THINK INDIA JOURNAL

ISSN:0971-1260

Vol-22- Issue-14-December-2019

Self-Sustaining Sewage Wastewater Treatment By Immersed Membrane Bio Reactor –A Review

Amit Chhillar[1], Rajesh Dhankhar[2], Savita Kalshan[3], Preeti[4] and Poonam[5]

Department of Environmental Science, Maharishi Dayanand University, Rohtak, 124001(Haryana), India

Abstract: Fresh water resources are depleting day by day and many regions in the world have scarce water resources, thus focus has shifted toward water recycling, recovery and reuse. With increase of industrial development, reuse of wastewater is becoming a common practice by sifting from conventional technologies to MBR systems due to low operation and maintenance costs of Membrane Bio reactor. Membrane bioreactor is a combination of conventional activated sludge process (ASP) and membrane separation technology. Membrane Bioreactor (MBR) is a promising technology for treatment of municipal and industrial waste water which represents a cost effective process and handles excellently with the rising needs for converting wastewater into clean water that can be given back to environment without harmful effects. This review article represents on membrane selection, Configurations, Membrane Fouling, Operating parameters and Biological performances for waste water treatment.

Keywords: Membrane Bioreactor, Wastewater treatment, Activated Sludge Process

1. Introduction

Water is a natural resource and the availability of fresh water became bottleneck in entire world. Recycling and reuse of wastewater is can become a supplementing source of available water supply. Untreated contaminants like total solids; total organic solids and total dissolved solids are discharged into the water by municipal and industrial sector. With increase in population and industrial development resulted in the depletion of numerous ecosystems on which human life relies. In India many states are facing water scarcity and emergency condition in many areas such as Maharashtra, Chennai, North India, Rajasthan and Punjab. Rapid increase in population leads to over exploitation of groundwater and fresh water. Many rivers of India polluted due to discharge of wastewater effluents. Increasing awareness for excess water pollution and groundwater contamination has forced industrial and domestic areas for membrane based technology for water need. Industrial effluent generation due to increased industrialization leads to large quantities of high organic biomass, suspended solids which if properly treated, can become an alternative source of recused water by treating through Membrane Bio rector which can remove suspended solids and turbidity close to zero. Wastewater contains toxic substance leads to sludge swelling during membrane separation and affects the resorted water quality.

ISSN:0971-1260

Vol-22- Issue-14-December-2019

The Membrane Bioreactor (MBR) technology has become an extensive solution for management of water scarcity. Membrane bioreactor is a combination of conventional activated sludge process (ASP) and membrane separation technology, it achieves the removal of total solids, high organic and nutrients for a minor bioreactor volume. This process replaced the gravity settling of conventional ASP. First MBR were developed commercially by Dorr-Olive in late 1960s, combining ultra filtration and activated sludge. Membrane Bioreactor replaced the conventional treatment process to single step membrane filtration processes and produces high quality effluent water which is suitable for reuse. In Bioreactor tank, activated sludge and membrane effectively improves the sludge concentration up to MBR 18000 - 19000 mg/L and process involved are1) Biochemical reactions such as, bio-oxidation, fermentation, nitrification and denitrification 2) Membrane Separation for subsequent solids, liquid separation.

This review article provides comprehensive overview of membrane evolution, Function and advantages, Membrane selection, Configurations, Membrane Fouling, Operating Parameters and Biological performances.

1.1 **Evolution of Membrane technology**

Since last 100 years, the conventional activated sludge processes based on clarification is a standard process and membrane based process is still a new approach. The first MBR installation technology commercialized in the 1970 and 1980 was based on MBR configuration was made by Dorr Oliver. The historical way of evolution of Membrane Bio Reactor (MBR) and the various researchers contribute to developed and improved wastewater management system and technology as shown in Figure 1.

