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Performance Evaluation of Municipal Wastewater Treatment Plant Based on Conventional Activated Sludge Process in Srinagar City

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ABSTRACT

The physical, chemical and bacteriological properties of wastewater were assessed in Brari Nambal STP by using standard methods. The results show significant ($P<0.05$) reduction in some of the physico-chemical features and in microbial load at outlet. Order of reduction was significantly ($P<0.05$) highest for chemical oxygen demand (COD) (and faecal coliform (FC) with reference to physico-chemical features and microbial characteristics, respectively. Overall, the wastewater treatment plant effectively removed total coliform, faecal coliform and faecal Streptococci in the order of 55%, 43% and 35%, respectively. The results further showed positive correlation between some of the physico-chemical features and microbial load at inlet. It was concluded from the study that all the physico-chemical features and microbial load exceeded the permissible limit in the effluent as per Indian National Standards. Therefore, as per the results, it is suggested that there is an urgent need for additional treatment before the discharge of wastewater.

Key Words: Microbial Load, Sewage Treatment Plant, Pollution Load, Efficiency Rate.

1.INTRODUCTION

Sewage treatment is the process of removing pollutants from domestic sewage and effluents from industries, tanneries and distillaries. Physical, chemical and biological pollutants are removed by various physical, chemical and biological processes. Wastewater treatment aims at to generate an effluent and a solidified material known as sludge which is appropriate for discharge or reuse back into the surroundings [1]. Inefficient removal of impurities can pose a serious health hazard. However, reclaim must be secure to stay away from damaging wellbeing of the public and the environment [2].

The potential undesirable effects of untreated water on receiving water bodies include loss of fish life, high levels of sludge deposition ultimately resulting in septic conditions, higher oxygen demand, nutrient loading of the water bodies and odour production resulting from anaerobic reactions occuring at the bottom of the receiving water body, increased water treatment cost, eutrophication and eventual loss of water resources [3][4][5][6][7][8][9]. In several developing countries, direct addition of sewage into the waterbodies has caused their deterioration resulting from contamination and has left them unfit for drinking, industry and aesthetics [10][11][12][13]. In developed nations, where raw sewage is being given treatment by active means, purification consumes significant economic material and energy resources.

Studies have shown that sewage treatment processes might also affect physico-chemical parameters of the final effluent such as biochemical oxygen demand (BOD), chemical oxygen demand (COD), electrical conductivity, total hardness, alkalinity, dissolved oxygen, some metals and non-metal ions [14]. Although, various microorganisms in water are considered to be critical factors in contributing to numerous waterborne outbreaks, they play many beneficial roles in wastewater influents. In addition, purification processes remove pathogenic microorganisms. Furthermore, microbiological indicators have been used for decades to monitor fecal pollution of water ([15]. The comparative studies between STPs have shown both significant and insignificant variation [16][17] in efficiency rates. In the past, some studies have also shown that STPs deviate from normal permissible limit which have been given by WHO and the United States Environmental Protection Agency (EPA) [18][19][20].

The removal efficiency of each STP can be evaluated on the basis of presence of pollutants in influent as well as in the effluent [1]. The performance efficiency of treatment plant depends on proper design and construction and also on good operation and maintenance [17]. The most favoured wastewater purification system is that which is able to purify the wastewater to meet the recommended physical, chemical and microbiological guidelines at a low cost with least amount of operational and maintenance requirements [9].

In past, there has been no extensive study carried out to assess the efficiency and quality of this STP. Because of the associated dangers of sewage, the present study was carried out to investigate the impact of the wastewater effluent discharged and to estimate the pollutant removal efficiency of STP. It was predicted that removal efficiency will depend on the characteristic features (working capability) of the individual STP, extent of aeration, hydraulic retention time, contact time and type of treatment used.

