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# Ambazari lake water treatment using hybrid membrane bioreactor and nanofiltration system

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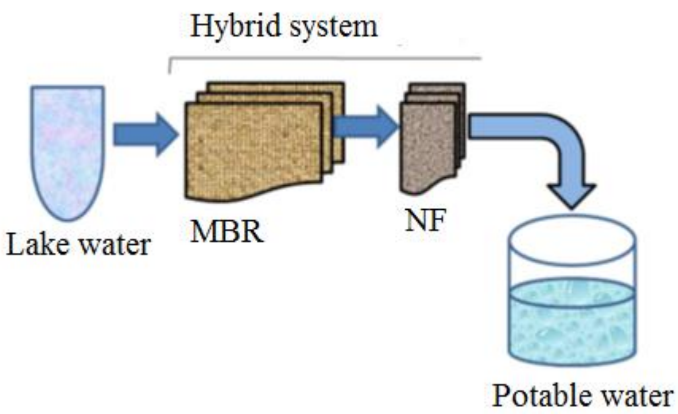
## GRAPHICAL ABSTRACT

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## ABSTRACT

Advanced water treatment methods are needed for good quality of lake water. In this study, the hybrid membrane bioreactor (MBR) and nanofiltration (NF) system was investigated to treat Ambazari lake water. The performance of the hybrid system was checked as removal efficiency of chemical oxygen demand (COD), total dissolved solids (TDS), biochemical oxygen demand (BOD), and permeate flow rate (PFR). All parameters in the hybrid MBR-NF system were operated batch-wise for 5 h. The COD and BOD removal efficiencies were observed to be 95.67 % and 94.64 %, respectively. TDS removal efficiency was obtained to be 92.33%. The highest TSS removal efficiency was reported to be 36.0 % for airflow rates of 1.0 L/min. The pH variation at different airflow rates was found to be significantly low. Hence, from above information, we conclude that this hybrid system treated Ambazari lake water successfully. The treated water had high quality as good as potable water.

### 1. Introduction

Water is a significant source of important habitat for plants and animals survival. Wastewater restoration considered a convenient option to solved shortage of water caused by increasing populations, climate change, rapid urbanization, and continuous industrialization (Bhuyar et al. 2015; Shaabani et al. 2018; Samari et al. 2020). Lakes are an essential feature of Earth's landscapes. The lake is a large body of water surrounded by land, inhabited by various forms of aquatic life. Pure water contained low suspended or dissolved solids and low in biological life for all practical purposes. The lakes life and their biological diversities are directly related to every component of ecosystem. The lakes facing quality of water problems everywhere; eutrophication is one of the major concerns. The term eutrophication used to describe age of a lake, results in nutrients accumulation, silt, sediments, and organic components in lake from surrounded watershed (Sulekh et al. 2012). Lakes some time deep or shallow, temporary or permanent; and may have fresh or salty water. Although lakes having 50.01 % water on surface of Earth and hold liquid surface freshwater about 49.8 %. Most of the organisms to survive depend on freshwater. However, people mostly depend on lakes for various ‘goods/services’ such as drinking water, waste removal, agricultural irrigation, fisheries, and recreation, industrial works. These reasons lakes are important ecosystems on earth (Bhateria and Jain. 2016).

The micropollutants in water may cause significant adverse effect on health (Das et al. 2017). However, such pollutants difficult to effectively separate out from wastewater by conventional treatment such as activated sludge process, flotation and coagulation methods

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(Englande et al. 2015). For this reasons, secondary effluents of wastewater again treated by advanced an integrated membrane technique consist of reverse osmosis (RO) and microfiltration (MF) or ultrafiltration (UF) membrane for micropollutants effectively removal from waste liquid.

Recently, the MBR has accomplished considerable as a pretreatment of water for NF membranes techniques due to its low recovery of sludge and effluents of high-quality. This technology can be replaced with conventional biological treatment process, which encompasses secondary sedimentation and an activated sludge methods. Even though, the MBR technology is more superior for separating the number of contaminants from wastewater, including organic materials and nutrients (Ren et al. 2010). However, the MBR process effectively removed pharmaceutical contaminant from wastewater such as tonalide, galaxolide, bisphenol-A, ibuprofen, and bezafibrate (Clara et al. 2005). Moreover, carbamazepine and diclofenac, nonylphenoxy ethoxy acetic acid and nonylphenoxy acetic acid were can not be separated. Therefore, nonporous NF membranes should be applied for more efficient removal of pollutants.

