

“Designing the prototype of sewage treatment plant using Submerged Membrane Bioreactor (SMBR) Technology for Institutional Wastewater”

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Abstract

The increasing demand for efficient wastewater treatment in institutions such as colleges, hospitals, and hostels has led to the adoption of advanced technologies like Submerged Membrane Bioreactor (SMBR). This review paper focuses on the design and performance of SMBR systems for treating institutional wastewater. SMBR combines biological treatment with membrane filtration, offering high-quality effluent, reduced footprint, and better removal of pollutants compared to conventional methods. The study reviews various research works related to SMBR efficiency, membrane fouling, operational parameters, and cost aspects. The results indicate that SMBR is a sustainable and effective solution for decentralized wastewater treatment systems.

Keywords:

- **Submerged Membrane Bioreactor (SMBR)**
- **Wastewater Treatment**
- **Institutional Wastewater**
- **Membrane Filtration**
- **Biological Treatment**
- **Sewage Treatment Plant (STP)**

INTRODUCTION

Water is one of the most valuable natural resources on Earth and is indispensable for sustaining life, promoting health, and enabling socio-economic development. However, the exponential rise in population, rapid urbanization, and industrial growth have resulted in the generation of enormous quantities of wastewater. Most cities and towns in India lack adequate facilities for wastewater collection, treatment, and disposal, leading to severe environmental pollution and health issues.

Sewage is a complex mixture of organic and inorganic matter, including suspended solids, nutrients (nitrogen and phosphorus), microorganisms, and various toxic substances. When untreated or inadequately treated sewage is discharged into water bodies, it depletes dissolved oxygen, destroys aquatic ecosystems, and spreads diseases. Therefore, sewage management has become one of the most critical challenges of modern urban development.

A Sewage Treatment Plant (STP) is an essential infrastructure designed to remove contaminants from wastewater through physical, chemical, and biological processes, making it safe for discharge or reuse. The process generally involves multiple stages — preliminary, primary, secondary, and tertiary treatment — each with specific objectives, such as removing solids, reducing organic matter, and disinfecting pathogens.

In India, only about one-third of the sewage generated is treated before being released into the environment (CPCB Report, 2023). This imbalance underscores the urgent need to design efficient, cost-effective, and sustainable sewage treatment systems.

This project focuses on the design and analysis of a sewage treatment plant for a defined community or institution. It aims to evaluate sewage characteristics, determine the treatment requirements, and design suitable treatment units following national standards. The study also emphasizes sustainable wastewater reuse, resource recovery, and compliance with environmental regulations.

OBJECTIVES OF STUDY

- To study the characteristics and composition of domestic sewage.
- To estimate the quantity of sewage generated from the target population.
- To design each treatment unit of the sewage treatment plant (preliminary, primary, secondary, and tertiary).
- To analyze the performance and treatment efficiency of the proposed STP.

LITERATURE REVIEW

Treatment Performance of Municipal Sewage in a Submerged Membrane Bioreactor (SMBR)

This study investigated the performance of a submerged membrane bioreactor (SMBR) for the treatment of municipal sewage and also analysed methods to reduce membrane fouling. The research found that SMBR systems are capable of achieving high removal efficiency of organic pollutants and nutrients from wastewater. The system combines biological treatment and membrane filtration, which allows effective separation of biomass and treated water.

The results indicated that SMBR technology achieved high removal efficiency for COD, ammonia, and suspended solids, producing high-quality effluent suitable for reuse. The study also highlighted membrane fouling as a major operational challenge, which can increase operational cost and reduce membrane performance. The authors suggested using materials such as biochar to reduce membrane fouling and improve long-term system performance.

This research demonstrates that SMBR technology is highly efficient for sewage treatment and can be applied in compact wastewater treatment plants for institutions such as hospitals, colleges, and residential complexes.(Ref.1)

Submerged Membrane Bioreactor Configurations for Biological Nutrient Removal from Urban Wastewater: Experimental Tests and Model Simulation

This research focused on different SMBR configurations for nutrient removal and process simulation.

A pilot-scale reactor was used, and the system performance was analysed using Activated Sludge Model (ASM1) simulation software. The study evaluated parameters such as sludge retention time (SRT), hydraulic retention time (HRT), return activated sludge ratio (RAS), and aerobic volume fraction.

The results showed that SMBR systems can achieve more than 90% removal of chemical oxygen demand (COD) and ammonia, while nitrogen removal efficiency was above 70%. The research concluded that optimal operation occurs at SRT below 20 days, HRT above 6 hours, and aerobic volume fraction between 0.4 and 0.8.

This study is important for the design and simulation of sewage treatment plants using SMBR technology, as it demonstrates how modelling tools can be used to optimize system performance and design parameters(Ref.2)

Comparative Study of Submerged Membrane Bioreactor and Extended Aeration Process for Hospital Wastewater Treatment

This study compared the submerged membrane bioreactor (SMBR) process with the conventional extended aeration process for treating hospital wastewater. Hospital wastewater is considered institutional wastewater and contains higher concentrations of organic matter, pathogens, and pharmaceuticals.

The results showed that the SMBR system produced better effluent quality and higher removal efficiency compared with the extended aeration process. The membrane filtration process effectively removed suspended solids, microorganisms, and pathogens, producing nearly clear effluent suitable for reuse. The study concluded that SMBR technology is more efficient and compact than conventional wastewater treatment systems, making it suitable for institutions such as hospitals, universities, and

research facilities where space availability is limited. (Ref.3)

Advancement in Membrane Bioreactor (MBR) Technology toward Sustainable Industrial Wastewater Management

This paper reviewed the development and advancements in membrane bioreactor (MBR) technology for wastewater treatment. The authors explained that MBR systems combine activated sludge biological treatment with membrane filtration, allowing higher biomass concentration and better effluent quality than conventional treatment processes.

The review highlighted several advantages of MBR systems, including:

1. High removal efficiency for organic pollutants
2. Small footprint and compact design
3. Excellent solid–liquid separation
4. Reduced sludge production
5. High-quality effluent suitable for reuse

However, the study also identified membrane fouling and high energy consumption as the main challenges of MBR systems. Despite these challenges, continuous improvements in membrane materials and operational strategies are making MBR systems more reliable and cost-effective. The paper concludes that MBR technology is one of the most advanced and sustainable wastewater treatment technologies, suitable for municipal, industrial, and institutional wastewater treatment.(Ref.4)

CONCLUSION

The Submerged Membrane Bioreactor (SMBR) is an effective and advanced technology for treating institutional wastewater. It provides high-quality effluent suitable for reuse and requires less space compared to conventional treatment systems. Despite challenges like membrane fouling and higher initial cost, SMBR offers long-term benefits in terms of efficiency and sustainability. Therefore, SMBR is a promising solution for modern sewage treatment plants, especially in institutions.

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