ISSN:0971-1260

Vol-22- Issue-14-December-2019

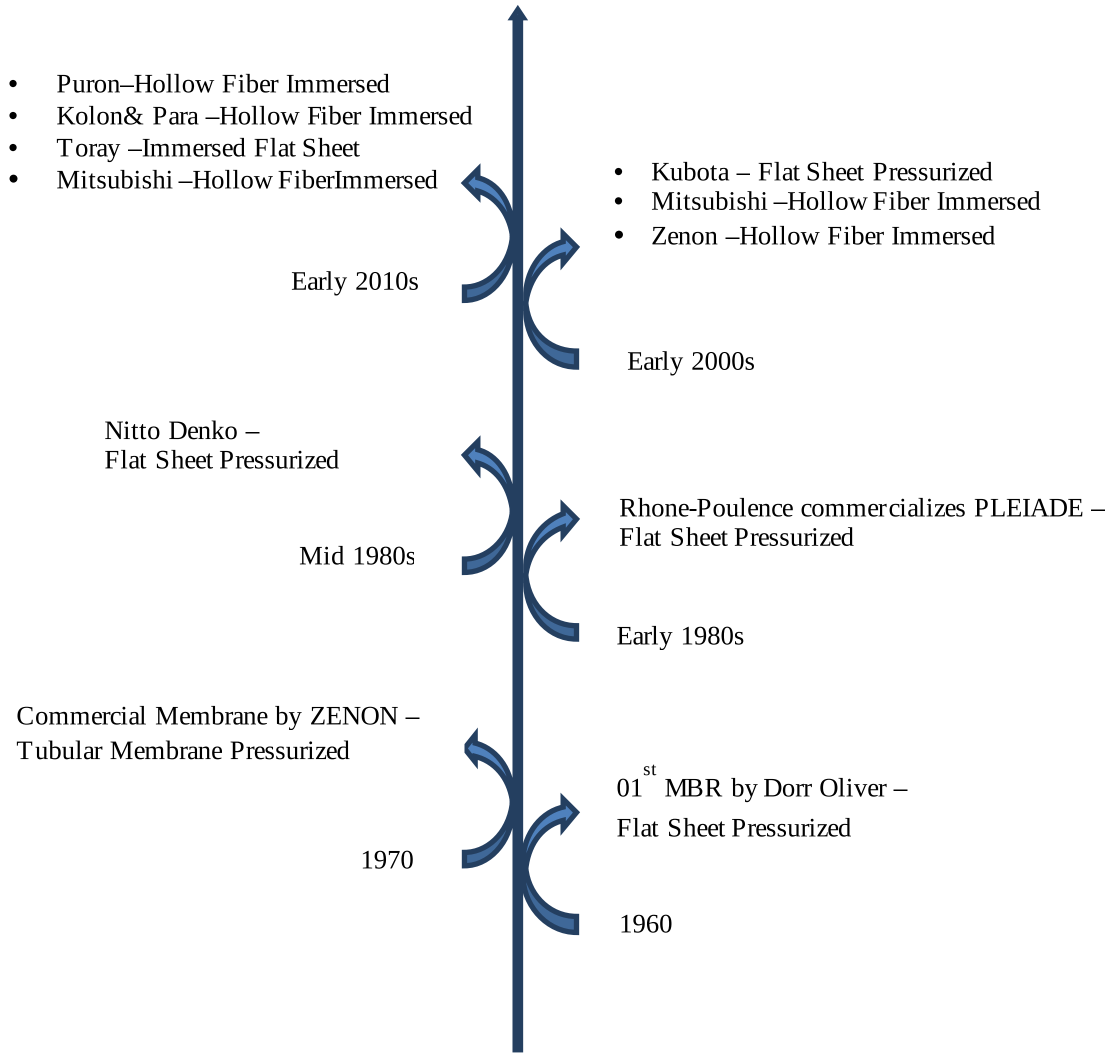


Figure 1. The evolution of Membrane Bio Reactor (MBR) [1]

Present Scenario of membrane bio reactor:

According to membrane bioreactor (MBR) systems market in 2012-2019, Submersed hollow fiber MBR technology proves an excellent and eminent techniques for recycle and re-use of water and seems to be dominate the global market overs the coming years. Entire world facing water scarcity and continuously focus and implementation water reclamation which is expected to achieve fresh water reclamation through MBR technology to 10-12 %. India is its initial stages of development and implementation using MBR technology and many plants across India were commissioned using Membrane Technology.

2. Selection of Membrane and Configuration:

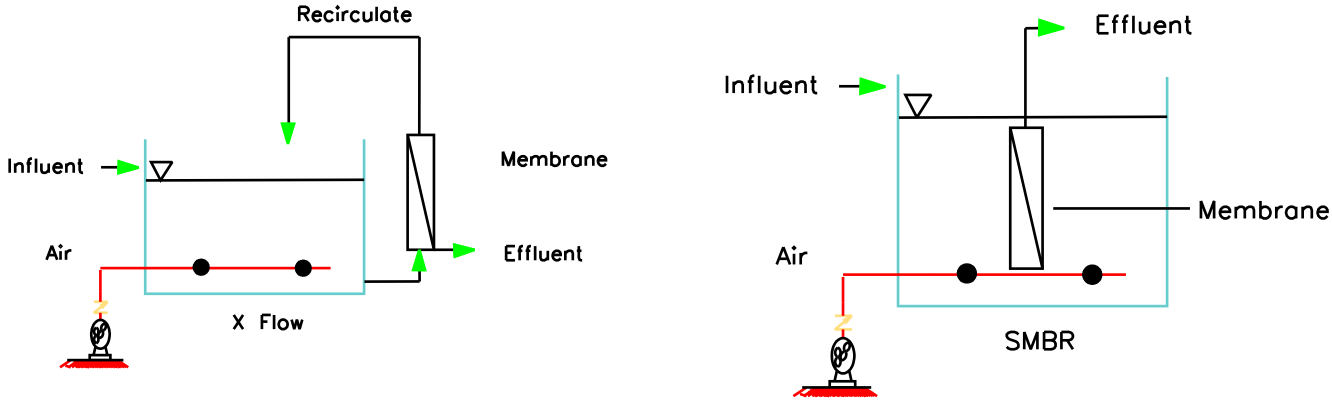
Recent development in field of membrane separation and significant cost reduction in manufacturing membrane, establish MBR process become an alternative source for water treatment and reuse waste water[2]. As evidenced by constantly rising numbers and capacity. Membrane Bioreactor market is