The water contaminants removal capabilities were affecting by few important factors such as characteristics of water, physicochemical characteristics of solute, and characteristics of membrane (Qasem et al. 2021). Although several reports show that, membrane processes apply to removal of nutrients, and an integrated membrane system mainly focused on reclamation of municipal wastewater (Chon et al. 2012). This technique is most similar to the RO before MBR. High-quality water effluents related to the RO permeate can be produced through NF membrane with relatively low pressure as compared to RO membrane (Bellona and Drewes. 2007).

A study on NF receiving MBR treated wastewater of lake has been hardly performed. Consequently, removal components and the MBR-NF hybrid system mechanisms for reclamation of lake water need to be urgently performed. Our objective is to reuse treated water for potable domestic purposes using advanced method for lake water treatment, i.e., NF and MBR in combination. This system is more compact and easier to maintain than existing water treatment method for reclamation of lake water.

## 2. Materials and methods

### 2.1. Water source

This study deals with the Ambazari lake (Fig. 1), situated near the Southwest border of Nagpur (20'35'21.44"N and 78'15'79.40"E), in the state of Maharashtra, India. The total catchment area of the lake is 6.06 Sq. Miles.

**Fig. 1.** Ambazari lake.

The water of Ambazari Lake of Nagpur (Orange city) collected in clean and sterilized plastic canes of about 30 L capacities required from time to time evaluate water quality in Winter-Summer season. Water samples were collected in depth surface of some feet and brought to the laboratory for analysis. The physico-chemical parameters investigated in this study are including pH, temperature, COD, BOD, TDS, total suspended solids (TSS), gauge pressure, permeate flow rate. Characteristics of Ambazari Lake water are given in Table 1.

**Table1.** Characteristics of Ambazari Lake water.

| Property | Quantity |
|---|---|
| Color | Greenish |
| Turbidity | 8 NTU |
| Dissolved oxygen (DO) | 5.2 mg/L |
| Chemical oxygen demand (COD) | 370 mg/L |
| Biological oxygen demand (BOD) | 280 mg/L |
| Mix liquor suspended solid (MLSS) | 1300 mg/L |
| Total dissolved solid (TDS) | 535 mg/L |
| pH | 7.6-7.9 |
| Conductivity | 980 us/cm |
| Total suspended solid (TSS) | 1340 mg/L |
| E-Coli (CFU/100 mL) | 15.0 |

### 2.2. Acclimatization stage

Biomass acclimatized at room temperature 30°C and carried out in sequencing batch reactor of volume 10 L over one month. In a sequencing batch reactor 3 L of activated sludge and rest of volume (7 L) filled with lake water. The activated sludge mixed with cow dung was obtained from the effluent Government Milk Dairy, Nagpur, Maharashtra, India. A small amount of jaggery was used as food for growth of microorganisms. Every day, 5 L of clear liquid was withdrawn, and fresh 5 L of water was added regularly to enhance microbial growth. The Acclimatization stage needed to keep microorganisms alive in new environment; this activated sludge was used for further experiments.

### 2.3. Experimental Set-up

The lab-scale MBR with a membrane pouch about 20 L volume operated for 5 hours batch-wise run. The submerged membrane module area 0.06 $m^2$ per pouch. The MBR was performed at a constant volume 12 L feed. Initially, the bioreactor was charged with lake water and activated sludge in the ratio 2:1. The activated sludge was filtered with 100 and 120 mesh networks to remove impurities and large particles to feed the bioreactor. The COD, BOD, TDS, MLSS, pH, Gauge Pressure were observed regularly after every one-hour operation for the batch of 5 hours. The pH within 7-8 of lake water maintain throughout the experiment. In this process, airflow rates were kept constant at 0.6, 0.7, 0.8, 0.9, 1.0 LPM for a batch-wise run of 5 hours, there provides sufficient amount of oxygen for the growth of micro-organisms. Washing was performed by removing the membrane pouch from assembly and clean manually with clear water. And again, fresh batch operated for the same time hours. The optimum effluent obtained from MBR and passed to treat in NF system operation to study selected parameters like COD, BOD, TDS, and permeate flow rate. Fig. 2a shows the pictures of the MBR and NF used during the experiments. Feed pressure and retention pressure were kept constant during NF operation. Fig. 2 b shows the schematic representations of the hybrid MBR and NF unit system.

