

# A REVIEW ON WASTE WATER TREATMENT USING MEMBRANE BIOREACTOR

Soumya Gupta

MTech. Biotechnology

School of Biosciences and Technology

Vellore Institute of Technology, Vellore, Tamil Nadu

## **ABSTRACT**

The advancements in technologies are important source of discharge of adulterants in the environment. Wastewater is major pollutant which is produced in very large from domestic use and different industries such as dairy industry, pharmaceutical industry, food industry etc. Here, the discussion is about membrane bioreactor, efficiently used for waste-water treatment which is produced from various sources in to make it fit for its release in the environment. Microfiltration and ultra-filtration techniques used by membrane bioreactor makes it more efficient for maintaining the pH, COD removal, BOD, total quantity of solids in wastewater.

**keywords:** pH, Total suspended solids, BOD, membrane bioreactor, wastewater ,microfiltration, ultrafiltration, COD, aerobic, environment,

## **1. INTRODUCTION**

Inadequate water quality is produced from industries, commercial and agricultural activities (Tilley, 2014).This water is adverse for human health and also for the animals, plants. It causes some serious harm to the people therefore water treatment should be done well before use.

The various waste water source from household activities include human excreta, surfactants etc. Industries facing difficulties to treat pharmaceutical non-biodegradable waste Industries produce waste (Naddeo, Meriç, Kassinos, Belgiorno, & Guida, 2009) or pesticide manufacturing, production of oil and natural gas, Physical and chemical pollutants: fluorinated compound(Arvaniti & Stasinakis, 2015), hormones(Bletsou, Asimakopoulos, Stasinakis, Thomaidis, & Kannan, 2013), substances which harms our endocrine system (Gatidou et al., 2016) and polyamides and polyesters (Gatidou, Arvaniti, & Stasinakis, 2019) produce polluted water.

Biological pollutants can have tendency of water deterioration quality. Non- pathogenic bacteria, arthropods and small fishes also degrade the purity of water wastage (Andersson, 2016) and pollution in water is increasing. Therefore elimination of scarcity of water for humans, plants and animals, the wastewater produced from various domestic, industrial, agricultural sources etc should be made free from waste.

Removal of the pathogenic microbes, color and waste water odour is the elimination of harmful agents from water and it should not pose any threat to human health (Organization WHO, 2006) and the pure fluid can be returned to water cycle without any ill effect on the environment. Treatment of waste-water is a part of a technique known as sanitation.

There are a variety of methods for it like implementation of processes using biologically available agents which involves aerobic condition presence – aerated lagoons and activated sludges etc. Other bioreactors which are used for treatment such continuous stirred tank reactor, membrane bioreactor (Samer, 2015). Membrane bioreactors are the bioreactors which are made up of combination of ultra-filtration and micro filtration techniques with biological waste water for treatment.

For waste from municipalities and industries membrane bioreactor is widely(Hernaningsih, 2014). In this a grid to terminate solid waste, a pre-treatment chamber where waste water is pretreated, the water is then aerated and passed through filters and is disinfected. Further the treated water is collected and is considered fit for different purposes (Pandey & Singh, 2014)

Membrane bioreactors may provide with plenty opportunities to overcome a lot of problems in sludge activation which results tertiary treatment. Exhibition of high operational reliability and delivery of pure effluent hygienically are step concerning qualities (Morrow et al., 2018). Membrane bioreactor can produce the high quality effluent which is treated well to enable it being discharged in water bodies or to reuse it.

Waste water can be treated by membrane bioreactor containing suspended solids with high concentration. Bioreactors are of two types which are used which include submerged membrane bioreactor which is present in the integral portion of bioreactor and an external membrane bioreactor having separate membrane unit (Atkinson, 2006)

## **2. METHODS AND DESCRIPTION**

There are plenty settings which are required for membrane bioreactor such as extraction and diffusion systems (Livingston et al., 1998) In extractive systems to extract specific component from one side of membrane to another for discrete bio treatment or remaining effluent treatment (M. S. Lee, 2007) .To magnify the use for treatment, diffusive Membrane bioreactors are installed in which the membrane was involved in gaseous input form of molecule (Stephenson, 1994) without having to undergo dissolution, it symbolizes that the gas was allowed to pass directly into the biofilm, formed directly on membrane (K.-C. Lee & Rittmann, 2002) It leads to the complete use of the gas as compared with conventional sparging (McAdam & Judd, 2006). The membrane bioreactors therefore require a bioreactor setup with the membrane for ultrafiltration or micro filtration technique.

