International Journal of Environmental Sciences
ISSN: 2229-7359
Vol. 11 No. 8, 2025
https://theaspd.com/index.php

Performance Evaluation Of Sewage Treatment Plants (Stps) In Northern India

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Abstract
The present study focuses on the evaluation of the performance of seventeen full-scale sewage treatment plants (STPs) with capacities varying from 3 MLD to 182 MLD, employing diverse technologies. The methods assessed were the conventional activated sludge process (ASP), biofilm process (MBBR), biological nutrient removal processes (MBR, A/O, and SBR), chemical process (DENSADEG), natural process (WSP), and anaerobic process (UASB). The total clearance rates of STPs were 69–98% for BOD, 73–97% for COD, 70–98% for TSS, 55–96% for NH4-N, 54–90% for TN, and 36–92% for TP. The MBR-based STP was the best at getting rid of all kinds of waste: BOD (97%), COD (97%), TSS (98%), NH4-N (95%), TN (90%), and TP (85%). The UASB with FPU-based STPs was similarly good at getting rid of BOD, COD, and TSS, with efficiencies of 70%, 73%, and 80%, respectively. Each form of STP used roughly 0.17 m2 of land per person equivalent (p.e.), except for the WSP, which needed the highest space for all types of plants. The MBR-based STP had the highest operating and maintenance (O&M) cost, which was INR 214 per person per year. This is remarkably comparable to the STP that used densadeg and biofor, which cost INR 83 per person per year to run and maintain. The MBR used the most electricity to run the STP, but the WSP didn't need any. The range was from 0 to 26.41 kWh per person per year. The average cost of putting in a STP was INR 1428 per person, while the most expensive cost of putting in an MBR was INR 7137 per person.
Keywords: *Techno-economic, India, Sewage treatment plant, Wastewater.*

1 INTRODUCTION

Currently, approximately 40% of the global population does not have access to sanitation facilities, with conditions in small and rural communities of developing countries being significantly worse than those in larger communities (Massoud et al., 2009; Chong et al., 2012; Ho, 2005). India's population represents 16 percent of the global total, yet the country possesses merely four percent of the world's water resources (CPCB, 2002). The annual population growth rate of 1.9 percent, coupled with swift economic development, is exerting significant pressure on the already limited water resources. A study conducted by the CPCB in 2013 revealed that merely 11,787.38 million litres of wastewater are treated daily, leading to a treatment rate of just 31 percent. The investigation additionally uncovered that among the 152 centralized sewage treatment facilities examined in Class I cities and Class II towns, 49 did not meet the established discharge standards. These results indicate the necessity for a comprehensive study regarding the selection of treatment plants. The rapid growth in the urbanisation process is likely to result in the potential for both centralised and decentralised wastewater treatment plants in the near future. In the past ten years, numerous centralized wastewater treatment facilities utilizing various technologies have been established throughout India. Nonetheless, some are not operating effectively, and several have also encountered failures for a range of reasons. Consequently, the understanding of the performance of these existing technologies is quite restricted, and a thorough evaluation of those plants is essential to draw

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reliable conclusions and recommendations for future wastewater management strategies in India. The assessment of WWTPs' efficiency is gaining significance as it highlights the facilities that optimize their financial resources while maintaining the quality of the water they process. To conduct a thorough economic analysis of wastewater treatment options, it is essential to gather data from previously constructed projects. Moreover, the implementation of new technologies must be approached with caution, considering the existing experiences in India. The objective of this study was to assess and track the qualitative and technical aspects of various technology-based STPs implemented in Northern India. Seventeen full-scale wastewater treatment plants located in the northern region of India were chosen for evaluation in this study.

2 METHODOLOGY

2.1 Study area and data collection

A total of 17 STPs, reflecting various climates and topographies, were chosen for this study, installed by municipal, institutional, and residential organizations. Table 1 presents specific details regarding the STPs, including plant ID, plant name, type of technology employed, capacity, design population served, and hydraulic retention time (HRT). Field visits took place to qualitatively assess STPs, focusing on treatment performance, planning, costs, conditions, operations, and the maintenance of functional practices at the plants. During this study, every STP was visited, and a checklist was filled out based on observations, discussions with the officials managing the STP, and feedback from the community being served.