II.MATERIALS AND METHODS

This study was conducted at Brari Nambal sewage treatment plant situated at an altitude of 1587m (a.m.s.l) with the geographical coordinates of $34^{0}05'$ 03.96" N latitude and $74^{0}48'$ 56.31" E longitude near Brari Nambal lagoon which is connected with the Dal lake through Nowpora channel. This lagoon due to its specific topography receives sewage/drainage from an area of about 270 hectares. To save this lakelet from further deterioration, a pilot project viz., Pollution Pilot Sewerage Scheme Brari Nambal (PPSSBN) was incepted for its first phase in 1983 by the Urban Environmental Engineering Department (UEED). This scheme envisages tackling of the sewerage discharge from the areas around Brari Numbal which include Munawarabad, Aqilmir, Khanyar, Nowpora, Rainawari, Bohri Kadal, Mukhdoom Sahib, Nowhatta, Baba Dem, Malik Angan, Fateh Kadal, Maharaj Gunj, Baba Pora, Barbar Shah, Boulevard and Naqashpora and treating the same in 17.08 MLD capacity treatment plant situated at Brari Nambal itself before its disposal into the River Jehlum at Chinkra mohalla in Habba Kadal [21]. The Brari Nambal Treatment plant is based on the principle of activated sludge process. The water samples were collected at inlet and outlet on monthly basis for a period of 24 months between June 2010 and May 2012 for analysis of physico chemical features, in white plastic containers, which were previously sterilized with 70% alcohol and rinsed with distilled water. For microbial analysis, samples were collected seasonally. At the sites, the containers were rinsed thrice with the wastewater before being used to collect the samples.

Physico-chemical parameters of water samples

The influent and effluent water samples were collected between 10.00 and 15.00 h from the sampling points (inlet and outlet) in 1 L polyethylene bottles (Fig. 1). The parameters temperature, pH and conductivity were recorded on the spot. For the estimation of dissolved oxygen, separate samples were collected in separate glass bottles and fixed at the sampling sites in accordance with the Winklers method [15]. BOD was determined by the 5 day test method, while COD determination was carried out using the open reflux method as per Standard Methods in APHA (1998).

Microbial examination of water samples

Microbiological examination of samples was conducted promptly as possible (within 24 h) after collection or were stored at 4°C in a refrigerator until use. Serial dilutions were prepared immediately after sample collection. The proper dilutions for various bacterial groups were selected so that number of colonies on plate was between 30 and 300 using spread plate method. A multiple tube fermentation technique or most probable number (MPN) technique was used to determine the bacterial indicators as coliforms (FC) and faecal *Streptococci* (FS) according to standard methods described in APHA (1998). Multiple tube fermentation method used in the present work included measurement of total plate count and MPN of coliform. After incubation for 24 h at 35°C, results were recorded when acid and gas liberated in Durham tubes had changed in color to yellow. The spread-plate method was used for all counts. FC agar and FS agar were used for enumeration of faecal coliform and faecal *Streptococci*. Each test was done in triplicate and the geometric means were recorded. The removal efficiency of bacterial indicators was calculated using the following formula:

Removal efficiency was calculated by using the following formula as per [22][23][19]:

$$\text{Removal efficiency} = \frac{\text{Concentration in influent} - \text{concentration in effluent}}{\text{Concentration in influent}} \text{ X } 100$$

2.1 Statistical analysis

Student's t-test was used to assess the statistical significance in efficiency rate between raw and effluent in physic-chemical features and microbial load. Similarly, efficiency rate in two years was tested by using Student's t-test. Correlation analysis was carried out to assess the association between physicochemical features and microbial load at inlet and outlet. All statistics were carried out with the SPSS 11.5 statistical software package with significance levels set at $P<0.05$.