### **2.1 Wastewater from municipalities**

The wastewater from municipalities is treated to remove carbon, nitrogen and also harmful bacteria and viruses from it (Rosenberger et al., 2002). In this removal the wastewater the foremost thing to be kept in mind for high quality of effluent should be maintained (Sari Erkan, Bakaraki Turan, & Önköl Engin, 2018)

Oxygen demand in water is gained by using aerobic membrane bioreactors in municipal wastewater treatment (Judd, 2010) and elimination of coliform bacteria. A pilot scale research was conducted using HF membrane (Wei, Huang, Aim, Yamamoto, & Amy, 2011) (Habib et al., 2017)worked on membrane blocking by studying relaxation effect on it during wastewater treatment by Membrane bioreactor. Several times relaxation period was taken into consideration from zero to two minutes with increment of 0.5 min and filtration was done for a total of 10 minutes. Freeing of waste from industries from contaminants depends on industry type from which wastage is coming.

### **2.2 Industrial wastewater treatment**

The wastewater from industries consists of many environment harming agents. The various parameters which have to be kept in mind are pH , oxygen demand of chemical , biological oxygen demand, total solids which are suspended in the wastewater to be treated, total amount of nitrogen present in water, ammonia, concentration of heavy metals ,turbidity (Dohare & Trivedi, 2014). Biological agents i.e. microbes are not very effective due to very high pH and salts(Lefebvre & Moletta, 2006)

Salts of high concentration are found mostly in wastewater from leather industries, petroleum industries etc. Physico-chemical methods are preferred for salty water from industries. Bioreactors with membranes are setup for the industrial wastewater for low salt concentration as these bioreactors eliminate the major harmful contents like phenols and volatile compounds and also maintain the BOD and COD of wastewater.

The wastewater is treated so well that there is no need for the tertiary treatment of water (Sipma, Osuna,

Emanuelsson, & Castro, 2010). (Marrot & BARRIOS-MARTINEZ, n.d.) in his review concluded that submerged membrane bioreactor is very advantageous for the eliminating waste from water than the conventional methods. The main focus of the study was on the removal of COD and TSS.

### **2.3 Wastewater from food industry**

A lot of wastewater is generated from industries with food production which is a potent source of environmental pollution. It is very costly for produced waste water when it comes to its treatment as it consists a lot of organic compounds, total suspended solids, fat and oil grease concentration (Mutamim, Noor, Hassan, & Olsson, 2012). In addition, it has high biochemical and chemical oxygen demand. (Jianlong & Jing, 2005) Anoxic and membrane bioreactor combination is used in their study. They pumped the wastewater via anoxic bioreactor and then allowed it move through bioreactor for treatment. For the removal of nitrogen liquid mixture from reactor was transferred to anoxic bioreactor to provide a mechanical mixing with  $21\text{h}^{-1}$  flow rate.

In another study the membrane bioreactor was involved remove suspended solids and COD of wastewater (Kleerebezem & Macarie, 2003). Suspended solids are eliminated by anaerobic bioreactor from waste and also reduced the COD of wastewater and Membrane Fouling was a limiting factor. (Farizoglu & Uzuner, 2011) conducted their study on wastewater from dairy industry with biological high-performance system. There were different parameters which were observed such as the organic compounds and the hydraulic time.

### **2.4 Paper and pulp Mill Wastewater**

A lot of required in the paper industry for pulp preparation and for the bleaching of paper by destroying the lignin which turns the paper white in color (Lerner, Stahl, & Galil, 2007). It has been estimated that on an average for every ton of its production in the paper industry 17,000 gallons of water which has been industrially processed is required (Južnić, 2018). The wastewater produced has impacted the environment thermally and has also raised in the growth of slimes in the surroundings.