Table 1 Characteristics of the WWTPs evaluated

Plant ID	**Plant Name**	**Type of Technology[a]**	**Capacity (MLD)**	**Design PE served[b]**	**HRT[c] (Hours)**
P1	Swargashram	SBR	3	22222	15.4
P2	Sanjahuli-Malyana, Shimla	EA + Clariflocculator	4.44	32889	11.0
P3	Akshardham, Delhi	MBR	4.54	33630	44.6
P4	Lakkarghat, Rishikesh	WSP	6	44444	185.3
P5	Sen Nursing Home, Delhi	Densadeg+ Biofor	10	74074	0.9
P6	Jagjeetpur, Haridwar	PST + SBR	27	200000	11.9
P7	Salori, Allahabad	MBBR (FAB)	29	214815	1.2
P8	Saharanpur	UASB+FPU	38	281481	12.8
P9	Numaya Dhai, Allahabad	Biotower + ASP	50	370370	4.0
P10	Kalibari, Chandigarh	SBR	50	370370	24.3
P11	Indirapuram, Ghaziabad	SBR	74	548148	31.7

P12	Dhandupura, Agra	UASB +FPU	78	577778	10.9
P13	Dinapur, Varanasi	PST + TF + ASP	80	592593	4.1
P14	Bamroli, Surat	UASB+EA+ UF +RO	100	740741	15.7
P15	Jajmau, Kanpur	ASP	130	962963	5.5
P16	Okhla, Delhi	A-O	136.4	1010370	6.8
P17	Rithala, Delhi	ASP (Hi Rate)+ Biofor	181.8	1346667	3.0

[a]Preliminary treatment by screenings

[b]PE: Population equivalent.

[c]HRT: Hydraulic retention time.

2.2 Sampling and analysis

The overall treatment efficiency of all the plants was assessed through the analysis of influent and effluent samples from each facility. Samples from each STP were analyzed for key water quality parameters including chemical oxygen demand (COD), biological oxygen demand (BOD5), total suspended solids (TSS), ammonia nitrogen (NH3-N), total Kjeldahl nitrogen (TKN), total nitrogen (TN), and total phosphorus (TP) in accordance with Standard Methods (APHA, 2005).

2.3 Economic data such as land usages, O&M cost and energy consumption

The establishment of sewage treatment plants in India faced significant obstacles, particularly regarding land data. Measurements and calculations were conducted along the perimeter, leading to the generation of the total area utilized for the STPs. The annual capital investment and O&M costs are two critical factors that must be considered in the economic evaluation of treatment plants. The gathered data underwent thorough analysis and evaluation to identify correlations between various capacities, while the recurring costs were examined in detail to establish concrete facts and figures.

Data on energy consumption were gathered and assessed using information from field records, working loads, equipment inventories, monthly electricity bills, and discussions with operators to analyze and develop estimations for determining the working load and operational hours of the plants.

3 RESULTS AND DISCUSSION

3.1 Treatment performance of existing STPs

The removal efficiencies of STPs were determined to be 69-98% for BOD, 73-97% for COD, 70-98% for TSS, 55-96% for NH4-N, 54-90% for TN, and 36-92% for TP. The treatment findings indicated that the MBR-based plant had the highest removal rates across all parameters, with 97% BOD removal, 97% COD removal, 98% TSS removal, 95% NH3-N removal, 90% TN removal, and 85% TP removal. In contrast, the UASB with FPU-based STPs demonstrated notable removal rates for BOD, COD, and TSS, with 70%, 73%, and 80% removal, respectively. The ASP-based plant at Varanasi P13 exhibits minimal removal rates for NH3-N and Total Nitrogen, approximately 55%, due to unsatisfactory operational conditions characterized by a very low system MLSS of less than 1000 mg/l. Figure 1 illustrates the total removal efficiency of BOD, COD, TSS, NH3-N, TN, and TP for each of the STPs.