III RESULTS

The data shows significant differences ($P<0.005$) in physico chemical features and microbial data between the inlet and outlet samples (Tables 1 and 3). The temperature, pH and conductivity in the raw sewage was found to be 17.58±8.94^{0}C, 7.52±0.16 and 1043.79±173.5µScm^{-1} respectively. The DO, BOD and COD concentration in raw sewage ranged from 0.35±0.47mg/L, 245.58±54.8 mg/L and 588.61±91 mg/L respectively. The temperature, pH and conductivity in the effluent was found to be 16.8±8.82 0^{0}C, 7.71±0.14 and 809±138.4 µScm^{-1} respectively. The DO, BOD and COD concentration in effluent ranged from 2.09±0.43 mg/L144.5±26.27 mg/L and 333.47±83mg/L respectively (Table 1). The values of efficiency rate of conductivity, BOD and COD in the STP depicted significantly greater values (*P*<0.05) as 22.50±2.51, 40.47±5.0 and 42.82±4.77 % (Table 2).

In the case of microbial load, TCC, TC, FC and FS concentrations in the inlet sample were found to be 8.87±0.1 to 9.08±0.41(cfu/ml), 8.9±0.07(MPN/100ml), 7.95±0.09(MPN/100ml) and 7.02±0.11(MPN/100ml), respectively (Table 3). TC, FC and FS concentrations were found to vary in the outlet water samples as 7.32±0.39 (cfu/ml), 7.11±0.04 (MPN/100ml), 6.89±0.07 (MPN/100ml) and 6.31±0.06 (MPN/100ml), respectively. Observations also revealed that the percent removal efficiency of TC, FC and FS was found to be 47.019±3.5, 55.15±3.35, 43.80±3.04 and 35.11±3.9, respectively (Table 4).

Table 1. Mean values of physico-chemical features in the influent and effluent of Brari Nambal STP

Parameter	Brari Nambal STP			
	Influent	**Effluent**	***t-test***	***P value***
Temperature (0^0C)	17.58±8.94	16.8±8.82	0.26	0.79
pH	7.52±0.16	7.71±0.14	-4.2	0.0001

Conductivity (μScm^{-1})	1043.79±173.5	809±138.4	9.8	0.0001
Dissolved oxygen (mgl^{-1})	0.35±0.47	2.09±0.43	-14.2	0.0001
BOD (mgl^{-1})	245.58±54.8	144.5±26.27	13.8	0.0001
COD (mgl^{-1})	588.61±91	333.47±83	13	0.0001

Table 2. Mean values of removal efficiency (%) in Brari Nambal STP

Parameter	**Removal efficiency (%)**
Conductivity	22.50±2.51
BOD	40.47±5.0
COD	42.82±4.77
One Way ANOVA (Overall)	
F-test	***P-value***
21.2	P<0.0001

Table 3. Mean values of microbial features in the influent and effluent of Brari Nambal STP

Parameter	**Brari Nambal STP**			
	Influent	**Effluent**	***t- test***	***p value***
Total colony count (cfu/ml)	9.08±0.41	7.32±0.39	26.27	0.0001
Total coliform	8.9±0.07	7.11±0.04	26	0.0001

(MPN/100ml)				
Faecal coliform (MPN/100ml)	7.95±0.09	6.89±0.07	27.1	0.0001
Faecal *Streptococci* (MPN/100ml)	7.02±0.11	6.31±0.06	20.2	0.0001

Table 4. Mean values of removal efficiency (%) in microbial load in Brari Nambal STP

Microbial features	Removal efficiency (%)
Total colony count	47.019±3.5
Total coliform	55.15±3.35
Faecal coliform	43.80±3.04
Faecal *Streptococci*	35.11±3.9

IV DISCUSSION

Although data shows significant differences in physico- chemical features and microbial load between the inlet and outlet, nevertheless, these variations do not meet the Indian national standards. As per Indian standards, to discharge effluents into water bodies, BOD, COD and faecal coliform should be less than 30 and 250 mg/L and 2500 MPN/100ml, respectively [24].

The higher temperature recorded for all sewage samples was because of the addition of warm water from domestic use and composite composition of sewage. The variations between inlet and outlet samples were, however, not significant. Our results correspond very well with the findings of earlier researchers like [25][26].

