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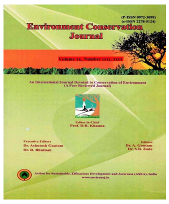

Efficiency assessment of 3.2MLD MBR based sewage treatment plant of IFFCO township Aonla, Bareilly, Uttar Pradesh, India

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ABSTRACT

Increasing urbanization and industrialization is continuously putting a pressure on the ground and fresh water resource in form of quality and quantity. Therefore water recycling through wastewater treatment is the need of the present hour. Therefore in the present study the efficiency of the 3.2MLD sewage treatment plant (STP) based on membrane bioreactor technology (MBR) located in Indian Farmers Fertilizer Cooperative Limited (IFFCO) township Aonla, Bareilly, Uttar Pradesh, India was studied. The plant was recently commissioned on 10th of June 2022. The plant shows highest efficiency for turbidity (98.6%) followed by total suspended solids (TSS) (95.7%), chemical oxygen demand (COD) (89.0%), iron (86.7%), and biochemical oxygen demand (BOD) (85.0%). The efficiency for the rest of the parameters is below 50%. The MBR based STP is working efficiently as the values of parameters in treated water is within the discharge standards of central pollution control board (CPCB) listed in The Environment (Protection) Rule, 1986. One of the major problems of MBR based STP reported in literature is membrane fouling which is also rectified in the current treatment plant by using sodium hypochlorite for membrane cleaning.

Introduction

Water is a natural resource of vital importance and act as elixir of life. It makes around 80% part of the protoplasm and is essential for all the cell metabolic activities. Water is used in almost all the activities of human routine life but we all underestimate the importance of water and thus despite this much of importance this natural resource is categorized as mismanaged resource. Continuously we are heading towards water shortage due to more extraction of groundwater than recharge (Bhutiani *et al.,* 2019; Kumar *et al.,* 2010). More than 80% of the supplied to a residency returned as wastewater which is called as domestic wastewater or sewage (Bhutiani and Ahamad, 2018; Ruhela *et al.,* 2020). Sewage is mixed water containing the water from kitchens, bathrooms, floor washing and surface runoff during rainy seasons (Kumar *et al.,* 2010). Globally two million tonns of wastewater is generated and about 80% of this wastewater is discharged without any treatment (UNEP, 2010; WWAP, 2017). As per the central pollution control Board (CPCB) report of 2021, in class I cities of India, the percentage of sewage treatment in 1978 was 39.3% (treatment of 2755MLD out of 7006MLD generation), in 1988 was 21.7% (treatment of 2633MLD out of 12145MLD

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generation), in 1999 was 24% (treatment of 4037MLD out of 16662MLD generation), and in 2008 was 30.8% (treatment of 11787MLD out of 38254MLD generation). Presently in each state of India, sewage generation capacity is more in comparison to sewage treatment. This data shows that public as well as government interests have been increased in recent decades towards the water recycling (Qayoom *et al.,* 2021).

The direct dispose of untreated wastewater makes the ground as well as surface water bodies contaminated (Yaqub *et al.,* 2020; Osmani *et al.,* 2021). The consumption of contaminated water, unhealthy sanitation and hygiene practices alone contribute about 7% in disease and 19% in child mortality rate (Cairncross *et al.,* 2019: Bhutiani *et al.,* 2021). Due to the upgraded soaps, detergents, toothpaste, shampoos and increased lavish life style, the nature of sewage also changes (Von Sperling, 1996; Forrez *et al.,* 2011). Now days, besides organic matter it also contains various chemicals, heavy metals and pathogens (Ali *et al.,* 2022). Therefore the treatment of sewage becomes an urgent need of the present time. Establishment of new STP's requiring large land areas which are also an issue in developing countries like India. Therefore efficiency enhancement is the sustainable solution to the above discussed problem so that more water is treated effectively in short time period (Nelson *et al.,* 2017).