Membrane bioreactors have been used to reduce wastewater released in nature by treating it (Bérubé & Hall, 2000) (Dias, Rezende, Silva, & Linardi, 2005). The membrane bioreactors used were able to remove the suspended solids, maintain the COD level and also made it less harmful to be discharged (Lin, Lee, & Huang, 2010). There were various studies which were conducted that indicated that ancient systems were not as efficient as this bioreactor system. It was so because chemical oxygen demand removal efficacy was more in this system. The pH could be maintained and the total suspended solids can be removed more effectively.

### **3. RESULT AND DISCUSSION**

#### **3.1 Wastewater from municipalities**

Different studies which have been discussed above for the indicated that there are certain factors which needs to be considered for purifying water from municipalities like oxygen content in water should be maintained which was shown by (Wei et al., 2011) in which the concentration of COD, BOD,  $\text{NH}_4\text{-N}$ , and TP was found to be 40, 1, 3.4, and 1.5 mg/L. In observation, coliform bacteria were not found.

(Ueda & Hata, 1999) confirmed the BOD (biological oxygen demand), TOC( total oxygen content), Total suspended solids and coliform bacteria removal efficiencies were found to be 99%, 93%, 100%, 79%, 74% and 6 log units. The nitrogen and carbon level should be decreased to make it fit for use. Membrane bioreactors proved to be a very useful tool for improving the quality of water.(Habib et al., 2017) observed in his study that the 96.5% efficiency changed.

Without relaxation of removal of COD varied from 96.5% and in the range 92% and 96.5% with relaxation. Total % of Nitrogen pull out efficiency was 79.2% without relaxation and from 85.5% - 81.7% with range of 1 to 2 min.

#### **3.2 Wastewater from industries**

The toxic and the harmful compounds from wasterwater can be withdrawn using membrane bioreactors. These bioreactors use fine membrane and follow the principle of ultrafiltration. High salt containing wastewater cannot be treated by these bioreactors as there could be a problem of microbial inhibition and also the deflocculation of sludge.

(Yang, Cicek, & Ilg, 2006) stated in his study that extreme pH, high toxicity etc can be treated really well in submergerd bioreactors and therefore it has proved to be very advantageous The total amount of solids suspended in the industrial wastewater can be washed off with this bioreactor.

#### **3.3 Wastewater from food industry**

(Jianlong & Jing, 2005) observed from their study that change in rate of COD loading was from 1.2-3.4 kg COD  $\text{m}^{-3} \text{day}^{-1}$ , % of COD flushed off from 72.2 to 97.5. The maximum volumetric  $\text{NH}_4^+ - \text{N}$  and Total load of Nitrogen was 1.02 kg N  $\text{m}^{-3} \text{day}^{-1}$

(Farizoglu & Uzuner, 2011) used high performance biological membrane system and observed the organic load was

53 kg COD/m<sup>3</sup> /day, percentage of Chemical oxygen demand was 97%–98% in 3 h of hydraulic retention time. Thus it was concluded from the studies that these bioreactors functions effectively as the total dissolved solids, oil and grease waste, COD and other toxic compounds can be removed.

### **3.4 Pulp and Paper Mill Wastewater**

(Lin et al., 2010) reported in his study that membrane bioreactors process can generally remove 82%–99% of COD and 100% of Solids suspended. In the comparative studies conducted between the conventional and the membrane bioreactor system. (Bertanza et al., 2017) A COD, N<sub>2</sub> and phosphorus mass balance was estimated. COD removal was approximately same in both systems .The only difference was that a slightly higher amount of oxidation of COD in water line of the Membrane Bioreactor system (+5%).

Similarly in case of nitrogen the difference was a slightly better quality of effluent obtained due to better retention of slow-growing nitrifying biomass. The effluent phosphorus concentration is slightly higher for the MBR comparatively (1.0 vs 0.6 mg/L). This reduced discharge of Phosphorus with the excess and dewatered sludge for the MBR system.

