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Efficiency evaluation of sewage treatment plants of Bikaner city (Rajasthan), India

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Abstract
The present case study is the evaluation of the efficiency of sewage treatment plants (STP) of Bikaner city (Rajasthan), India. Bikaner city have two sewage treatment plants which cumulatively treat 52 million litre per day (12 MLD and 40 MLD) wastewater. Both STPs work on sequencing batch reactor technology. The performance of 40 MLD is conducted for 6 months duration (July to December 2022). The inlet and outlet wastewater samples are collected. Samples are analysed for pH, total suspended solids (TSS), Biological oxygen demand (BOD), phosphate and sulphate. The overall removal efficiency of STPs is in the order of TSS > BOD > Sulphate > Phosphate > pH. The results reveal that both STPs are considered efficacious. It is recommended that frequent monitoring and assessment should be done for proper functioning of STP.

Keywords: *Sewage Treatment Plant, Total Suspended Solids, Biological Oxygen Demand, Phosphate, Removal efficiency.*

Introduction

India being a developing and overpopulated country with availability of fewer water resources demands the need to treat wastewater and reuse it. Waste water contains a variety of contaminants. Various constituents of wastewater are potentially harmful to the environment and human health. Thus, treatment of wastewater is a critical issue. Sewage treatment plants (STP) are being used to remove contaminants from the domestic, commercial, and industrial wastewater. It involves physical, chemical, and biological procedures to remove contaminants and gives out an environmentally safe and treated effluent. The pollutants in the domestic wastewater arise from residential and commercial cleaning operations, laundry, food preparation, body cleaning functions, and from body excretions. The composition of domestic wastewater is relatively almost constant. Safe potable water supply and hygienic sanitation facilities are the basic essential requirements for a healthy community and it must be given a top priority. A good quality of life requires hygienic sanitation facilities by means of appropriate treatment options. It also becomes important because about 80% of water used by the community comes out from residential areas and mostly from kitchen, bathroom, and laundry sources. The safe disposal of wastewater is even much more vital to prevent any injury or health hazards. Sewage treatment plants (STPs) are being used for waste water treatment. STPs need to be well maintained and well operated for its efficient functioning. Performance of STPs have been investigated worldwide (Dantas et al., 2021; Bolong et al., 2022). In India, studies have been conducted in Delhi (Gautam et al., 2013; Jwala et al., 2020), Haryana (Saini & Singh, 2021), Navi Mumbai (Jothiprakash et al., 2020) and Uttar Pradesh (Ruhela et al., 2023). The continuous monitoring of STP is essential for its performance study. Thus, it is essential to evaluate influent and effluent concentrations of STPs. Currently, Bikaner city neither have appropriate capacity of domestic sewage treatment facility nor have sufficient sewerage networks to transport it from households to the STP plant. As a result, only some fraction of the sewage collected from these households is treated efficiently under current circumstances. Even, there is no systematic plan for reusing treated wastewater. The treated wastewater and sludge could be used effectively for crop irrigation or for public parks, sports

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fields, etc. provided certain quality constraints are met. The reuse of treated effluents has much wider application especially in arid or semi-arid regions. Considering the increasing population, which consequently rises the amount of domestic sewage generation, there is a great need to speed up the process of connecting all households to STP plants. Further, continuous monitoring of STPs is needed for its proper functioning. The objective of the study is to investigate the efficiency of two sewage treatment plants (12 MLD and 40 MLD) of Bikaner city.

Materials and Methods

Study Area

Bikaner city lies in the northwest region of Rajasthan state. The city is the administrative headquarters of Bikaner district. The city is located at 28°1' N and 73°19' E. It is situated in the middle of the Thar desert and has a hot desert climate. The maximum temperature rises to around 48°C in summer and minimum dips to 4°C in winters. It receives very nominal rainfall throughout the year. The scarcity of water affects the vegetation of the area. The soil type of the area is majorly alkaline. The population of city as per the Census 2011 is 644,406. The area of Municipal Corporation is about 155 sq.km. The density of city is 4157 persons per sq.km which is very high as compared to state average of 201 persons per sq.km. Slum population represents 18.9% of the total population. According to Census 2011, 64% of city is dependent on offsite systems. Population connected to sewer line is 41% and user interface directly discharging in open drain is 23%. 10% of wastewater is lost in transmission via sewer lines and 13% is lost in transportation via open drains. Around 41% waste water is treated at STP which also includes 10% of waste water tapped from open drains. Rest 31% of the city is dependent on onsite sanitation systems, out of which 23% is dependent on septic tanks and 8% on pits. Bikaner city has two waste water treatment plants. These are 12 MLD treatment plant and 40 MLD treatment plant as illustrated in Figure 1.