Due to complex nature of wastewater originated conventional wastewater treatment technologies shows low efficiency (Sahar *et al.,* 2011). Therefore, trend of advanced treatment technologies application is going on these days. These technologies include membrane bioreactor (MBR) (Tadkaew *et al.,* 2011), Nano filtration (NF) and reverse osmosis (RO) (Nghiem *et al.,* 2004), and UV oxidation (Lekkerkerker-Teunissen *et al.,* 2012).

About MBR based STP

MBR technology is an advanced version of classical activated sludge (CAS) process. Membrane Bioreactor Technology (MBR) is a combination of two phenomenon's that is the Membrane Filtration (Micro and Ultra Filtration) process and the Biological Process. Therefore MBR based Sewage Treatment Plant (STP) means STP's where the numbers of membranes are used for the removal of smaller impurity particles from the sewage water mainly (greater than 0.1 micro-meter size) and these membranes are submerged in aerated biological reactors where the biological process will occur. In this biological process the air is added or blown into the sewage water so that the bacterial concentration will increases very rapidly in the sewage so that they easily degrade or digest/decompose the organic matter present in the sewage water and also breaks down the organic matter into smaller parts and this process also similar to the activated sludge process (Figure 1).

So in this MBR section of the STP plant these two processes works together such that firstly the Biological process converts organic matter into smaller parts and after that the Membranes easily removes or filtered out these impurities from the sewage water so that we got highly treated effluent from this MBR section.

MBR technology possesses several advantages such as smaller physical footprint and higher efficiency in comparison to CAS (Tadkaew *et al.,* 2011; Nguyen *et al.,* 2013). Some Advantages of MBR based STP plants are-

1- It requires less space in comparison to ASP plants.
2- In these plants the operation should be performed easily.
3- We got the High-quality treated effluent from this type of STP.
4- It produces less volume of sludge.

MBR based STP plants can be used for Municipal wastewater treatment, Industrial wastewater treatment and many other places having less space so these plants are very effective. But there is one major problem of this MBR based STP plant is that the problem of membrane fouling in the membranes of the MBR chamber and due to this major problem, the efficiency of the plant decreases to some extent. Membrane fouling means the membranes or filter medias used for the removal of different impurities from the wastewater are to be blocked or clogged due to the cake formation of these impurities and it affect the efficiency of the plant but this MBR system is better than activated sludge plants and also, we easily solve the problem of membrane fouling by the help of coagulation,