(Dufresne, Lavallee, Lebrun, & Lo, 1998) stated the same results for the removal to contaminants to reuse the water. (Galil, Sheindorf, Stahl, Tenenbaum, & Levinsky, 2003) conducted a research on membrane bioreactor system and conventional activated sludge system for improving effluent quality from an anaerobic reactor and observed that the removal efficiency of COD using conventional method was only 86% in case of organic load of 1 kg COD/m<sup>3</sup> which was very less.

## **4. CONCLUSION**

In the study it was concluded that membrane bioreactor system is an efficient system to enhance wastewater quality that is produced from various industries. It can treat the wastewater on a pilot scale mainly. The membranes used in this bioreactor are cheaper, easily available and can be reused numerous times. The production cost is cut down as the water can be so well treated that it is fit for reuse.

The system proved itself to be much better than the conventional methods used for wastewater treatment process which enables it to be more precise and more beneficial. The comparative studies between the conventional and bioreactor system indicated that the observation with respect to chemical oxygen demand removal, pH maintenance, total solids suspended and N<sub>2</sub> and Phosphorus removal from wastewater made it fit for reuse was much more by modern method.

Thus, membrane bioreactor system proved to have much more advantages than the conventional methods. The let down condition of the system is its incapability to purify wastewater with high salt concentration. Thus to overcome this drawback one could use a membrane bioreactor with halophilic bacteria as they have an ability to grow in high salt concentration.

## 5. ACKNOWLEDGMENT

I would like to show my gratitude towards my institute and my faculties for encouraging me to work on this review article.

## 6. REFERENCES

- Andersson, K. (2016). *Sanitation, wastewater management and sustainability: from waste disposal to resource recovery*. UN Environmental Programme Global Programme of Action for the protection of ....
- Arvaniti, O. S., & Stasinakis, A. S. (2015). Review on the occurrence, fate and removal of perfluorinated compounds during wastewater treatment. *Science of The Total Environment*, 524–525, 81–92. <https://doi.org/https://doi.org/10.1016/j.scitotenv.2015.04.023>
- Atkinson, S. (2006). Research studies predict strong growth for MBR markets. *Membrane Technology*, 2006(2), 8–10. [https://doi.org/https://doi.org/10.1016/S0958-2118\(06\)70635-8](https://doi.org/https://doi.org/10.1016/S0958-2118(06)70635-8)
- Bertanza, G., Canato, M., Laera, G., Vaccari, M., Svanström, M., & Heimersson, S. (2017). A comparison between two full-scale MBR and CAS municipal wastewater treatment plants: techno-economic-environmental assessment. *Environmental Science and Pollution Research*, 24(21), 17383–17393. <https://doi.org/10.1007/s11356-017-9409-3>
- Bérubé, P. R., & Hall, E. R. (2000). Effects of elevated operating temperatures on methanol removal kinetics from synthetic kraft pulp mill condensate using a membrane bioreactor. *Water Research*, 34(18), 4359–4366.
- Bletsou, A. A., Asimakopoulos, A. G., Stasinakis, A. S., Thomaidis, N. S., & Kannan, K. (2013). Mass Loading and Fate of Linear and Cyclic Siloxanes in a Wastewater Treatment Plant in Greece. *Environmental Science & Technology*, 47(4), 1824–1832. <https://doi.org/10.1021/es304369b>
- Dias, J. C. T., Rezende, R. P., Silva, C. M., & Linardi, V. R. (2005). Biological treatment of kraft pulp mill foul condensates at high temperatures using a membrane bioreactor. *Process Biochemistry*, 40(3–4), 1125–1129.
- Dohare, D., & Trivedi, R. (2014). A review on membrane bioreactors: an emerging technology for industrial wastewater treatment. *International Journal of Emerging Technology and Advanced Engineering*, 4(12), 226–236.

