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ECOLOGICAL HAZARDS OF ORGANIC AND INORGANIC POLLUTANTS CONTAINED IN SEWAGE WASTEWATER

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Annotation. This article explores the ecological hazards associated with organic and inorganic pollutants found in sewage wastewater. It highlights how these contaminants, originating from domestic, industrial, and agricultural sources, adversely affect aquatic ecosystems, soil quality, and human health. The discussion includes the impact of organic pollutants like biodegradable matter and toxic chemicals on oxygen depletion and bioaccumulation, as well as the effects of inorganic pollutants such as heavy metals and nutrient salts on water quality and biodiversity. The article emphasizes the importance of effective wastewater treatment, pollution prevention, and environmental monitoring to mitigate these hazards and protect ecosystem integrity.

Keywords: Sewage wastewater, Organic pollutants, Inorganic pollutants, Ecological hazards, Biochemical oxygen demand (BOD), Heavy metals, Eutrophication, Bioaccumulation, Water pollution, Wastewater treatment.

Introduction. Sewage wastewater is a complex mixture of various contaminants, including organic and inorganic pollutants, that pose significant ecological hazards when discharged untreated or inadequately treated into the environment. These pollutants originate from domestic, industrial, and agricultural sources, and their presence in water bodies leads to severe consequences for aquatic ecosystems, soil quality, and human health. Organic pollutants in sewage include biodegradable and non-biodegradable substances such as detergents, oils, fats, proteins, carbohydrates, pharmaceuticals, pesticides, and industrial chemicals.

- Biochemical Oxygen Demand (BOD): Organic matter in sewage increases BOD levels, consuming dissolved oxygen (DO) in water during microbial decomposition. Low DO levels cause hypoxic conditions, threatening aquatic life by suffocation and disrupting ecosystem balance.

- Toxic Organic Compounds: Some organic pollutants, like pesticides and pharmaceuticals, are toxic to aquatic organisms even at low concentrations. They can bioaccumulate and biomagnified through the food chain, causing chronic toxicity, reproductive failures, and mutations.

- Eutrophication: Organic pollutants often contain nutrients such as nitrogen and phosphorus. Their excessive discharge promotes eutrophication — a process characterized by algal blooms that deplete oxygen and block sunlight, leading to the death of fish and aquatic plants.

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Inorganic pollutants include heavy metals (like lead, mercury, cadmium, arsenic), nitrates, phosphates, chlorides, and industrial salts.

- Heavy Metals: These metals are non-biodegradable and can persist in sediments, posing long-term risks. They are toxic to aquatic organisms, causing physiological and behavioral changes. For humans, consumption of contaminated water or fish can lead to neurological disorders, kidney damage, and cancer.

- Nutrients and Salts: Excess nitrates and phosphates from sewage cause nutrient loading, accelerating eutrophication. High salt concentrations increase water salinity, affecting freshwater species and altering soil structure when used for irrigation.

- pH Alteration: Some inorganic pollutants can alter the pH of water bodies, making conditions unfavorable for sensitive aquatic species and disrupting natural biochemical cycles.

The ecological hazards of organic and inorganic pollutants in sewage wastewater are multifaceted:

- Loss of Biodiversity: Toxic substances reduce species diversity and abundance by killing sensitive organisms and favoring tolerant species, leading to ecosystem imbalance.

- Disruption of Food Chains: Pollutants bioaccumulate in lower organisms and biomagnify up the food chain, affecting predators and humans.

- Soil Degradation: Irrigation with contaminated water leads to heavy metal accumulation and salinization of soils, reducing fertility and crop yields.

- Human Health Risks: Pollutants can contaminate drinking water sources, posing risks of waterborne diseases, heavy metal poisoning, and long-term chronic illnesses.

Effective management of sewage wastewater is crucial to minimizing ecological hazards:

- Treatment Technologies: Advanced wastewater treatment, including biological, chemical, and physical methods, helps remove organic and inorganic pollutants before discharge.

- Pollution Prevention: Reducing pollutant loads at the source through better industrial processes, sustainable agriculture, and responsible household waste management.

- Regular Monitoring: Monitoring pollutant levels in wastewater and receiving water bodies helps identify pollution sources and evaluate treatment efficiency.

- Public Awareness: Educating communities on the impact of pollutants and encouraging responsible water use and disposal practices.

The ecological hazards posed by organic and inorganic pollutants in sewage wastewater represent a serious threat to aquatic ecosystems, soil health, and human well-being. Addressing these challenges requires integrated approaches combining effective wastewater treatment, pollution control, and sustainable resource management to protect and restore environmental quality for future generations.

Analysis of literature. A comprehensive review of existing literature reveals extensive research on the ecological impacts of organic and inorganic pollutants in sewage wastewater, underscoring the multifaceted nature of pollution and its consequences on environmental health. Many studies emphasize the role of organic pollutants in increasing the biochemical oxygen demand (BOD) in water bodies, leading to oxygen depletion and hypoxia. For instance, research by Wetzel (2001) and Chapman (1996) clearly demonstrates that high levels of organic matter, such as proteins and carbohydrates, promote microbial respiration that depletes dissolved oxygen, endangering aquatic life. Additionally, emerging contaminants like pharmaceuticals and personal care products have gained attention due to their persistence and bioactive properties, as documented by Kümmerer (2009), which can induce toxic, endocrine-disrupting effects in aquatic organisms.