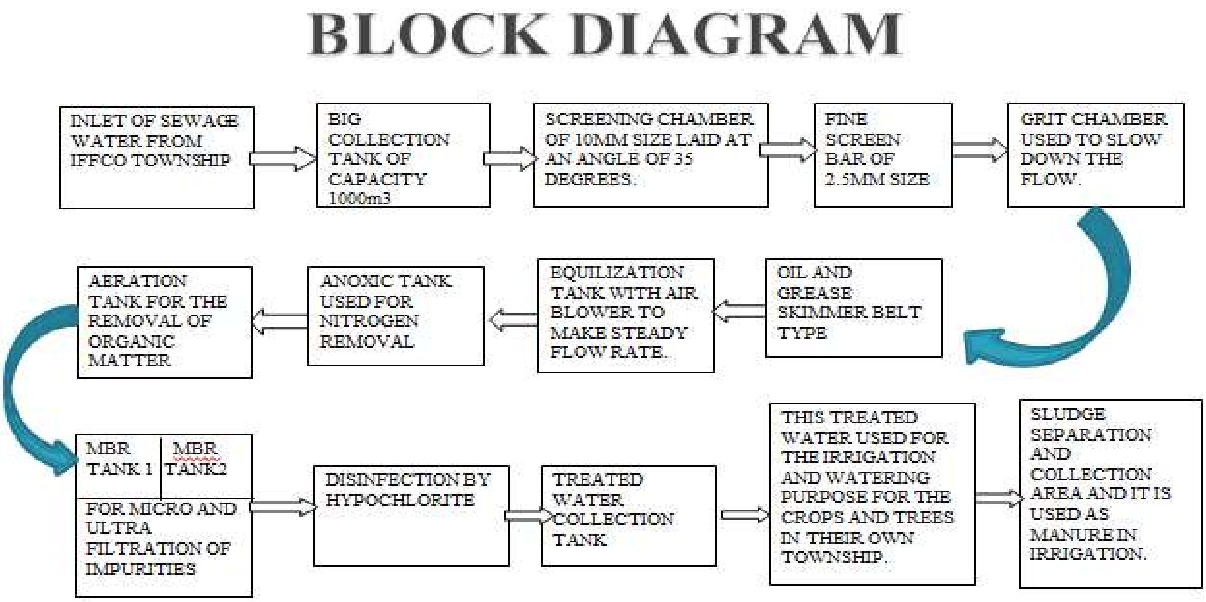

Figure 1: Showing block diagram of MBR-STP

adsorption process and aerobic granulation technique. Therefore by the help of these methods, we should improve the efficiency and also increases the life of the membranes used in the MBR section of this STP plant. Literature review suggests that anoxic MBR based STP show maximum efficiency (Sima *et al.,* 2011; Xiang *et al.,* 2014; Miura *et al.,* 2015; Schaeffer *et al.,* 2018; Shen *et al.,* 2019).

Material and Methods

Study area

MBR based STP plant of 3.2 MLD is situated in IFFCO Township near IFFCO Urea Plant in Aonla, Bareilly, UP, India at the 28.208303 latitudes and 79.245088 longitudes. This plant starts working from 10th of June 2022 and having a capacity of 3240 m3/day. Inside the IFFCO Township this STP plant is located at the very back side where the sewage water of the whole Township collected in proper way. The nearest location around this plant is Chakarpur Ramnagar.

Sample Collection

Water samples were collected from inlet and outlet point in the morning hour. The sampling was performed for five months (from August 2022 to December 2022). Samples were collected in the prewashed plastic containers of 2 litres throughout the study period. The parameters studied during the study period were turbidity, total dissolved solids (TDS), total suspended solids (TSS), pH, biochemical oxygen demand (BOD), chemical oxygen demand (COD), total hardness, calcium, magnesium, iron, sulphate, alkalinity, chloride, sodium, and salinity. All the parameters were analyzed following the standard methods (APHA 2017; Trivedy and Goel, 1986 and Khanna and Bhutiani, 2008).

Results and Discussion

The average results of different physicochemical parameters are presented in table 1 and figure 2. Turbidity is due to the presence of solids present in suspended form in the water. Turbid water interferes in pathogen removal process (WHO, 2004). The turbidity in raw sewage ranged from 30-75NTU with an average value of 62.2NTU±19.0 and in treated water 0.5-1.4NTU with an average value of 0.8NTU±0.3. Therefore the efficiency of the plant for turbidity reduction was 98.6%. Our results are in full agreement with Nguyen *et al.* (2013) which observed the turbidity below 0.2NTU in all the samples in laboratory scale MBR based STP. Total Suspended Solids (TSS)is a measure of the floating particulate content of the wastewater

Table 1: Showing the minimum, maximum and average values of different physicochemical parameters of treated and untreated sewage and the efficiency of STP (n=5)

Parameters	Inlet point (Untreated water)				Outlet point (Treated water)				Efficiency
	Average	SD	Minimum	Maximum	Average	SD	Minimum	Maximum	
Turbidity (NTU)	62.2	19.0	30.0	75.2	0.8	0.3	0.5	1.4	98.6
TDS (mg/l)	361.8	21.4	350.0	400.0	289.4	39.7	245.0	326.0	20.0
TSS (mg/l)	71.8	25.6	28.0	92.0	3.1	0.3	2.6	3.5	95.7
PH	7.2	0.3	7.0	7.6	8.3	0.1	8.1	8.4	-14.3
BOD (mg/l)	33.6	13.6	18.0	48.0	5.1	2.8	1.5	8.8	85.0
COD (mg/l)	94.0	19.6	70.6	124.0	10.4	6.9	4.0	18.9	89.0
T. Hardness (mg/l)	94.9	12.3	80.0	110.0	52.7	9.6	38.0	62.4	44.67
Calcium (mg/l)	59.9	21.2	30.0	80.7	39.7	9.4	25.0	48.0	33.8
Magnesium (mg/l)	15.8	12.2	4.0	35.0	9.4	7.4	2.0	19.0	40.5
Iron (mg/l)	3.0	0.3	2.5	3.3	0.4	0.3	0.2	0.8	86.7
Sulphate (mg/l)	61.5	30.4	30.0	105.0	32.8	17.3	20.0	60.0	46.7
Alkalinity (mg/l)	310.4	32.1	280.0	360.0	252.0	52.2	200.0	320.0	18.8
Chloride (mg/l)	55.0	22.6	40.0	95.0	44.8	20.1	32.0	80.0	18.5
Sodium (mg/l)	132.4	14.8	110.0	150.0	70.4	19.6	49.0	100.0	46.8
Salinity (mg/l)	408.0	52.6	330.0	470.0	304.2	48.5	250.0	380.0	25.4