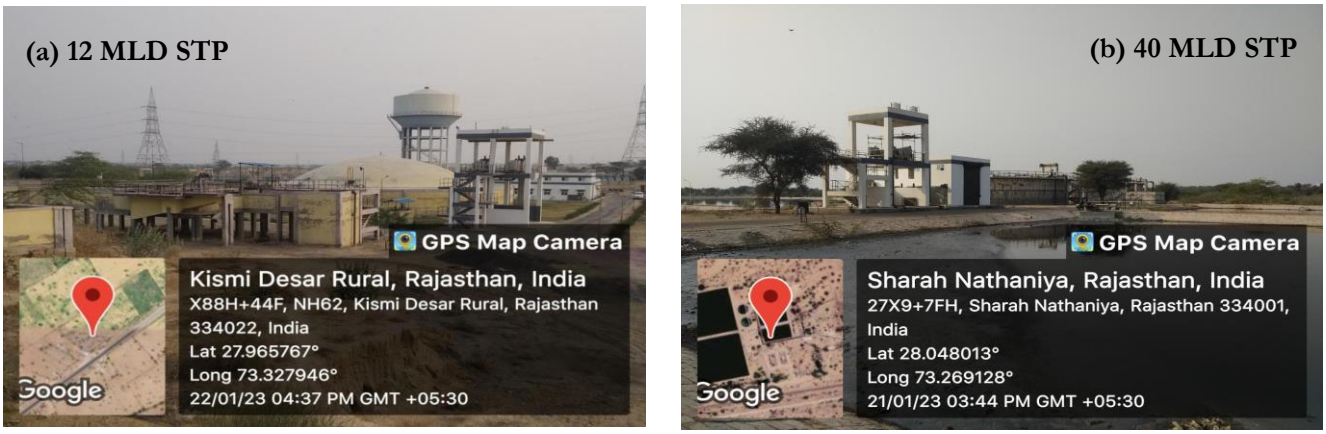

Figure 1. *Locations of (a) 12 MLD and (b) 40 MLD sewage treatment plants in Bikaner.*

These STPs are based on Sequencing Batch Reactor (SBR) technology. In this process, different water stabilization tanks are used for storage and batching process. Here the waste water or sewage enters in treatment plant is called as influent or inlet water while after treatment processing, solid waste is segregated and disposed. Then, the remaining liquid undergoes to secondary and tertiary level for chemical and biological

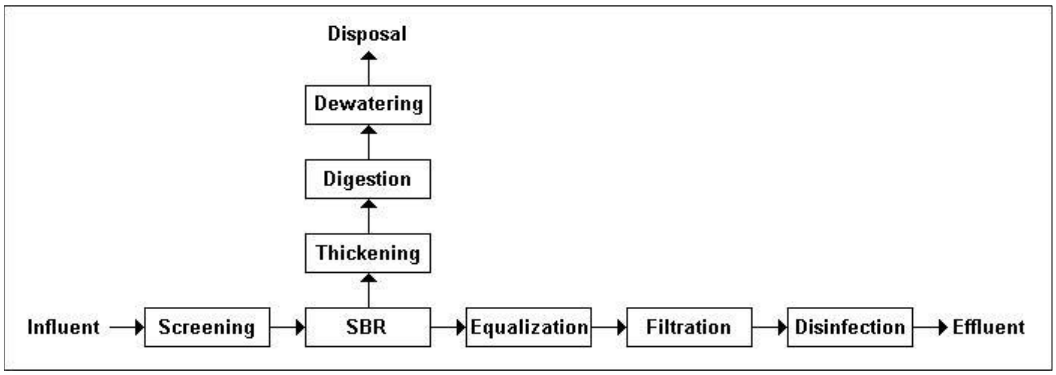

Figure 2.
Flow chart of sewage treatment plant with sequencing batch reactor process.

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treatments. After equalization, filtration and disinfection processes, the treated water comes out as Effluent (outward water). Sequencing batch reactor process in STPs is depicted in Figure 2.