- Dufresne, R., Lavallee, H.-C., Lebrun, R.-E., & Lo, S.-N. (1998). Comparison of performance between membrane bioreactor and activated sludge system for the treatment of pulping process wastewaters. *Tappi Journal*, 81(4), 131–135.
- Farizoglu, B., & Uzuner, S. (2011). The investigation of dairy industry wastewater treatment in a biological high performance membrane system. *Biochemical Engineering Journal*, 57, 46–54.
- Galil, N. I., Sheindorf, C., Stahl, N., Tenenbaum, A., & Levinsky, Y. (2003). Membrane bioreactors for final treatment of wastewater. *Water Science and Technology*, 48(8), 103–110.
- Gatidou, G., Arvaniti, O. S., & Stasinakis, A. S. (2019). Review on the occurrence and fate of microplastics in Sewage Treatment Plants. *Journal of Hazardous Materials*, 367, 504–512. <https://doi.org/https://doi.org/10.1016/j.jhazmat.2018.12.081>
- Gatidou, G., Kinyua, J., van Nuijs, A. L. N., Gracia-Lor, E., Castiglioni, S., Covaci, A., & Stasinakis, A. S. (2016). Drugs of abuse and alcohol consumption among different groups of population on the Greek Island of Lesbos through sewage-based epidemiology. *Science of The Total Environment*, 563–564, 633–640. <https://doi.org/https://doi.org/10.1016/j.scitotenv.2016.04.130>
- Habib, R., Asif, M. B., Iftexhar, S., Khan, Z., Gurung, K., Srivastava, V., & Sillanpää, M. (2017). Influence of relaxation modes on membrane fouling in submerged membrane bioreactor for domestic wastewater treatment. *Chemosphere*, 181, 19–25.
- Hernaningsih, T. (2014). Aplikasi Membrane Bioreactor (Mbr) untuk Proses Daur Ulang Air Limbah. *Jurnal Air Indonesia*, 7(2).
- Jianlong, W., & Jing, K. (2005). The characteristics of anaerobic ammonium oxidation (ANAMMOX) by granular sludge from an EGSB reactor. *Process Biochemistry*, 40(5), 1973–1978.
- Judd, S. (2010). *The MBR book: principles and applications of membrane bioreactors for water and wastewater treatment*. Elsevier.
- Južnić, A. (2018). *Određivanje kemijskih parametara filtrata odlagališta komunalnog otpada*. University of Zagreb. Faculty of Mining, Geology and Petroleum Engineering ....
- Kleerebezem, R., & Macarie, H. (2003). Treating industrial wastewater: anaerobic digestion comes of age: anaerobic treatment systems offer important advantages over conventionally applied aerobic processes for removing organic pollutants from water-based streams.(Cover Story). *Chemical Engineering*, 110(4), 56–65.
- Lee, K.-C., & Rittmann, B. E. (2002). Applying a novel autohydrogenotrophic hollow-fiber membrane biofilm reactor for denitrification of drinking water. *Water Research*, 36(8), 2040–2052.

[https://doi.org/https://doi.org/10.1016/S0043-1354\(01\)00425-0](https://doi.org/https://doi.org/10.1016/S0043-1354(01)00425-0)

