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REVIEW OF LATEST TECHNOLOGIES ON WASTE WATER TREATMENT

Dr. Manjula Spah [1], Dr. D.C. Spah [2]

[1] Principal, GVM Girls College Sonipat, Haryana, India
[2] Retd. Associate Professor, Retirement from Govt. College Gohana

ABSTRACT

Public concern about the environmental effects of wastewater pollution has grown. Traditional wastewater treatment methods, such as chemical coagulation, adsorption, and activated sludge, have been used to address the issue, but they still face limitations, particularly in terms of high operational costs. Aerobic wastewater treatment is gaining attention as a cost-effective alternative due to its low operational and maintenance expenses. It is also readily accessible, highly effective, and capable of breaking down pollutants. This paper explores various wastewater treatment technologies for removing contaminants like halogenated hydrocarbons, heavy metals, dyes, pesticides, and herbicides, which are the primary pollutants found in wastewater.

Keywords: Environment, Groundwater, Hydrocarbon, Technology, Chemical Coagulation, Aerobic Wastewater, Sustainable Development

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1. INTRODUCTION

As the global population continues to grow rapidly, water is becoming an increasingly scarce resource in the 21st century. By 2015, the majority of the world's population, over 5 billion people, will live in urban areas. There will also be 23 megacities, each with a population of over 10 million, 18 of which will be in the developing world. One of the major challenges associated with urbanization is the provision of municipal services, including access to clean water and sanitation. Meeting the basic needs of housing, healthcare, and infrastructure such as clean water and waste disposal is a significant challenge for engineers, planners, and policymakers. As the population grows, the pressure on resources will increase, putting even more strain on environmental systems. There is growing concern that the current use of freshwater by both developing and developed nations is unsustainable. Water usage is increasing at a rate more than three times the global population growth, leading to significant public health issues, as well as limitations on economic and agricultural development, while also negatively impacting ecosystems. India, which accounts for only 2.4% of the world's land area, is home to over 15% of the global population. Despite this, India has only 4% of the world's total water resources, and per capita water availability is rapidly decreasing.

As population and water demand continue to rise, water resources in India are becoming increasingly strained. In 1991 and 2001, per capita surface water availability was 2300 m^3 and 1980 m^3, respectively, and these numbers are expected to decrease further to 1401 m^3 by 2025 and 1191 m^3 by 2050. By 2050, India's total water requirement is projected to exceed its current water availability. Much of the pollution in water bodies results from the discharge of waterborne waste from domestic, industrial, and nonpoint sources. Although wastewater collection dates back to ancient times, treatment methods have only become more widely developed in recent centuries. Modern understanding of the need for water sanitation began in the mid-1800s, following cases such as John Snow's demonstration that a cholera outbreak in London was linked to contaminated water from the Thames River. In developed countries, wastewater treatment systems can vary greatly depending on factors like income levels and location. Common methods include centralized aerobic treatment plants and lagoons for domestic and industrial wastewater. In many developing countries, wastewater treatment is less consistent, with some domestic wastewater being disposed of through pit latrines, septic systems, or open sewers.

In some areas, untreated industrial wastewater is discharged directly into water bodies. Many developing countries, including those in Latin America, the Middle East, and Africa, face challenges in treating wastewater. In countries like Venezuela and China, a significant proportion of sewage is released untreated into the environment. In South Africa, inadequate maintenance of sewage treatment systems has led to the pollution of water bodies, posing serious public health risks. In many parts of sub-Saharan Africa, wastewater treatment is virtually nonexistent. The rapid industrialization and population growth in countries like India have created a delicate balance between economic development and environmental sustainability. Urban expansion has made it increasingly difficult to plan and expand water and sewage infrastructure, which is costly and challenging. On a smaller scale, technologies such as aerobic activated sludge reactors have been used to treat odorous air in North America, though their performance can be inconsistent due to biological factors. Newer systems, such as membrane bioreactors (MBRs), offer solutions by replacing gravitational settling with physical filtration. These systems are also being explored for their potential to address odor removal, particularly in livestock operations, where ventilation systems could be enhanced to improve air quality.