Sample analysis

The chemical analysis of both inward water and outward water of both plants is done. The parameters selected for analysis are pH, Total Suspended Solids (TSS), Biological Oxygen Demand (BOD), phosphate and sulphate. These parameters are assessed by following the standard methods of APHA (APHA, 2012). The data were analysed in MS Excel version 2019.

Results and discussion

Analysis of basic water parameters i.e., pH, TSS, BOD, phosphate and sulphate is done for inlet and outlet water. The study was carried out from July 2022 to December 2022 (184 days) for 40 MLD plant and for one month (December, 2022) for 12 MLD plant.

Removal efficiency of 40 MLD STP plant

A line graph represents pH of inlet and outlet water of 40 MLD plant in Figure 3. It was observed for inlet water that the maximum average value of pH records 6.88 for the month of August, while November and December stay on minimum average value of pH 6.80 equally.

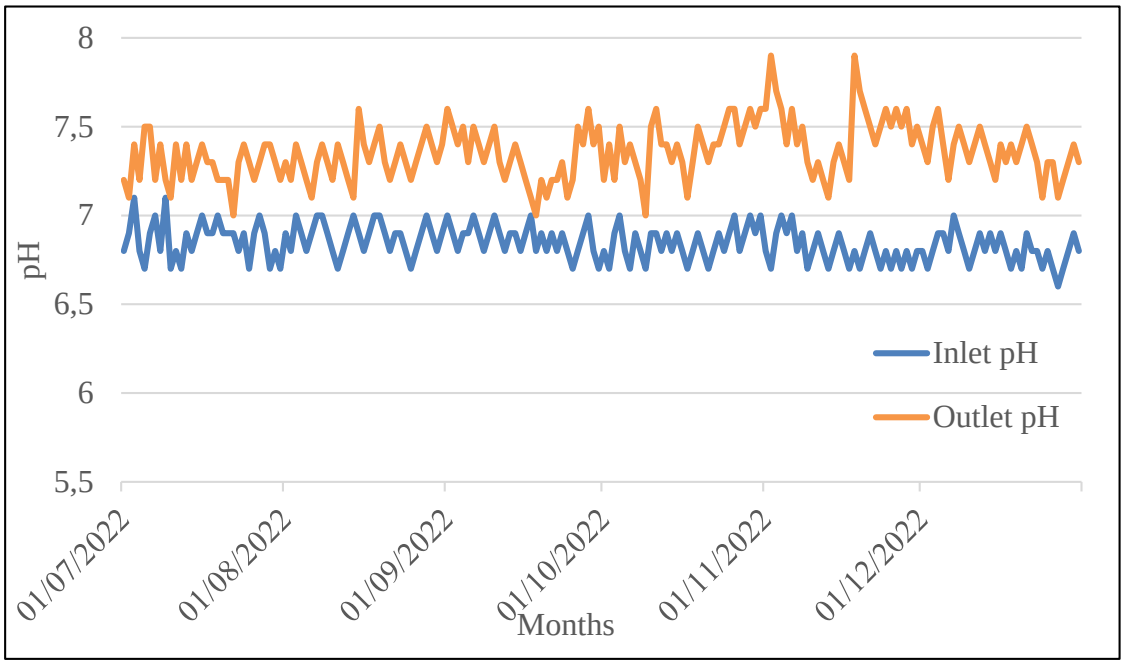

Figure 3

pH of inlet and outlet water of 40 MLD sewage treatment plant.

Here the decreasing order of months of average pH values is August > September > July > October > November = December. For outlet water maximum average value of pH is 7.48 for the month of November, while July stays on minimum average pH value 7.28. And the order of months of average pH is November > October > December > September > August > July. The monthly average comparison of TSS for inlet water (Figure 4) shows the maximum average value of TSS as 427.52 mg/l for the month of August, while September stays on minimum average value 339.73 mg/l. Here the order of months of average TSS values is December > November > August > July > October > September. For outlet water maximum average value of TSS is 8.30 mg/l for the month of November, while December stays on minimum average value 7.64 mg/l. Here the order of months of average TSS is November > September > July > October >August > December. The monthly average comparison of BOD (Figure 5) for inlet water has the maximum average value of BOD as 318.87 mg/l for the month of July, while October stays on minimum avera ge BOD is July > December > August > September > November > October. For outlet water maximum average value of BOD records 8.26 mg/l for the month of October, while July stays on minimum average value 7.58 mg/l. The order of months of average BOD is October > November > September > August > December > July. The monthly average comparison of phosphate for inlet water (Fig. 6) has the maximum average of Phosphate

