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Detrimental Characteristics of Wastewater

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ABSTRACT
Identifying many unfavourable properties of wastewater and its effects on the environment and public health is crucial. Sewage is a complex mixture of effluents from industrial processes, domestic usage, and agriculture, and it poses a terrible risk of holding infectious agents, heavy metals, plastics microbeads, and toxic chemicals. Such pollutants cause water pollution and promote rapid growth of algae and aquatic plant life at the same time slowing water circulation, affecting aquatic life and causing eutrophication suffering from waterborne diseases, and other chronic sicknesses brought about by chemicals. New risks such as AMR genes and endocrine disruptors add to the picture making it even more complex. In this work, the chemical, biological, and physical properties of the wastewater are discussed with much emphasis on their implications for the environment and health. Besides, it analyzes generic risk management measures, such as the technological developments of treatment processes, efficient legislative mechanisms, and public involvement, and provides recommendations. The outcomes highlighted by the findings suggest that significant enhancements of both, effective interventions and guidance research, are needed for the sustainable improvement of the management of wastewaters as well as the protection of ecosystems and human beings.

Keywords
Sewage Contamination, New Pollutants, Heavy Metals, Bacteria and Viruses, Microbeads, Bacteria and Virus Removal, Wastewater Treatment Systems, Environmental Influence, Waterborne Diseases, Wastewater Laws, Chemical Pollutants, Water Eutrophication, Endocrine Disruptors.

1. INTRODUCTION
Wastewater may be defined as the used water that comes from several activities such as domestic, industrial and commercial as well as agricultural practices (Kesari *et al.,* 2021). It is composed of organic and inorganic pollutants, pathogens, nutrients or emerging substances and hence poses a serious threat to the environment. Due to the above composition, wastewater is dangerous to society and the environment if not properly treated.
Studying the negative qualities of wastewater is crucial to predict its possible impact since it influences multiple aspects of life. Lack of proper wastewater management services increases challenges such as pollution of water, and soil, and frequent disease outbreaks in densely populated and industrialized areas. Due to the new pollutants, including microplastics and pharmaceuticals, society needs a fresh perspective of a more detailed study of the negative impacts of wastewater on public health.
It is the purpose of this research to ascertain and then discuss the major pathogenic properties of wastewater based on physical, chemical, and biological properties. Also, the paper identifies the effects of these pollutants on the environment and the health review and recommends appropriate measures for addressing them. The purpose of the research is to offer all the information about the several negative impacts of wastewater so that policymakers, industries, and communities can work together to follow the best practices towards sustainable wastewater management.

2. DETRIMENTAL CHARACTERISTICS OF WASTEWATER
2.1 Chemical Characteristics
Wastewater consists of several chemicals that are potentially disastrous to water resources and human lives. In industrial wastewater, there are basic ***heavy metals*** including lead, mercury, and arsenic. Many of these metals are not biodegradable, found in water, enter the food chain, and lead to long-term health problems, including neurological disorders and cancer.
Furthermore, wastes such as industrial solvents and pesticides threaten the chemical toxicity of wastewater. Chemicals like polychlorinated biphenyls (PCBs) and hydrocarbons, which are so prevalent in water bodies, create the most havoc since they tend to interfere with the general natural functioning of aquatic living organisms (Rajmohan, Chandrasekaran and Varjani, 2020). Some of the other hazards include ***ammonia, nitrates***, pesticides, and heavy metals of which high levels of inputs, particularly from agricultural drainages can result in toxicity within water systems.
This also suggests that wastes containing hazardous chemicals are more challenging and expensive to remove from

the wastewater. Some pollutants which are relatively new to pollution control, including pharmaceutical residues and personal care products, are particularly harder to remove since they often remain invisible to conventional treatment processes and contribute endocrine disruptors into the environment.