2. A REVIEW OF MECHANISMS

The total amount of wastewater generated by the 299 class-1 cities in India is 16,652.5 million liters per day (MLD). Among these cities, 23 major metropolitan areas contribute approximately 59% of the total wastewater. The state of Maharashtra accounts for around 23%, while the Ganga River basin contributes about 31% of the total wastewater from these cities. However, only 72% of the wastewater generated is collected for treatment. Of the 299 class-1 cities, 160 have a sewerage system that covers more than 75% of their populations, and 92 cities have coverage for over 50%. Overall, 70% of the total population in these cities has access to sewerage facilities, a significant improvement from 48% in 1988. Sewerage systems are either open, closed, or piped. The primary focus of the study was to review the treatment of domestic sewage using aerobic sludge to ensure its effective discharge and potential for reuse or recycling. In terms of wastewater treatment, out of the 16,652.5 MLD of wastewater generated, only 4,037.2 MLD (24%) is treated before being released into the environment, while the remaining 12,626.3 MLD is disposed of untreated. Among the cities, 27 have only primary treatment facilities, and 49 cities have both primary and secondary treatment capabilities. The need for sewage treatment is critical as untreated wastewater can cause several environmental problems.

Wastewater treatment helps break down complex organic compounds into simpler, stable compounds, either through physical-chemical processes or by utilizing microorganisms in biological treatment. If untreated wastewater is allowed to enter groundwater, surface water bodies, or land, it can have severe environmental consequences, such as: The decomposition of organic materials in wastewater can release large amounts of foul-smelling gases. Discharging untreated sewage into rivers or streams can deplete the dissolved oxygen in the water, leading to the death of aquatic life and other harmful effects. Nutrients in wastewater can promote the growth of aquatic plants and algae, resulting in eutrophication of water bodies, including lakes and streams. Untreated wastewater often contains harmful pathogens and toxic substances that can contaminate land and water bodies, posing risks to public health. For these reasons, the treatment and proper disposal of wastewater are essential to protect the environment and public health.

Treated wastewater can be reused for various purposes, including industrial, municipal, and domestic applications. Municipal uses include irrigation of parks, roadside plants, playgrounds, golf courses, and flushing toilets. In industrial settings, treated wastewater is often used for cooling systems, irrigation, aquaculture, and in food processing industries, among other high-water-use activities. In some Middle Eastern countries, where water is scarce, dual distribution systems are being developed to provide high-quality treated effluent for toilet flushing in hotels, office buildings, and other establishments. In India, treated wastewater is already being used for purposes such as irrigation, gardening, toilet flushing, cooling air conditioning systems, and as processed water in industries. Similarly, in China, national policies have been implemented to encourage the reuse of reclaimed municipal wastewater first for agricultural purposes and later for industrial and municipal uses. In Japan, reclaimed wastewater is utilized for applications like toilet flushing, industrial use, stream restoration, and enhancing urban green spaces, thereby creating "urban amenities."

3. TECHNOLOGICAL OVERVIEW

A successful and sustainable wastewater management system starts at the household level and heavily relies on the "software" or human aspect. Only when the need for and the potential benefits of wastewater reuse are understood and embraced by communities will effective planning and implementation follow. Local support for treatment and recovery schemes can stimulate proactive institutions and gain governmental backing. Once the human component is integrated into the project, the "hardware" or technological aspect can help create a comprehensive and sustainable wastewater treatment strategy, provided it is appropriate and well-chosen. An effective wastewater treatment technology must meet certain criteria to be sustainable for a community. These include being cost-effective, suitable for local conditions, low-energy, and simple to operate. The system should be labor-intensive, use local resources, and be maintained by the community. Additionally, the technology should avoid relying on expensive chemicals for pathogen reduction and should be capable of resource recovery. Another important feature is the ability to scale up or improve the technology incrementally as demand increases or quality standards change. Public acceptance is crucial for the success of wastewater reuse projects. If the community does not perceive the system as necessary, future reuse projects may face significant challenges. Therefore, it is essential to assess the community's capacity for managing and maintaining treatment technologies before selecting an appropriate system.