having the diameter greater than 2 micrometre and is an indicator of the clarity of the wastewater (Johal *et al.,* 2014). During the study period, the range of TSS was observed from 28-92mg/l with an average value of 71.8mg/l±25.6 in inlet and in outlet from 2.6-3.5mg/l with an average value of 3.1mg/l±0.3. Therefore the efficiency of the plant for TSS reduction was 95.7%. The reduction in suspended solids may be due to sedimentation of these particles. Besides this, biological degradation in aerobic zone is also another method observed (Wang *et al.,* 2010). Xiang*et al.* (2014) also observed the similar results (more than 96%) in MBR based STP. Total Dissolved Solids (TDS)value of the wastewater is mainly due to the ions/salts added during the use of water or dissolved from the rock dissolution (Salunke *et al.,* 2014). During the study period, the range of TDS was observed from 350-400mg/l with an average value of 361.8mg/l±21.4 in inlet and in outlet from 245-326mg/l with an average value of 289.4mg/l±39.7. Therefore the efficiency of the plant for TDS reduction was 20.0%. TDS removal may be due to oxidation and biological degradation of dissolved solids (Singh and Varshney, 2013; Bhutiani *et al.,* 2016; Ruhela *et al.,* 2020).

pH is the indicator of salinity or acidity of the water and wastewater. Efficiency of the treatment plant depends of the pH value because it determine the transformation of many pollutants and is an essential measure to maintain the nutritive balance for the proper development of aquatic biota (Bolawa and Gbenle, 2012; Ruhela *et al.,* 2020; Osmani *et al.,* 2021), and it's optimum range essential for bacterial activity (Sincero and Sincero, 1996). During the study period, the range of pH was observed from 7.0-7.6 with an average value of 7.2±0.3 in inlet and in outlet from 8.1-8.4 with an average value of 8.3±0.1. Therefore the efficiency of the plant for pH gain was 14.3%. Less removal percentage in pH was observed due to chlorine dosing to remove the color, odour and pathogens in treated water (Bhutiani and Ahamad, 2018; Showkat and Najar, 2019).

Microbes degrade organic matter present in the wastewater and for this purpose they demanded the oxygen. Thus the amount of oxygen demanded by the microbial population present in fixed quantity of wastewater to degrade the organic matter is known as Biochemical Oxygen Demand (BOD). Therefore the value of BOD is the indicator of amount of organic matter of wastewater (Hur and Kong, 2008). During the study period, the range of BOD was observed from 18-48mg/l with an average value of 33.6mg/l±13.6 in inlet and in outlet from 1.5-8.8mg/l with an average value of 5.1mg/l±2.8. Therefore the efficiency of the plant for BOD reduction was 85.0%. BOD removal is indicative of the efficiency of biological treatment processes and is the most widely used parameter to