- Lee, M. S. (2007). Enhancement of phenol transfer through dense membrane in an extractive membrane bioreactor. *Proceedings of the 4th IWA Membranes Conference: Membranes for Water and Wastewater Treatment: 2007 May 15–17; Harrogate*. Cranfield University Press.
- Lefebvre, O., & Moletta, R. (2006). Treatment of organic pollution in industrial saline wastewater: a literature review. *Water Research*, 40(20), 3671–3682.
- Lerner, M., Stahl, N., & Galil, N. I. (2007). Comparative study of MBR and activated sludge in the treatment of paper mill wastewater. *Water Science and Technology*, 55(6), 23–29.
- Lin, J. C.-T., Lee, D.-J., & Huang, C. (2010). Membrane fouling mitigation: Membrane cleaning. *Separation Science and Technology*, 45(7), 858–872.
- Livingston, A. G., Arcangeli, J.-P., Boam, A. T., Zhang, S., Marangon, M., & Freitas dos Santos, L. M. (1998). Extractive membrane bioreactors for detoxification of chemical industry wastes: process development. *Journal of Membrane Science*, 151(1), 29–44. [https://doi.org/https://doi.org/10.1016/S0376-7388\(98\)00237-3](https://doi.org/https://doi.org/10.1016/S0376-7388(98)00237-3)
- Marrot, B., & BARRIOS-MARTINEZ, A. (n.d.). P. MOULIN et N. ROCHE (2004). *Industrial Wastewater Treatment in a Membrane Bioreactor: A Review*. *Environ. Prog*, 23, 59–68.
- McAdam, E. J., & Judd, S. J. (2006). A review of membrane bioreactor potential for nitrate removal from drinking water. *Desalination*, 196(1), 135–148. <https://doi.org/https://doi.org/10.1016/j.desal.2006.03.008>
- Morrow, C. P., Furtaw, N. M., Murphy, J. R., Achilli, A., Marchand, E. A., Hiibel, S. R., & Childress, A. E. (2018). Integrating an aerobic/anoxic osmotic membrane bioreactor with membrane distillation for potable reuse. *Desalination*, 432, 46–54. <https://doi.org/https://doi.org/10.1016/j.desal.2017.12.047>
- Mutamim, N. S. A., Noor, Z. Z., Hassan, M. A. A., & Olsson, G. (2012). Application of membrane bioreactor technology in treating high strength industrial wastewater: a performance review. *Desalination*, 305, 1–11.
- Naddeo, V., Meriç, S., Kassinos, D., Belgiorno, V., & Guida, M. (2009). Fate of pharmaceuticals in contaminated urban wastewater effluent under ultrasonic irradiation. *Water Research*, 43(16), 4019–4027. <https://doi.org/https://doi.org/10.1016/j.watres.2009.05.027>
- Organization, W. H. (2006). *WHO guidelines for the safe use of wastewater excreta and greywater* (Vol. 1). World Health Organization.
- Pandey, A., & Singh, R. K. (2014). *Industrial Waste Water Treatment by Membrane Bioreactor System Industrial Waste Water Treatment by Membrane Bioreactor System*. (April).

- Rosenberger, S., Krüger, U., Witzig, R., Manz, W., Szewzyk, U., & Kraume, M. (2002). Performance of a bioreactor with submerged membranes for aerobic treatment of municipal waste water. *Water Research*, 36(2), 413–420. [https://doi.org/https://doi.org/10.1016/S0043-1354\(01\)00223-8](https://doi.org/https://doi.org/10.1016/S0043-1354(01)00223-8)
- Samer, M. (2015). Biological and Chemical Wastewater Treatment Processes. In *Wastewater Treatment Engineering*. <https://doi.org/10.5772/61250>
- Sari Erkan, H., Bakaraki Turan, N., & Önkall Engin, G. (2018). Chapter Five - Membrane Bioreactors for Wastewater Treatment. In D. S. Chormey, S. Bakirdere, N. B. Turan, & G. Ö. B. T.-C. A. C. Engin (Eds.), *Fundamentals of Quorum Sensing, Analytical Methods and Applications in Membrane Bioreactors* (Vol. 81, pp. 151–200). <https://doi.org/https://doi.org/10.1016/bs.coac.2018.02.002>
- Sipma, J., Osuna, M. B., Emanuelsson, M. A. E., & Castro, P. M. L. (2010). Biotreatment of industrial wastewaters under transient-state conditions: process stability with fluctuations of organic load, substrates, toxicants, and environmental parameters. *Critical Reviews in Environmental Science and Technology*, 40(2), 147–197.
- Stephenson, T. (1994). *Hollow fibre bioreactor for wastewater treatment using bubbleless membrane aeration*. 1354(December 2017). [https://doi.org/10.1016/0043-1354\(94\)90037-X](https://doi.org/10.1016/0043-1354(94)90037-X)
- Tilley, E. (2014). *Compendium of sanitation systems and technologies*. Eawag.
- Ueda, T., & Hata, K. (1999). Domestic wastewater treatment by a submerged membrane bioreactor with gravitational filtration. *Water Research*, 33(12), 2888–2892.
- Wei, C.-H., Huang, X., Aim, R. Ben, Yamamoto, K., & Amy, G. (2011). Critical flux and chemical cleaning-in-place during the long-term operation of a pilot-scale submerged membrane bioreactor for municipal wastewater treatment. *Water Research*, 45(2), 863–871.
- Yang, W., Cicek, N., & Ilg, J. (2006). State-of-the-art of membrane bioreactors: Worldwide research and commercial applications in North America. *Journal of Membrane Science*, 270(1–2), 201–211.