Skilled operation and maintenance are key for achieving satisfactory performance, and technologies should require minimal upkeep and control. The primary goal is for the system to reduce pathogens effectively enough to allow the treated effluent to be reused for purposes such as irrigation or soil enrichment. Several traditional treatment technologies have been used to address wastewater contaminated with organic substances. Activated carbon is widely regarded as one of the most effective materials for controlling organic load but is costly and inefficient due to loss during regeneration. As a result, alternative adsorbents like fly ash, peat, and sawdust have been explored with varying degrees of success. Ionic liquids also show promise as alternatives to toxic solvents. The adsorption process for removing organic materials has been the subject of numerous studies. For example, fly ash has been used as an adsorbent to treat wastewater and remove toxic substances and color. Methods for removing copper from wastewater using fly ash have also been proposed.

Additionally, active filtration using alkaline media for phosphorus removal from domestic wastewater has been suggested. Ozone is another powerful oxidizing agent used in wastewater treatment, effective at breaking down a wide range of pollutants such as phenols, pesticides, and hydrocarbons. However, its major limitation is its short half-life, requiring continuous ozonation, which makes it an expensive option for large-scale treatment. Anaerobic wastewater treatment, which operates without the use of oxygen, is another approach used primarily for removing organic pollutants from wastewater, slurries, and sludge. While it cannot yet fully replace aerobic treatment due to the lower quality of its effluent, anaerobic processes are often used as a pre-treatment method, particularly in countries like Colombia, Brazil, and India, where they can replace more costly aerobic systems. Different types of anaerobic digesters exist, some of which have been effective over time, while others are still under development. One such system, the Upflow Anaerobic Sludge Blanket (UASB), is particularly suited for tropical conditions. A combination of UASB for pre-treatment and an aerobic Down Flow Hanging Sponge (DHS) reactor for post-treatment has been proposed as a cost-effective and sustainable solution for developing countries, offering simplicity and operational ease. This anaerobic-aerobic system provides a simplified and affordable treatment process that meets the needs of developing regions.

4. IN CONCLUSION

effective wastewater management is essential for promoting environmental sustainability and public health, particularly in rapidly growing urban areas. This study highlights the importance of both human and technological components in developing a functional and sustainable wastewater treatment system. A community-based approach that involves local participation and support is crucial for the success of wastewater treatment and reuse projects. Furthermore, selecting appropriate and cost-effective technologies is key to ensuring the long-term viability of these systems, especially in resource-limited settings. The study underscores the need for wastewater treatment technologies that are simple, low-cost, and adaptable to local conditions. Whether through traditional methods like activated carbon and anaerobic treatment or innovative solutions like ozone and ionic liquids, the goal remains the same: to effectively remove harmful pollutants and reduce the environmental impact of untreated wastewater. Additionally, promoting the reuse of treated wastewater for purposes such as irrigation and industrial cooling can help alleviate water scarcity and reduce pressure on freshwater resources. As global urbanization continues to rise, the challenge of managing wastewater will only intensify. Thus, it is crucial to foster public acceptance of wastewater reuse and implement technologies that are not only efficient but also socially, economically, and environmentally sustainable. By focusing on appropriate, community-driven solutions, developing countries can achieve sustainable wastewater management that contributes to both environmental protection and public health improvement. Ultimately, the integration of human and technological elements, alongside robust planning and local support, is key to addressing the growing demand for effective wastewater management systems worldwide.

CONFLICT OF INTERESTS

None.

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