that includes cholera, dysentery, etc.
Plastics & Microplastics	Solid Waste	Improper disposal, urban runoff and plastic industries	Physical harm to aquatic organisms and bioaccumulation
Oil & Hydrocarbons	Organic Pollutants	Oil spills, industrial discharge and shipping activities	Coats fish/gills, reduces oxygen and long-term ecosystem damage
Pesticides & Herbicides	Organic Chemicals	Agricultural runoff, lawn care and pest control	Bioaccumulation, endocrine disruption and toxicity to aquatic species
Pharmaceuticals	Organic Chemicals	Improper disposal, hospital and household wastewater	Hormonal disruption and antibiotic resistance
Suspended Solids	Physical	Soil erosion, construction sites and unpaved roads	Turbidity, reduced sunlight and clogging of fish gills

Conclusion

Water bodies globally are under multi-dimensional stress from a wide array of contaminants including traditional and emerging. Effective assessment and mitigation require integrated approaches that consider source control, monitoring and advanced treatment technologies, regulatory frameworks, and public awareness. Key priorities for future work include improving detection of trace contaminants, understanding mixture effects, tracking antibiotic resistance, and scaling feasible treatment options. Collaboration between scientists, engineers, policymakers and communities is essential to safeguard aquatic ecosystems and human water security.

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Conflict of Interests

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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