2.2 Biological Characteristics

Some of the characteristics of biological components of wastewater involve high ***pathogen load*** affecting the health of the people. The water supplied to these Wastewater systems contains bacteria, viruses and protozoa that lead to diseases such as cholera, dysentery and hepatitis respectively (Jia and Zhang, 2020). These risks are particularly heightened in other parts of the world where sanitation is lacking and where treatment of water supplies is inadequate in low- income areas.

The measure of the extent of biological pollution is ***BOD or the biological oxygen demand***, which shows the amount of oxidizable organic matter present in the wastewater (Wojnárovits *et al.,* 2024). High BOD also reduces dissolved oxygen in water bodies and as such forms hypoxic and therefore uninhabitable space for aquatic life. The resulting diminution in species biodiversity affects the communities and fish stocks.

Other new biomarkers are AMR genes – the presence of genes that are carriers of ***antimicrobial resistance***. Hospitals and pharma industries are the biggest contributors of wastewater to the AMR threats since they disseminate drug-resistant pathogen species. This results in a global public health implication and calls for improvement in wastewater management systems.

2.3 Physical Characteristics

Temperature, turbidity and ***colour*** of the wastewater have a large effect on its effects on the environment. Thus, heat from industrial emissions may also affect water quality in that they lower dissolved oxygen content which is crucial to most water-dwelling species (Aditya *et al.,* 2022).

This category (***Turbidity***) originates from suspended particles in water and reduces light transparency to affect photosynthesis in water plants (Matos *et al.,* 2024). This disintegration of the primary production sector has implications for the rest of the food supply system. Interfere with embryonic development and/or suspended solids damage the gills of fish, and sediment over spawning grounds decreases fish production.

An equally major issue is ***odour***, mainly involving hydrogen sulphide and ammonia. These odours are not only a problem in neighbourhoods residing close to WWTP (wastewater treatment plant) facilities but show that dangerous anaerobic processes also exist.

Aerial pollutants are comparatively easier to identify than physical pollutants even though they need treatment strategies such as sedimentation and filtration to reduce harm toward communities.

3. EMERGING THREATS

Some of the chemical compounds new to the environment include ***microplastics, endocrine-disrupting chemicals***, and ***antimicrobial resistance genes*** in the wastewater. These are derived from the fragmentation of the larger polymer pieces and are characterized by high resistance to degradation and prone to bioaccumulation in water bodies (Ateia *et al.,* 2022). Besides, they are toxic to marine life and are consumed by humans through the food chain.

A type of toxins acting on the hormonal system of living organisms causes ***reproductive*** and ***development problems*** among wildlife, xenophobe estrogen and androgen, and are obtained from pharmaceuticals and personal care products. All of these substances, in any concentration, have enormous impacts on the entire ecosystem.

These ***ARGs (Antimicrobial resistance genes)*** contribute to the proliferation of drug-resistant bacteria, which are continually detected in untreated sewage. Hospitals and the production units of pharmaceutical firms are primary contributors of ARGs in wastewater, a major threat to public health (Ahmad, Malak and Abulreesh, 2021).

Preventing and controlling these threats needs sophisticated early warning systems and new technologies in wastewater treatment to minimize their impacts.

4. ENVIRONMENTAL AND PUBLIC HEALTH IMPACTS

4.1 Environmental Impacts

Wastewater has very negative consequences and has a malignant influence on the natural processes of the environment. The most unfortunate effect is ***eutrophication*** which is a result of nutrient overwhelming especially nitrogen as well as phosphorus. The nutrients increase the growth rates of algae that lay down oxygen in water bodies leading to the formation of hypoxic zones in which life is hard to support.

Diminishing the level of biodiversity is another important problem. Heavy metals and pesticides have on one occasion posed great danger to water animals and aquatic life for instance, fish, and invertebrates are easily poisoned to death by the pollutants (Ali *et al.,* 2020). Hazardous POP chemicals accumulate in the food chains endowed with long-term chronic impacts on the environment.