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13.49 mg/l) for the month of September, while December stays on minimum average value 11.12 mg/l The order of months of average Phosphate is September > August > July > October > November > December. For outlet water maximum average value of phosphate records 1.61 mg/l for the month of August, while July as minimum average value 1.13 mg/l. The order of months of average phosphate is August > November > September > October > December > July. The monthly average comparison of sulphate for inlet water (Fig. 7) has the maximum average sulphate (4.24 mg/l) for the month of July, while November as the minimum average sulphate (2.59 mg/l). The order of months on basis of average Sulphate value in decreasing manner is July > August > September > October > December > November. For outlet water maximum average value of sulphate was recorded 1.61 mg/l for the month of August, while July stays on minimum average value 1.13 mg/l. Here the order of months on basis of average sulphate value in decreasing manner is August > October > July > November > December > September. The Analysis results of 40 MLD inlet waste water for six months duration reveal that the months of November and December receive more acidic water with monthly average 6.80. The highest TSS was in month of December with monthly average of 427.5 mg/l. The months from July to September receive higher phosphate and sulphate as compared to other months. The lowest BOD was observed in October and November. Though, the highest BOD were recorded in July and December months. Overall, the month of October receives less polluted water than rest months.

The outlet analysis of 40 MLD plant for the period of July to December 2022 illustrates that July and December month record lowest average values of BOD and Phosphate. The highest and the lowest average of TSS was in November and December months. The

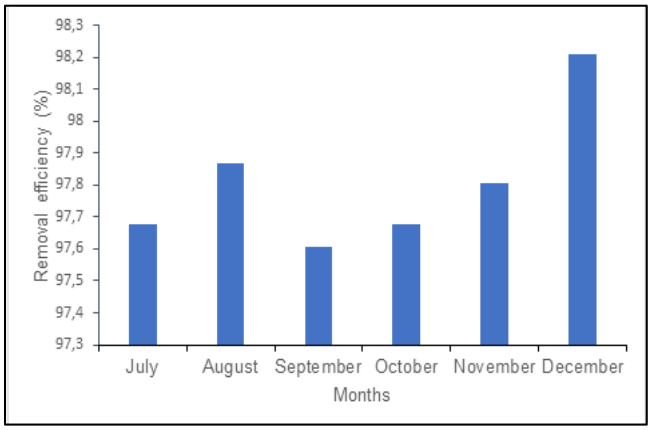

Figure 4. *Removal efficiency of 40 MLD sewage treatment plant for total suspended solids (TSS).*

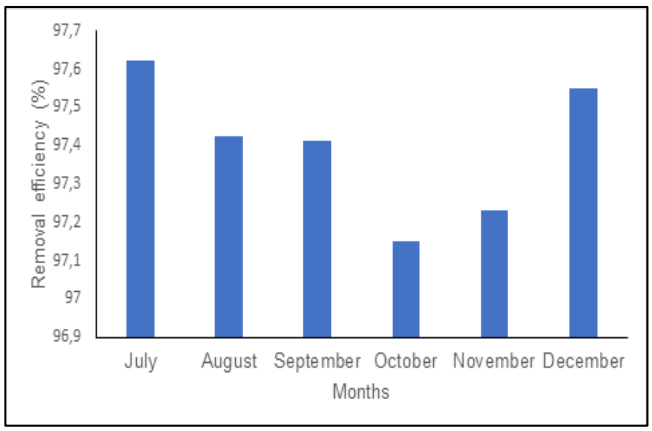

Figure 5. *Removal efficiency of 40 MLD sewage treatment plant for biological oxygen demand (BOD).*