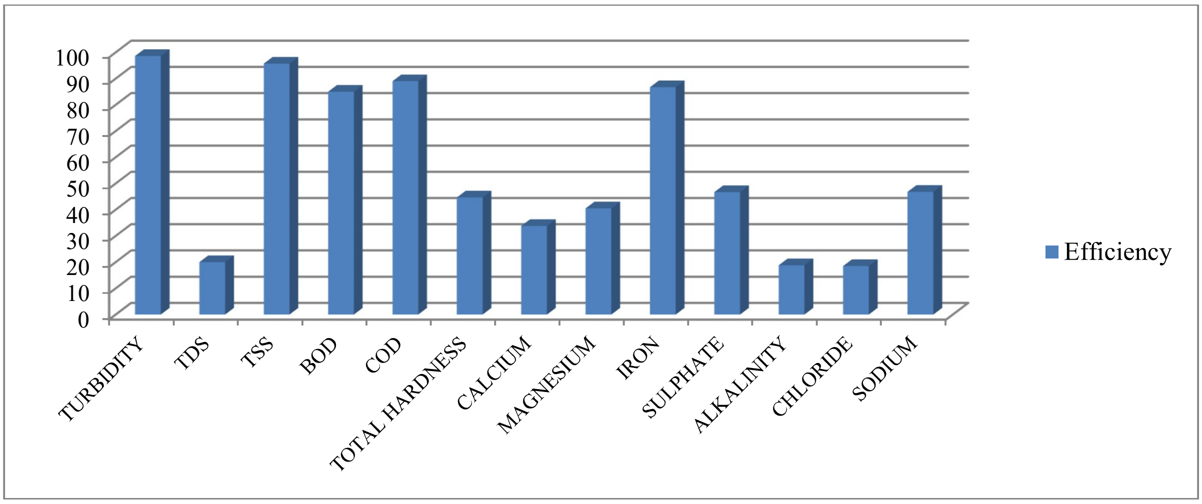

Figure 2: Showing the efficiency of STP for different physicochemical parameters

measure wastewater quality. The results of this study are concurrent to that Bolong *et al.* (2022) and Ali *et al.* (2021) who observed BOD reduction upto 92%.Chemical Oxygen Demand (COD) is the oxygen demand raised during chemical breakdown of organic and inorganic matter (Bhutiani *et al.,* 2017; Kumar *et al.,* 2018). Higher COD values of wastewater results into drastic oxygen depletion in the receiving water bodies. During the study period, the range of COD was observed from 70.6-124.0mg/l with an average value of 94.0mg/l±19.6 in inlet and in outlet from 4.0-18.9mg/l with an average value of 10.4mg/l±6.9. Therefore the efficiency of the plant for COD reduction was 89.0%. The decrease may be linked to the aeration and digestion processes, which have also been confirmed by Xiang *et al.* (2014), Jafarzadeh *et al.* (2014), Johal *et al.* (2014) and Ali *et al.* (2021) who obtained 84.5%, 94%, 98%, and 91.5% respectively reduction in their studies. COD test is complex in nature but less time consuming. In our study COD reduction was achieved much higher than those of Fluidized aerobic bioreactor (FAB) based STP (29.00%) and less than sequential batch reactor (SBR) based STP (22.32%) conducted by Qayoom *et al.* (2021). Total Hardness in water is due to the presence of carbonate, bicarbonate, chloride, and sulphate of calcium and magnesium The main sources of Ca and Mg in wastewater are calcite, dolomite, magnesite, anhydrite, gypsum feldspar, pyroxene and amphiboles present in catchment. The range of Total Hardness was observed from 80.0-110.0mg/l with an average value of 94.9mg/l±12.3 in inlet and in outlet from 38.0-62.4mg/l with an average value of 52.7mg/l±9.6. Therefore the efficiency of the plant for Total Hardness reduction was 44.67%. Decrease in concentration could be attributed to the grit separation, sedimentation process and active uptake of calcium and magnesium by microorganisms during treatment (Showkat and Najar, 2019). During the study period, the range of calcium was observed from 30.0-80.7mg/l with an average value of 59.9mg/l±21.2 in inlet and in outlet from 25.0-48.0mg/l with an average value of 39.7mg/l±9.4. Therefore the efficiency of the plant for calcium reduction was 33.8%. During the study period, the range of magnesium was observed from 4.0-35.0mg/l with an average value of 15.8mg/l±12.2 in inlet and in outlet from 2.0-19.0mg/l with an average value of 9.4mg/l±7.4. Therefore the efficiency of the plant for magnesium reduction was 40.5%. Similar reduction in hardness, calcium and magnesium ion (from 39.9% to 53.97%) was observed by Bhutiani *et al.* (2017) and Ruhela *et al.* (2020). Iron in raw effluent ranged from 2.5 to 3.3mg/l with an average value of 3.0mg/l±0.3 and from 0.2-0.8mg/l with an average value of 0.4mg/l±0.3 in treated water. Therefore the efficiency of the plant for iron reduction was 86.7%. In our study iron reduction was achieved much higher than those of Fluidized aerobic bioreactor (FAB) based STP (29.22%) and less than sequential batch reactor (SBR) based STP (52.28%)