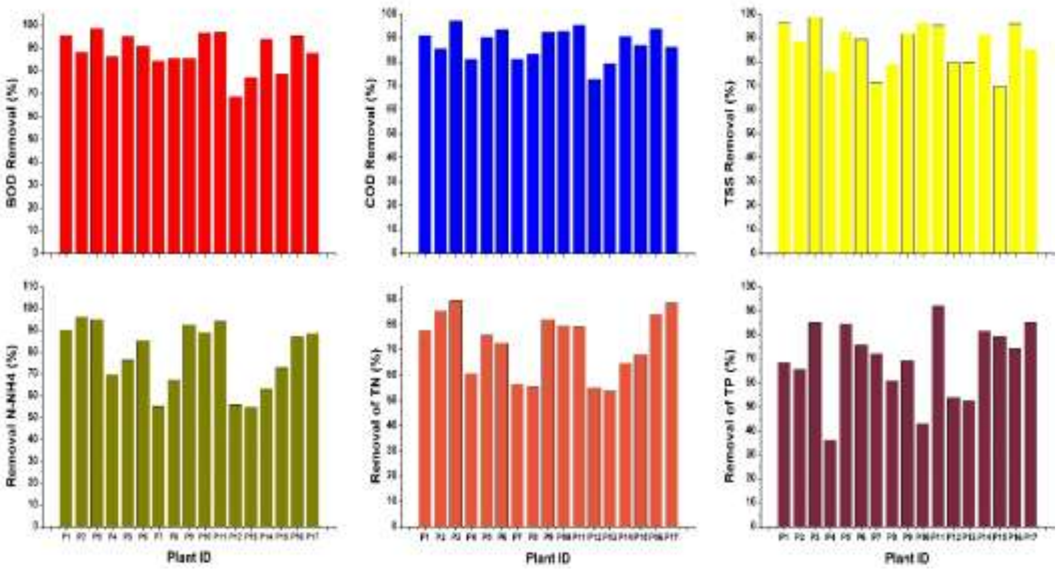

Fig. 1 Removal efficiency of various parameters of 17 STPs

3.2 Land Usages and sludge generation

Figure 2 illustrates the examined land utilization and the management of sludge from the assessed STPs. The data on land usage gathered from field visits to each STP. The average land usage for each type of STP was examined to be approximately 0.17 m² per person equivalent, with the exception of the WSP (P4), which necessitated the greatest land usage among all plant types. The assessment of the operational expenses of STPs indicated that it is significantly affected by the use of chemicals, personnel costs, and the consumption of electrical energy. The highest sludge disposal was noted in the case of ASP-based plants, whereas MBR exhibited the lowest sludge disposal.

3.3 Capital Investment

Information about capital investment was gathered from official records of plants as well as from discussions with plant workers. The cost of building all of the STPs, which was calculated by gathering information from the people who work at the plant. The capital cost was estimated in terms of Indian Rupees (INR) per inhabitant, and the average capital cost was calculated to be INR 1428 per inhabitant, while MBR required a maximum capital cost of approximately INR 7137 per inhabitant.

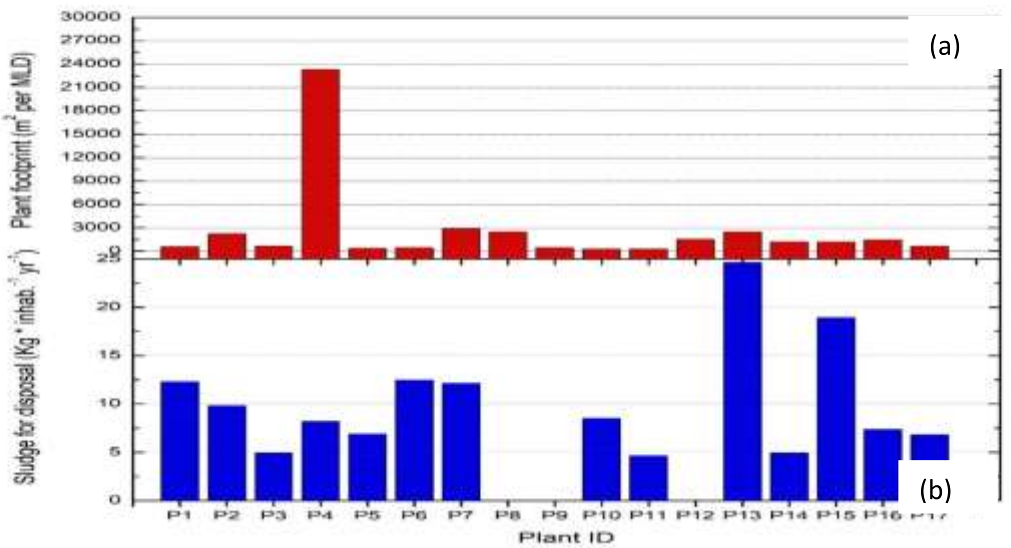

Figure 2 a) Plant Footprint and b) Sludge for disposal, with data collected from various STPs

3.4 Electricity use, Operational and maintenance (O & M) cost

For each plant, the cost of treatment was estimated, which also demonstrates the inference of O&M practice. The energy requirements of a combination of several methods for wastewater treatment are shown in Figure 3. According to research, the amount of electricity that is consumed by each type of plant in order to run varies from 0 to 26.41 kilowatt hours per inhabitant each year. The average amount of electricity that was consumed by all types of STP was found to be between 0 and 2.28 kilowatt hours per kilogram of BOD Removal. With a value of InR 214 per inhabitant per year, Plant P3 (MBR) took first place in the category of O&M cost. Plant P5 (Densadeg+ Biofor) was a close second. It was discovered that the average annual O&M expense was INR 83 per inhabitant.