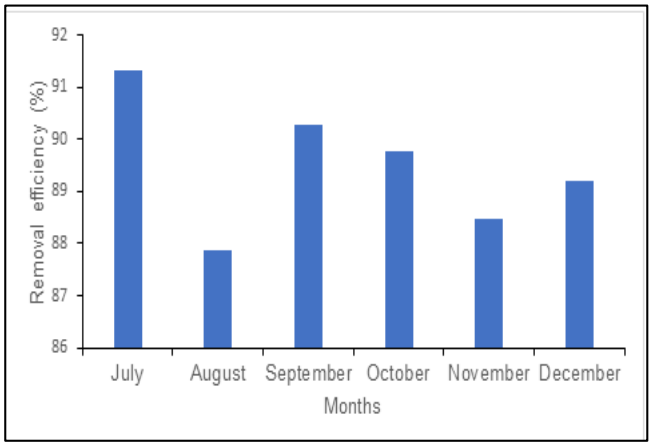

Figure 6. *Removal efficiency of 40 MLD sewage treatment plant for phosphate.*

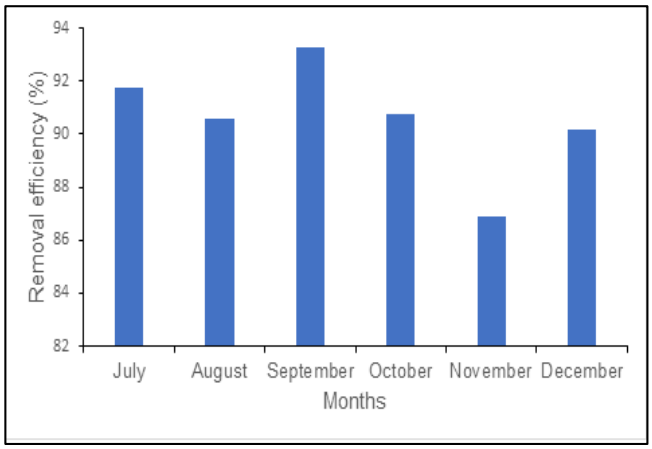

Figure 7. *Removal efficiency of 40 MLD sewage treatment plant for sulphate.*

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lowest average value of sulphate was in the month of September. The highest basic water releases in month of November with monthly average pH of 7.48. Overall, December month releases more treated water. Highest variation of pH was in month of July and December. In the months of July to September highest phosphate and sulphate recorded in waste water which may be due to the rain outflow. With the effect of rain and weather, increase in microbial growth is a significant cause of high BOD observed in the month of July.

Characteristics of 12 MLD sewage treatment plant

Wastewater characteristics of 12 MLD plant studied for one month (December 2022) are represented in Table 1. The maximum and minimum pH of inlet water record 6.9 and 6.6. However, for outlet water maximum and minimum pH record 7.6 and 7.0. Average pH value for inlet water is 6.75 and for outlet water is 7.34. The maximum and minimum TSS of inlet water record 573 mg/l and 368 mg/l. However, for outlet water maximum and minimum TSS record 12 mg/l and 9 mg/l. Average TSS value for inlet water is 489.4 mg/l and for outlet water is 9.91 mg/l. The maximum and minimum BOD of inlet water record 401 mg/l and 295 mg/l. However, for outlet water maximum and minimum TSS record 11 mg/l and 8 mg/l. Average BOD value for inlet water is 368.5 mg/l and for outlet water is 9.23 mg/l. The maximum and minimum phosphate of inlet water record 16.5 mg/l and 11.8 mg/l. However, for outlet water maximum and minimum phosphate record 1.60 mg/l and 0.7 mg/l. Average phosphate value for inlet water is 13.95 mg/l and for outlet water is 1.20 mg/l. The maximum and minimum sulphate of inlet water record 4.0 mg/l and 2.10 mg/l. However, for outlet water maximum and minimum sulphate record 0.60 mg/l and 0.10 mg/l. Average sulphate value for inlet water is 3.15 mg/l and for outlet water is 0.28 mg/l.

Parameters		12 MLD		40 MLD	
		Inlet water	Outlet water	Inlet water	Outlet water
pH	Maximum	6.9	7.6	7.0	7.6
	Minimum	6.6	7.0	6.6	7.0
	Average	6.75	7.34	6.8	7.35
TSS (mg/l)	Maximum	573	12.00	492	9.00
	Minimum	368	9.00	364	6.00
	Average	489.4	9.91	427.5	7.65
BOD (mg/l)	Maximum	401	11.00	340	9.00
	Minimum	295	8.00	270	6.00
	Average	368.5	9.23	315.8	7.74
Phosphate (mg/l)	Maximum	16.50	1.60	12.50	1.40
	Minimum	11.80	0.70	10.00	0.70
	Average	13.95	1.20	11.11	1.08
Sulphate (mg/l)	Maximum	4.00	0.60	4.90	0.50
	Minimum	2.10	0.10	2.10	0.20
	Average	3.15	0.28	3.72	0.31

Table 1
Inlet and outlet water characteristics of 12 MLD and 40 MLD sewage treatment plants.