conducted by Qayoom *et al.* (2021). Similarly, value of sulphate ranged from 30.0-105.0mg/l with an average value of 61.5mg/l±30.4 in inlet and from 20.0-60.0mg/l with an average value of 32.8mg/l±17.3 in outlet. Therefore the efficiency of the plant for sulphate reduction was 46.7%. In our study sulphate reduction was achieved much higher than those of Fluidized aerobic bioreactor (FAB) based STP (25.39%) and sequential batch reactor (SBR) based STP (8.79%) conducted by Qayoom *et al.* (2021).Alkalinity in water is due to presence of carbonate, bicarbonate, phosphates, and nitrates along with hydroxyl radical in their free state (Bhutiani *et al.,* 2016). In the raw sewage, alkalinity ranged from 280.0-360.0mg/l with an average value of 310.4mg/l±32.1 and from 200.0-320.0mg/l in treated effluent with an average value of 252.0mg/l±52.2. Therefore the efficiency of the plant for alkalinity reduction was 18.8%. Less reduction in alkalinity is due to the use of base to adjust the pH value during the treatment processes. Higher concentration of chloride in water is the indicator of the degree of contamination by a large quantity of sewage inputs, detergents and soaps (Von Sperling, 1996). It shows that the contamination at the site is higher. During the study period, the range of chloride was observed from 40.0-95.0mg/l with an average value of 55.0mg/l±22.6 in inlet and in outlet from 32.0-80.0mg/l with an average value of 44.8mg/l±20.1. Therefore the efficiency of the plant for chloride reduction was 18.5%. Less reduction in chloride value is pointing towards the use of high chlorine dosing (dosing of poly aluminum chloride) to remove the odour, color and pathogens which is also indicating towards the slow functioning or high organic loading in influent (Rao and Shruthi, 2002). In raw effluent, the range of sodium was observed from 110.0-150.0mg/l with an average value of 132.4mg/l±14.8 in inlet and in outlet from 49.0-100.0mg/l with an average value of 70.4mg/l±19.6. Therefore the efficiency of the plant for sodium reduction was 46.8%. Salinity is the amount of salts dissolved in a unit volume of water. Salinity can take three forms, classified by their causes: primary salinity (also called natural salinity); secondary salinity (also called dryland salinity), and tertiary salinity (also called irrigation salinity). During the study period, the range of salinity was observed from 330.0-470.0mg/l with an average value of 408.0mg/l±52.6 in inlet and in outlet from 250.0-380.0mg/l with an average value of 304.2mg/l±48.5. Therefore the efficiency of the plant for salinity reduction was 25.4%.

Conclusion

The performance of the MBR based STP located in IFFCO township area of Bareilly was conducted for a period of 5 months (August 2022 to December 2022). The overall efficiency is in the order Turbidity>TSS>COD>Iron>BOD>Sodium>Sulphate>Total Hardness> Magnesium>Calcium> Salinity >TDS>Alkalinity>Chloride. In case of chloride less removal efficiency was observed showing the use of chlorine in the treatment process for the purpose of disinfection. The treated waste can be re-used for irrigation purpose. In order to improve the efficiencies of the STPs, the treatment systems must be properly operated and maintained, sources of raw sewage need to be identified, and existing facilities should be upgraded accordingly. In terms of proper operation and maintenance, trained and experienced workers are required in a defined period of time to assess treatment performance.

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Conflict of interest

The authors declare that they have no conflict of interest.

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