Pollution of soil results from the improper usage of wastewater through irrigation (Hashem and Qi, 2021). Such chemicals and heavy metals which are in the wastewater form become a nuisance to the fertility of the soil as well as affecting the productivity of crops. Not only does it undermine agriculture's future but also puts the existence of toxins into the food chain.

Also, untreated wastewater is the cause of ***water pollution*** through the seepage of the ***latter into the ground***. Contaminants are mostly washed from their sources through leaching which in turn affects the quality of drinking water, an environmental problem of high magnitude.

4.2 Public Health Concerns

The effects of wastewater pollution on the public health cannot be underestimated. Cholera, typhoid, dysentery and other ***waterborne diseases*** can be attributable to ingestion of water which has been infected by bacteria or other water pathogens (Noureen *et al.,* 2022). Bacteria, viruses, protozoa and parasites from untreated or poorly treated sewage water negatively affect the poor and more so those living in areas that lack adequate sanitation systems.

Contact with the chemicals in wastewater creates diseases that have long-term effects. Some metals including mercury and lead to neurological disorders, development complications in children and organ diseases. Similarly, the impact of endocrine disruptors from wastewater also causes hormonal changes, infertility and cancer diseases.

A new development which makes public health difficult to handle is ***antimicrobial resistance (AMR)***. Hospital effluent and related pharmaceutical industries release healthcare products with antibiotic residues and resistance genes which help spread antimicrobial resistance (McCarthy *et al.,* 2021). This makes the work of the eradication of infections more challenging and puts so much stress on the health facilities.

To prevent these public health issues, wastewater treatment rules must remain very specific and people must be educated about the necessity for good hygiene. Many people are affected by the health risks that accompany contaminated wastewater and, therefore, need policy interventions and advanced technologies to tackle these problems.

5. MITIGATION STRATEGIES

5.1 Technological Interventions

Self-organized systems by the use of advanced technologies are pivotal in minimizing the adverse impacts of wastewater. Conventional and emerging pollutants are very effectively removed utilizing ***sophisticated wastewater treatment technologies***, including MBRs and reverse osmosis (Bera, Godhaniya and Kothari, 2022). These systems are better for filtration than tap systems they remove microplastics, pathogens, and heavy metals.

Another technology is ***bioremediation*** which uses microorganisms to break down and detoxify hazardous organic substances. This approach is especially important in halting the spread of oil and industrial solvents around the environment. ***Constructed wetlands*** imitate natural purification processes, hence providing an economical solution to wastewater treatment for small communities (Hassan *et al.,* 2021).

Electrochemical techniques are emerging as being effective for the elimination of novel pollutants including pharmaceuticals and endocrine disruptors. They also consume less energy when compared with conventional approaches in the polymer industry. Implementation of these technologies involves huge capital outlay, but the gains accrued from checking on environmental degradation and its effects on the population are apparent.

5.2 Policy and Regulation

Specifically, it was found that sound and comprehensive regulation is critical to adequate wastewater management. Much work has to be done and governments should put pressure on industries and municipalities to adhere to environmental standards of effluent discharge. Several policies such as the ***Clean Water Act*** in the United States and similar measures worldwide show that pollutant loads can be relieved (Jambeck *et al.,* 2023).

Polluter-pay principles may encourage industries to avoid polluting or at least limit pollution by carrying out their costs of wastewater treatment. Furthermore, the use of incentives such as tax credits and subsidies towards the adoption of smart technologies can lead to fast compliance.

For instance, the recent policy called ***Zero Liquid Discharge (ZLD)*** was put into practice in areas of India to prove the efficiency of stringent legislation on water usage and reduction in pollution. International cooperation between organizations, states and global industry is key to creating a unified code and addressing issues of interdisciplinary pollution.

5.3 Community and Stakeholder Engagement

Stakeholder engagement is important in managing and improving wastewater on a sustainable basis in the communities. Increasing awareness makes the public change their behaviour and avoid polluting water by managing chemical waste and lack of proper sewer systems (Obaideen *et al.,* 2022).