Comparison of Sewage treatment plants

The standards for effluent discharged from wastewater treatment plant set by CPCB (2015) states that pH should be in the range of 6.5 to 9.0, though BOD and TSS should not be more than 10 mg/l and 20 mg/l respectively. The BOD values crossed the standard limit only once which is 12 mg/l observed on 27 October 2022. Comparison of 12 MLD and 40 MLD plants is done for one month (December, 2022). Comparative removal efficiency of 40 MLD and 12 MLD plants is depicted in Figure 8. After data analysis, it is found that the 12 MLD plant receives water with higher contents of BOD, TSS and phosphate and the 40 MLD plant receives water with higher pH and higher sulphate content. Concentrations of TSS and BOD have higher values in 12 MLD plant while concentration of phosphate and sulphate have higher values in 40 MLD plant release.

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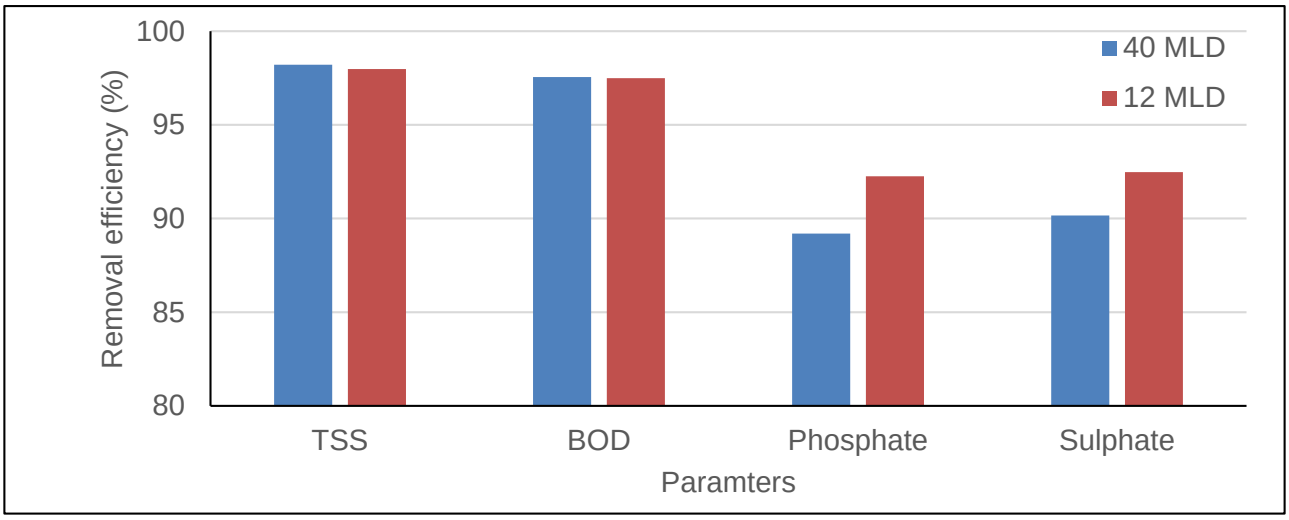

Figure 8. *Removal efficiencies of 40 MLD and 12 MLD sewage treatment plants.*

pH of released water is almost same in both plants. Overall, the 12 MLD plant is working with a little bit more efficiency as compared to 40 MLD plant. The study shows that the 12 MLD treatment plant receives more polluted water as compared to 40 MLD plant. This variation may be due to invasion of some industrial and chemical waste in domestic municipal waste water which is used as inlet waste water in 12 MLD treatment plant.

Conclusions

The purpose of this study was to identify the parametric values of wastewater of Bikaner city. Overall efficiency of both STPs were in the order of Sulphate < Phosphate < BOD < TSS. The results reveal that 100% effectiveness of both STPs as no variance was observed based on performance one being more efficacious than another. The study may provide a useful tool for evaluation of municipal wastewater of Bikaner city and both treatment plants for now and future too.

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