ISSN:0971-1260

Vol-22- Issue-14-December-2019

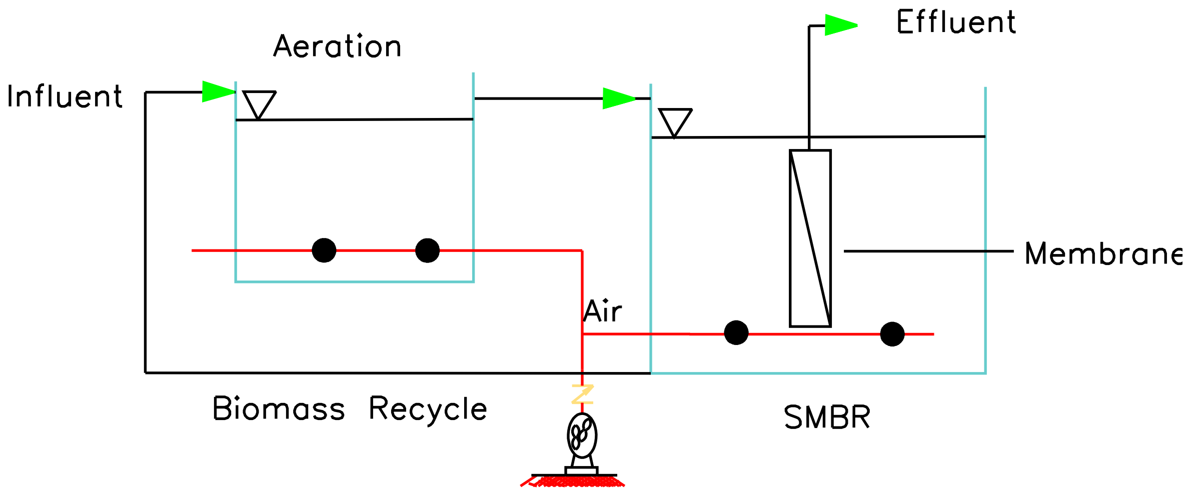
projected to reach $2,927 million by 2019, growth achieved at a CAGR of 15.28% between 2014 and 2019[3].Membrane are made up of variety of materials, including acetate , cellulose, Polyvinylidene difluoride (PVDF), Nitrate, Polysulfone (PS), Polypropylene (PE), poly tetrafluoro ethylene (PTFE) and Poly acrylonitrile. Other types of membrane are used, including ceramic, silicon rubber and ion exchange membranes.

Four decade ago, separate membrane filtration unit operated in cross-flow mode and feed to an aeration tank. This scheme, still used in some applications but require a lot of energy in optimization of each process to maintain sufficient cross-flow velocity which can control membrane fouling. Later in mid-1980s, scheme modified and membrane modules kept submerged directly in the aeration tank which results substantial decrease in energy requirements (up to 6 kWh/m3 for cross-flow versus 1 kWh/m3 for early versions of immersed membranes). Different treatment options were used to achieve good quality treated water from effluent as shown in Figs. 2 (a) and (b) together with further evolution of submerged MBRFigs. 2 (c) and (d)). Installation comparisonwith two different configurations was shown in Figure 2 and configuration comparison shown in table 1. Each configuration has its own advantages and disadvantages in term of operating parameters, power consumption, and footprint[4,5].