The pH of the sewage was found in the alkaline range which may be attributed to the presence of organic pollution, alkaline chemicals, soap and detergents produced due to commercial and residential activities [27]. This investigation is in agreement with the findings of [8] [28][29] who also found increase in pH level during treatment process. [30] attibuted the production of carbon dioxide and ammonia oxidation to the decrease in pH of alkaline waste waters in the activated sludge process. The pH range recorded for all the sampling sites lie within the WHO pH tolerance limit, that is, 6 to 9 for wastewater to be discharged into water body. Our results coincide with the findings of [8] who also found increase in pH level during treatment process. In addition, lower values of dissolved oxygen recorded at inlet sites may also be due to the organic matter in water, probably sewage or other biodegradable disposable residues, which lead to the rapid decrease in this oxygen availability [31]. Data presented here, however, agree with those reported elsewhere [32][33][34]. The DO concentrations of the effluents in our study were less than 5 mg/l. Consequently, these water sources would not be suitable for use in aquatic ecosystems.

High COD and BOD concentration observed in the wastewater might be due to the use of chemicals, which are organic or inorganic that are oxygen demanding in nature [35]. The values for most of the parameters in the discharged effluent were almost higher than the acceptable limits. The raw and effluent sewage showed significant differences in the sewage treatment plant. Since the BOD concentration of the influent was greater than 200 mg/L the strength of sewage can be considered to be high.The percentage removal of BOD was found to be below the expected value of 85 to 90%, thus showing that BOD reduction is less than the expected.

The high coliform count in raw sewage obtained in our results may be an indication that the sewage is comprised of faecal matter coming from household latrines [15]. The presence of pathogenic bacteria in treated wastewater effluent is a potential public health hazard, as this water source is directly discharged in receiving water bodies and may be used by communities for multiple purposes. Additionally, the concentration of physico-chemical parameters of sewage were relatively high which causes microbial biomass development, particularly coliform and faecal S*treptococci* [36]. Similar sewage characteristics were obtained by [36]. It is clear from our results that some amount of microbial load is retained even after the treatment process. In our case, it was observed that tertiary treatment was not carried out to remove pollutants from the wastewater. So, it is essential to include a tertiary treatment step in STPs so that the purification process results in bacterial concentrations that are in compliance with discharge [37]. The results show that faecal *Streptococci* are more resistant and persistent as compared to faecal coliforms. These results coincide very well with the findings of [38]. The reduction of microbes in activated sludge process also depends on protozoan predation, settlement of suspended solids, inactivation due to sunlight, activity of bacteria, lack of aeration, improper loading and environmental conditions [39][40][41][42][43][44].

The present study depicted the poor operational state of activated sludge based sewage treatment plant located at Brari Nambal. This could be due to inadequate maintenance of most of these municipalities sewage treatment works, i.e. design weaknesses, overloaded capacity, faulty equipment and machinery, toxic nature of sewage and insufficient aeration in the aeration tank [45][40][41][46][44]. One more possible reason for the inefficiency of Brari Nambal STP could be based on the fact that it receives an organic load higher than the design capacity [40][41]. It has been designed to treat a load of 17 MLD which sometimes reaches to 32MLD that means the present hydraulic load is almost 2 times more than the design capacity. Thus the results in our study are comparable with previously reported works of [47][48] who observed an increase in effluent values due to overloaded conditions. Bulking which is a wide phenomenon in ASP based treatment systems occurred seasonally and periodically, which bring serious operating problems and take a relating long time to restore [49][50][34].

V CONCLUSION AND SUGGESTIONS

All the municipal wastes that may have otherwise gone untreated into the environment are restricted from entering. Thus, these treatment plants play an important role in the control of pollution level. However, performance of this STP do not meet the permit standards set by the Indian national standards and WHO. Therefore, it is suggested that authorities should improve the efficiency of STP by including tertiary treatment processes such as chlorination, rapid sand filtration, UV disinfection, artificial lagoons, wetlands, adequate contact time, etc. In addition, there is need of trained and technical staff for proper monitoring and operation of this STP in a standardized manner. Furthermore, regular monitoring of this STP by national experts is necessary in order to improve its operational capability.

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