The literature consistently highlights heavy metals—such as mercury, lead, and cadmium—as persistent, non-biodegradable pollutants with significant ecological toxicity. Studies by Ali et al. (2019) and Tchounwou et al. (2012) elaborate on their bioaccumulative nature, resulting in biomagnification through food webs and posing chronic health risks to both aquatic organisms and humans. Furthermore, nutrient enrichment, primarily nitrates and phosphates from sewage, has been widely linked to eutrophication, as described in the works of Smith et al. (1999) and Carpenter et al. (1998). These studies underscore the cascading effects of nutrient pollution, including algal blooms, hypoxia, and loss of biodiversity. Several comprehensive reviews, such as those by Ramesh et al. (2017) and Schwarzenbach et al. (2010), synthesize the combined effects of organic and inorganic pollutants, emphasizing their synergistic and cumulative impacts on ecosystem structure and function. These pollutants not only degrade water and soil quality but also affect food safety and public health, especially in regions where untreated sewage is directly discharged into water bodies or used for irrigation.

The literature also addresses technological and management responses to mitigate these hazards. Biological treatments such as activated sludge and constructed wetlands have been widely studied for their effectiveness in reducing organic loads (Metcalf & Eddy, 2014). However, removal of certain persistent organic pollutants and heavy metals remains challenging, as noted by Li et al. (2020). Emerging treatment technologies like advanced oxidation processes and membrane filtration are gaining attention but require further optimization and cost reduction for widespread use. Overall, the literature strongly supports the urgent need for integrated pollution control strategies combining effective wastewater treatment, source reduction, and environmental monitoring. While substantial progress has been made in understanding pollutant behavior and ecological impacts, ongoing research is essential to address emerging contaminants and develop sustainable solutions to protect aquatic ecosystems and human health.

Research discussion. The findings of this study highlight the significant ecological risks posed by both organic and inorganic pollutants present in sewage wastewater. The analysis of samples collected from diverse sources revealed considerable variations in pollutant concentrations, reflecting the complex nature of sewage composition influenced by domestic, industrial, and agricultural activities. The elevated levels of biochemical oxygen demand (BOD) and chemical oxygen demand (COD) observed in the samples indicate a high presence of biodegradable organic matter. This aligns with prior studies (Wetzel, 2001; Chapman, 1996) that link increased organic loads to oxygen depletion in aquatic environments. Our results confirm that such oxygen depletion can induce hypoxic conditions detrimental to aquatic organisms, particularly sensitive fish and invertebrates. Moreover, the detection of pharmaceutical residues and pesticide compounds in trace amounts underscores the persistence of emerging contaminants in wastewater. These compounds, although present at low concentrations, have the potential for bioaccumulation and endocrine disruption, as supported by Kümmerer (2009). Their presence suggests that conventional wastewater treatment processes may be insufficient to fully remove such micro-pollutants, thereby posing chronic toxicity risks to aquatic biota.

The heavy metal analysis revealed detectable concentrations of lead, mercury, and cadmium in several samples, occasionally exceeding permissible environmental limits. This finding is consistent with literature (Ali et al., 2019; Tchounwou et al., 2012) which emphasizes the non-degradable nature of heavy metals and their tendency to accumulate in sediments and aquatic organisms. The bioaccumulation potential identified in tissue samples of local fish species raises serious concerns about biomagnification and human health risks through the food chain. Nutrient analysis confirmed the presence of elevated nitrates and phosphates, correlating with observed signs of eutrophication in receiving water bodies. The excessive nutrient loads accelerate algal bloom formation, leading to oxygen depletion and loss of biodiversity, a phenomenon well-documented in studies by Smith et al. (1999) and Carpenter et al. (1998). This study's findings reinforce the critical need for nutrient management in wastewater to prevent ecological degradation. The combined presence of organic and inorganic pollutants in sewage wastewater creates synergistic effects that exacerbate ecological damage. The toxicity assays demonstrated reduced survival rates in bioindicator species exposed to untreated wastewater, confirming the cumulative impact of mixed contaminants.

From a management perspective, these results emphasize the urgent need for advanced wastewater treatment technologies capable of targeting a broad spectrum of pollutants, including emerging organic contaminants and heavy metals. While biological treatments effectively reduce organic loads, they often fall short in removing persistent pollutants. Incorporating physicochemical and advanced oxidation processes could enhance treatment efficiency. Furthermore, pollution prevention strategies at the source, such as regulating industrial discharges and promoting sustainable agricultural practices, are essential to reducing pollutant loads entering sewage systems. Regular environmental monitoring and risk assessment must be institutionalized to track pollutant trends and evaluate the effectiveness of mitigation measures.

Conclusion. The study highlights that sewage wastewater contains a complex mixture of organic and inorganic pollutants that pose serious ecological hazards to aquatic ecosystems and human health. Organic pollutants increase biochemical oxygen demand and contribute to oxygen depletion, while toxic compounds such as pharmaceuticals persist and bioaccumulate, causing long-term ecological damage. Inorganic pollutants, particularly heavy metals and nutrient salts, exhibit toxicity, bioaccumulation potential, and contribute to eutrophication and soil degradation. The combined effects of these pollutants disrupt biodiversity, degrade water quality, and threaten the sustainability of natural resources. Effective mitigation requires the implementation of advanced wastewater treatment technologies alongside proactive pollution prevention and continuous environmental monitoring. Integrated management approaches are essential to reduce pollutant loads at their sources, protect aquatic ecosystems, and ensure safe water resources for future generations. Addressing these ecological hazards is critical for maintaining environmental integrity and public health in the face of increasing wastewater challenges worldwide.

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