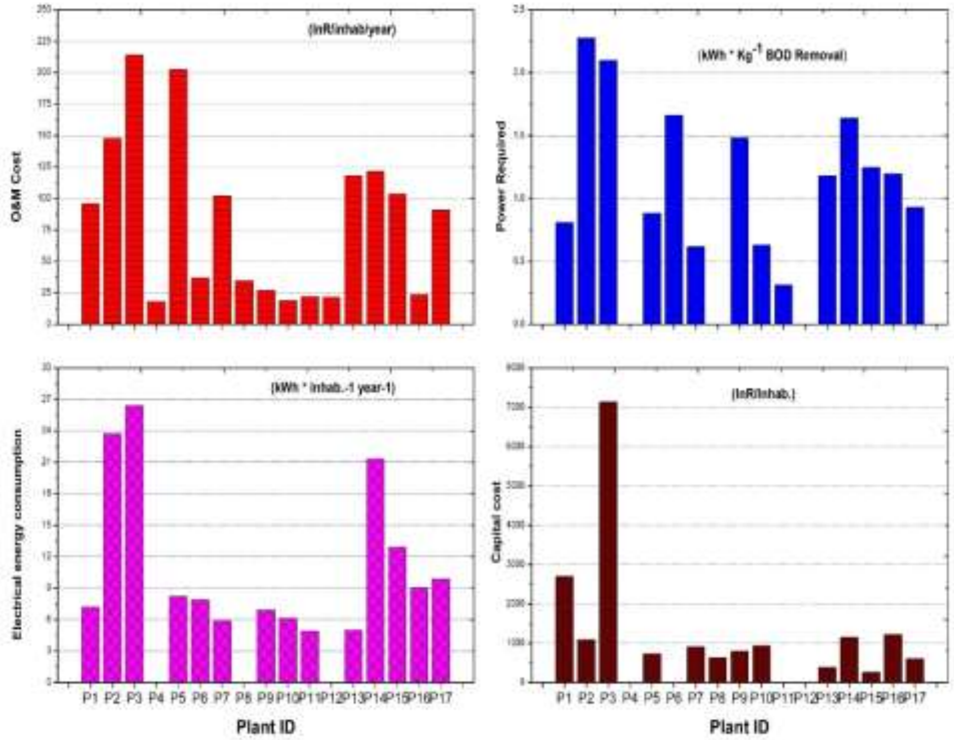

Fig. 3 Capital cost, O&M Cost, Electricity Consumption & Power required per kg BOD removal

4 Conclusions

Membrane Bioreactor (MBR)-based STPs consistently demonstrated superior pollutant removal efficiencies, achieving over 95% removal rates for BOD, COD, and TSS, and significantly higher rates for nutrient removal (NH_3–N, TN, TP) compared to alternative technologies. Conventional technologies like ASP and UASB + FPU showed moderate to low efficiencies, especially when they weren't working well (for example, when there wasn't enough MLSS in ASP plants). The average amount of land used was about 0.17 m² per person, with Waste Stabilization Ponds (WSPs) needing the most land. ASP plants made the most sludge, while MBR plants made the least. This shows that more advanced systems are better for business, even though they cost more. The average capital cost was INR 1428 per person, and MBR plants needed the most money (INR 7137 per person). The average O&M cost was INR 83 per person per year. The MBR (P3) and Densadeg + Biofor (P5) plants, on the other hand, had much higher costs, up to INR 214 per person per year. Electricity required between 0 and 26.41 kWh per capita per year, with an average of 0 to 2.28 kWh per kg of BOD removed. Advanced treatment systems used more energy, while traditional systems used less energy but were less effective at treating. MBR systems produce better effluent and less sludge, but they cost more to set up and run. ASP and UASB are still cost-effective conventional systems, but they need better operational control to reliably remove nutrients. So, choosing a technology should consider the performance of the treatment, the availability of land, the demand for energy, and the cost of the technology, based on local needs and resource limits.

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