### 2.4. Analytical Methods

The COD and TSS are measured using procedures described in the standard methods (APHA. 2005). The DO measured by using a dissolved oxygen probe, Hanna HI 98193 and washed after each use. The pH of sample within range 7-8 was maintained by HACH–HQ 411D pH meter. The TDS measured by using TDS Analyzer (ELICO CM-183EC). The BOD evaluated by using BOD meter Model no.-HI98193, Make-Hanna Instruments. Gauge Pressure was estimated by using a pressure measuring instrument set on equipment. The color of sample was observed by colorimeter model no.-HACH DR900.in hugen Unit. The turbidity of sample estimated by Turbidity meter Model no. Elico-CL 52D. E-Coli test was done by bacterial test for CFU per 100 ml by standard test method. The Connectivity of sample was analyzed by Connectivity meter Model no. Elico-CM 180.

## 3. Results and discussion

The methodology adopted for the treatment of lake water was MBR and NF's combination in the best possible manner.

(a)

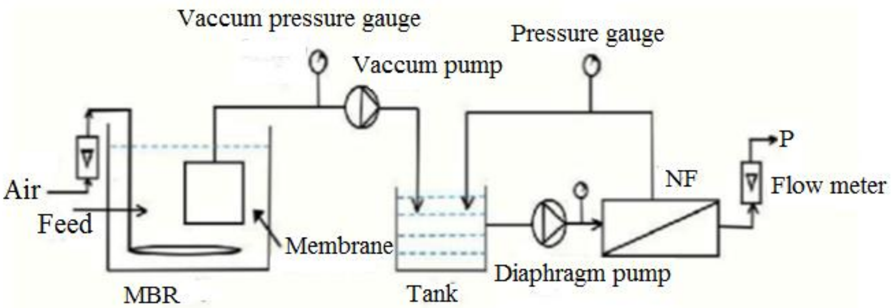


**Fig. 2**. (a) Pictures of the MBR and NF used during the experiments and (b) Schematic representations of Hybrid MBR & NF System.

Fig. 3 shows the trend of COD removal at room temperature for 5 h batch. Initially, 370 mg/l influent treated by MBR reduce to 105 mg/l with 71.62% COD removal after 5 h batch then it passed to the NF unit, and the final effluent value was observed 16 mg/l with 95.67 % after 5 h batch. The resulting sample obtained good water quality.