Collaboration with industries, local governments and NGOs gives a concerted outlook on wastewater issues. Such

initiatives are sponsorship programs that facilitate the delivery of public- private partnerships (PPP) to advance the frameworks of new technologies. Open communication channels flowing across stakeholders improve a business's accountability and credibility.

The case studies of the grassroots involvement in rainwater harvesting and decentralized wastewater treatment systems show a greater efficacy of community-led sustainable solutions.

6. FUTURE IMPLICATIONS

6.1 Implementation of Advanced Treatment Technologies:

Governments and industries should also embrace new treatment uses for wastewater like membrane bioreactors and reverse osmosis, electrochemical processes. These technologies present high efficiency in the elimination of a broad variety of pollutants including emerging issues such as microplastics and pharmaceuticals. The implementation of large-scale adoption of these systems can be driven through public-private partnerships (Feng, Wang and Sun, 2022).

6.2 Enhancement of Regulatory Frameworks:

Tightening controls on the discharge of wastewater are of immense importance in reducing the effects. Effluent quality should also be regulated through the authorities after stipulating a maximum proper content of effluent which contains specific prohibited contents like heavy metals, pesticides, and qualified pathogens (Tsaridou and Karabelas, 2021). Also, policy-based implementation of the polluter pays principle encourages industries to go for more clean technologies and better treatment technologies.

6.3 Promotion of Bioremediation and Eco-Technologies:

Thus, bioremediation and such eco-technologies as constructed wetlands can serve as possible and efficient ways of wastewater treatment. Such methods can be helpful, especially in rural communities or districts where there exists a scantily endowed environment since they readily provide outcome-oriented solutions.

6.4 Public Awareness Campaigns:

This means that governments and NGOs as well as affected communities should begin to educate people on the dangers of wastewater. Awareness programs must motivate people to scale down their use of chemical products, properly dump their garbage, and donate their efforts to water treatment facilities (Farooq *et al.,* 2022). Further, as much as consumers are informed about the effects of their products, on the environment such as personal care items, and pharmaceuticals in wastewater, their quantities will begin to dwindle.

6.5 Further Research into Emerging Contaminants:

Further research regarding the presence of other new and developing compounds is required as well as constant observation of And's and EED's. Enhancement of monitoring systems as well as focus towards the research of new effective treatment technologies is useful in addressing these compounds. Quite often, people in academia, business, and government institutions can work together more effectively to find the best solutions.

7. CONCLUSION

The characteristics of the detrimental nature of wastewater are multifaceted and constantly on the rise in terms of sustainability of the environment and health in general. Some of these pollutants are chemical, biological, and physical, and include hazardous compounds, pathogens, microplastics, and pharmacologically active compounds all of which pose potential risks to ecosystems and human health. These pollutants lead to waterborne diseases, loss of biological diversity and water and soil pollution, which bear the need to work towards proper wastewater handling at national and international levels.

Accompanying these risks needs to be addressed by using the most efficient existing technologies, ***the proper creation*** and ***implementation of policies*** and ***regulations*** as well as active ***involvement of the population***. Efforts aimed at achieving sustainable wastewater management must be supported at national and global levels through government, industries and the public.

Moreover, the need for a ***long-term study*** of the effluents-borne pollutants and more so the emerging contaminant's effects cannot be overemphasized since it will help in reporting the country's unique policy innovations. The world must wake up to the fact that wastewater generated is a source of pollution, and efforts to minimize contamination and enhance the treatment of wastewater are highly demanded.

Therefore, the effective treatment of wastewater to protect the environment and human health is not only pertinent but also a business could make the necessity into an opportunity. If invested in technology, regulatory compliance is improved, and people are informed on these issues, then the negative impacts of wastewater on our earth and future generations can be eliminated.

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