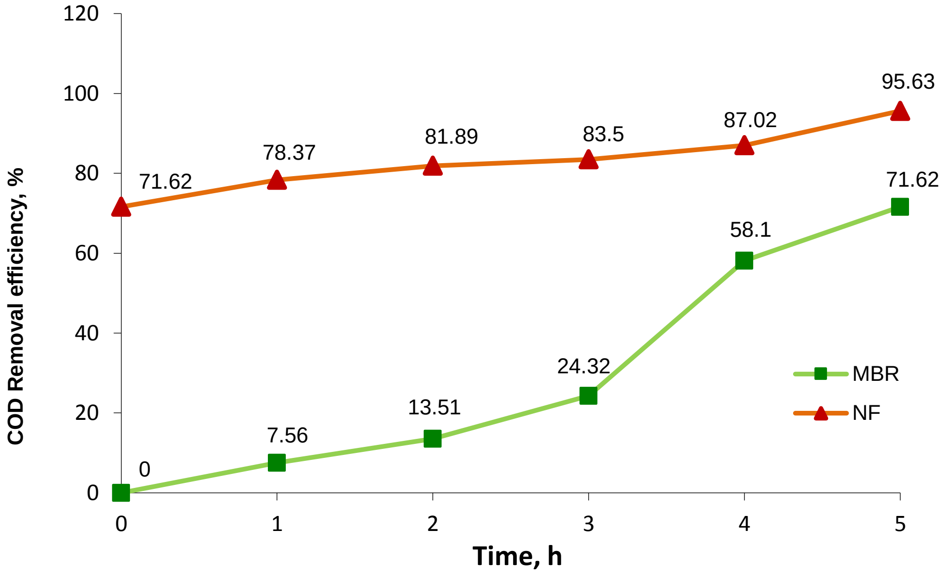


**Fig. 3.** Variations of overall COD removal efficiency with time.

Fig. 4 shows the trend of BOD removal for 5 h batch. Initially, 280 mg/l influent treated by SMBR reduce to 98 mg/L with 65 % BOD removal after 5 hrs batch then it passed to the NF unit, and the final effluent value was observed 15 mg/l with 94.64 % after 5 h batch. The final sample was obtained as good quality of water. Fig. 5 shows the hybrid MBR and NF system for TDS removal concerning the time at room temperature. It shows the trend of TDS removal for 5 h batch. Initially, 535 mg/L influent treated by SMBR reduces to 290 mg/l with 45.79 % TDS removal after 5 h batch, then it passed to the NF unit, and the final effluent value was observed 41 mg/L with 92.33 % after 5 h batch.

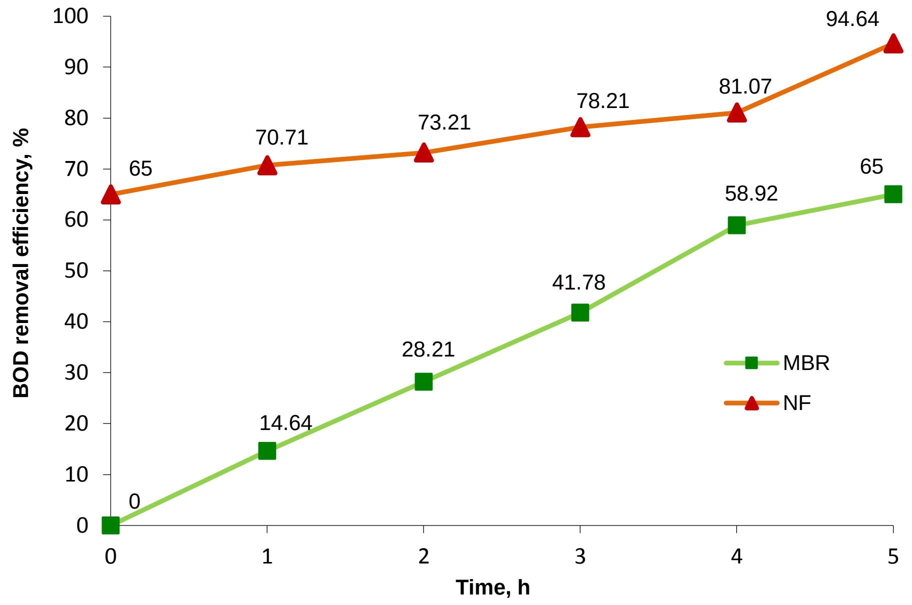


**Fig. 4.** Variations of overall BOD removal efficiency with time.

Fig. 5 shows the hybrid MBR and NF system for TDS removal concerning the time at room temperature. It shows the trend of TDS removal for 5 h batch. Initially, 535 mg/L influent treated by SMBR reduces to 290 mg/L with 45.79 % TDS removal after 5 h batch, then it passed to the NF unit, and the final effluent value was observed 41 mg/L with 92.33 % after 5 h batch.

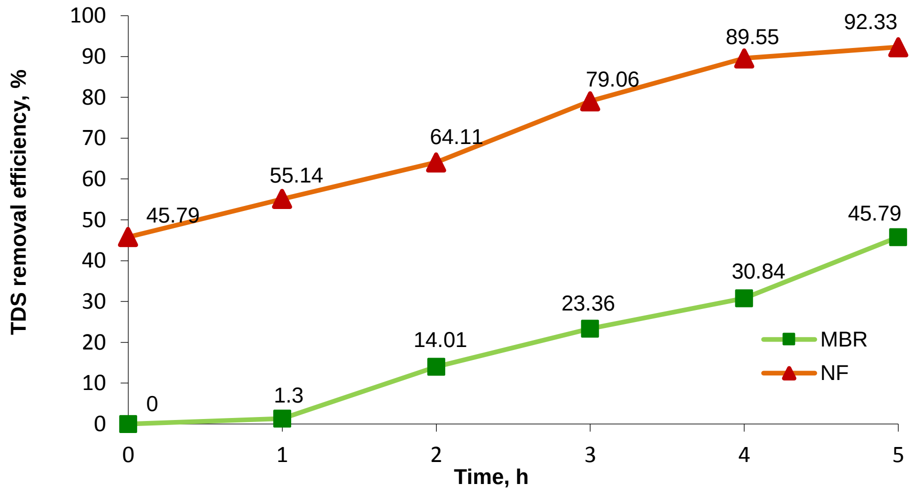


**Fig. 5.** Variations of overall TDS removal efficiency with time.

Fig. 6 shows overall TSS removal at different airflow rates at room temperature for batch of 5 h. There observed that, as time increases TSS removal efficiency increases at different airflow rates. It shows the results during the period of 1-5 h of batch experiments, the observed TSS removal efficiency of the system was 23.84 to 36.00 % for the airflow rate ranges of 0.6 to 1.0 L/min. It was found, as aeration rate and time increases, TSS removal efficiency increases. The initial sample has TSS of 1300 mg/L for all airflow rates; after MBR treatment, it increases 1610, 1695, 1705, 1754, and 1768 mg/L at 0.6 0.7, 0.8, 0.9, and 1.0 L/min, respectively. The result shows that maximum TSS removal efficiency was observed at airflow rate of 1.0 L/min for 5 h batch operations.

Fig. 7 shows the pH variation trend during 5 h of a batch-wise run at room temperature. It shows the result during the period of 1-5 h of the batch experiment; the system's observed pH showed a small decrease for all airflow rates.

Fig. 8 shows the trend of permeate flow during the period of 5 h of batch-wise run. It shows the measured permeate flow at constant feed pressure 3 bar and retentate pressure 1 bar. There observed that as time increases, permeate flow rate decreases. Initially, permeate flow rate was found as 100 l/h; after NF treatment, it reduces to 71 l/h.

Hence, from the above information, this technique to treat Ambazari lake water using hybrid MBR+NF combination was successful enough to attain as good as potable water quality with environment protection norms. Table 2 shows that, analysis of lake water before and after MBR+NF treatment and permeate comparison with Maharashtra pollution control board (MPCB) and general Indian water standards.

The hybrid MBR-NF system appears a feasible treatment option as compare to other conventional technologies to fulfill exploit standards. This new combine system has a modular configuration, compact size and low power consumption that reduces production cost. However, it is an economical, eco-friendly, clean process and requires a simple and inexpensive filtration process. Rejuvenation of lake water and improving with significant sustainable development for domestic, industrial, and global environments can be achieved.

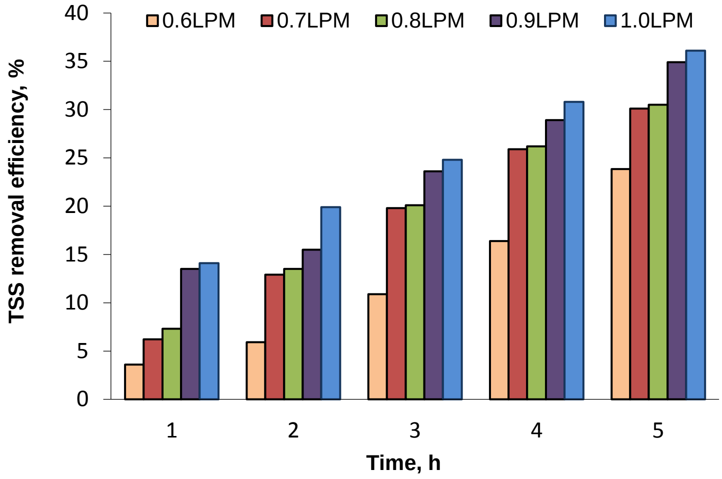


**Fig. 6.** TSS removal efficiency with time at different flow rates.

**Table 2.** Analysis of lake water before and after MBR+NF treatment and permeate comparison with MPCB and general Indian water standards.

| Parameters | Lake water before treatment (Influent) | Lake water after treatment (Effluent) | Permissible limit MPCB | Permissible limit general Indian standards |
|---|---|---|---|---|
| pH | 7.9 | 7.7 | 6.5-8.5 | 6.5-8.5 |
| COD | 370 mg/L | 16 mg/L | 250 | 250 |
| BOD | 280 mg/L | 15 mg/L | 100 | 100 |
| TDS | 535 mg/L | 41 mg/L | 250 | 250 |
| DO | 5.2 mg/L | 10.5 mg/L | 8.5-10 | 8.5-10 |
| Colour | Greenish | Colourless | 5 units (pt. cobalt scale) | 5-25 Hazen units |
| Odour | Nose irritating | Odourless | Unobjectionable | Unobjectionable |

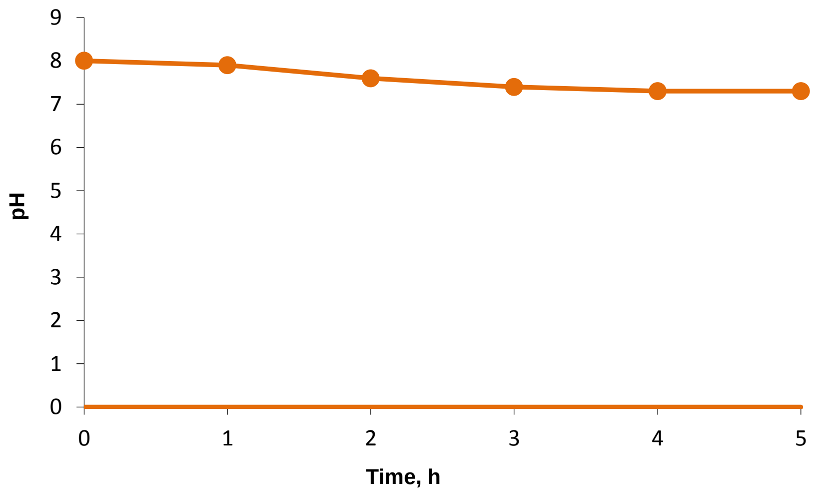


**Fig. 7.** Variation trend of pH with time.

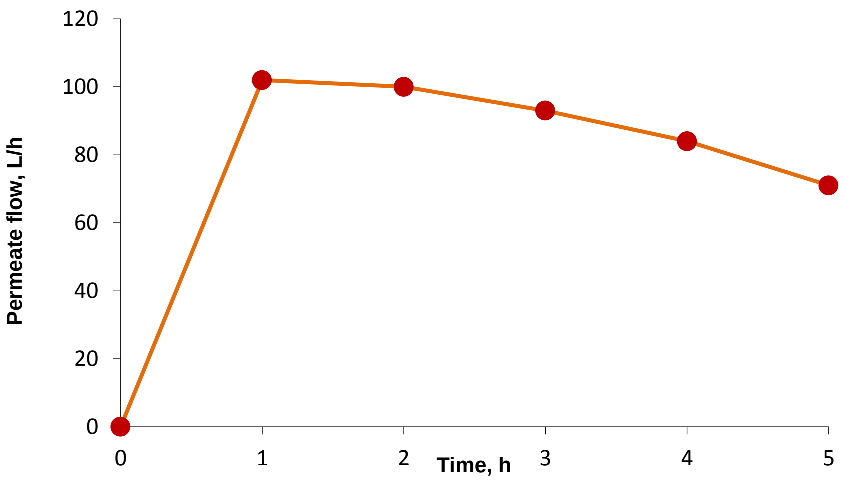


**Fig. 8.** Variations of permeate flow rate with time.

### 4. Conclusions

This study investigated combination of MBR and NF system for treatment of lake water. The COD, BOD and TDS reduction has been obtained to be 95.67 %, 94.64 % and 92.33 %, respectively. The TSS removal efficiency was found to be 36.0 % for airflow rates of 1.0 L/min. It has been observed that the pH variations at different airflow rates are significantly less. As time increases permeate flow rate, effluent BOD, COD, and TDS values reduce. Hence, from the results, we conclude that the hybrid MBR+NF system was successful to treat Ambazari lake water. The treated water had a high quality as good as potable water. This hybrid system can be applied to treat both municipal and industrial wastewaters. It also has applications in various industries like food, pharmaceutical, textile, and pulp and paper industries.

### Nomenclature

| | |
|---|---|
| BOD | Biochemical oxygen demand |
| COD | Chemical oxygen demand |
| CFU | Colony forming units |
| DO | Dissolved oxygen |
| LPM | Liter per minute |
| MBR | Membrane bioreactor |
| MLSS | Mixed liquid suspended solids |
| MF | Microfiltration |
| MPCB | Maharashtra pollution control board |
| NF | Nanofiltration |
| PFR | Permeate flow rate |
| RO | Reverse osmosis |
| SMBR | Submerged membrane bioreactor |
| TDS | Total dissolved solids |
| UF | Ultrafiltration |

### Acknowledgement

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