ISSN:0971-1260

Vol-22- Issue-14-December-2019



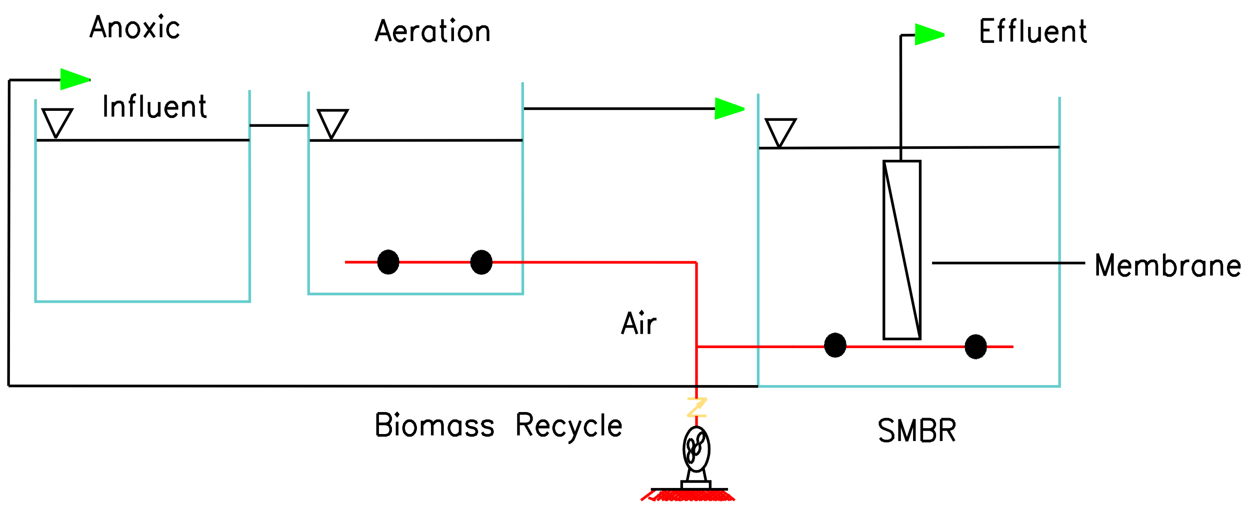


Figure 2. Various MBR configurations

ISSN:0971-1260

Vol-22- Issue-14-December-2019

Table 1. Difference MBR Technology Configuration Comparison

	CASP	Side Stream MBR	Immersed MBR
Configuration[1]	ASP + FST	TU, PF	HF, FS
Type of Operation		Cross Flow	Moderate Cross Flow
Packing Density		High	Low
CAPEX			
Footprint	Normal	> 10-12 times smaller	
Clarifier	Yes	No	
Tertiary Treatment	Sand Filtration	No	
Process Stability	Susceptible to bulking and toxicity	Susceptible to toxicity and high flow	
OPEX			
MLSS (mgL^{-3})	<4500	8000-20000	
HRT (h)	24	10-Aug	
SRT (d)	<20	15-100	
Sludge Yield ($gSS\ g^{-1}\ BOD_5$)	>0.75	<0.8	
Bioreactor Volume (m^3)	Higher	4-5 time smaller	4 time smaller
TMP (bar)	N/A	3-6	0.05-0.7
α Factor	0.6 -0.8	0.3-0.7	0.3-0.7
Permeate flux rates ($L\ m^{-2}\ h^{-1}$)	N/A	50-100	15-50
Permeability ($L\ m^{-2}\ h^{-1}\ kPa^{-1}$)	N/A	0.07-0.3	0.5-5
Recycle ratio (m3 feed m^{-3} effluent)	1.5-2.5	25-75	N/A
Sup. velocity ($m\ s^{-1}$)	N/A	2-6	0.2-0.3[2]
Sup. velocity (m3 air m^{-3} permeate)	N/A	N/A	7-30
Energy consumption ($kWh\ m^{-3}$)	0.15-0.25[3]	4-12[4]	0.2-1[4]
Fouling control methods	N/A	CFV backwashing, chemical cleaning	aeration, backwashing, back plus, relaxation, chemical cleaning

1) Plate and Frame -PF, Tubular –TU, Hollow Fibre –HF and Flat Sheet - FS
2) Data collected from existing big plant
3) Depending upon size and effluent concentration
4) Calculated from gas velocity

3. Membrane fouling

Membrane fouling is the most concern issue in the designing of MBR configuration. Membrane fouling is a process which increases the resistance of water contaminates using the process of adsorption, precipitation and deposition of contaminants. Adsorption process takes place on the pore of a filtration membrane and similarly, deposition process takes place on the surface of membrane. Membrane fouling is important because higher hydraulic resistance and increased energy consumption damage the MBR membrane and other system.

ISSN:0971-1260

Vol-22- Issue-14-December-2019

Membrane fouling types

Membrane fouling is classified into four categories as shown in fig 3. Fouling of membrane categorized on the basis of foulantspresent in the inlet feed concentration.

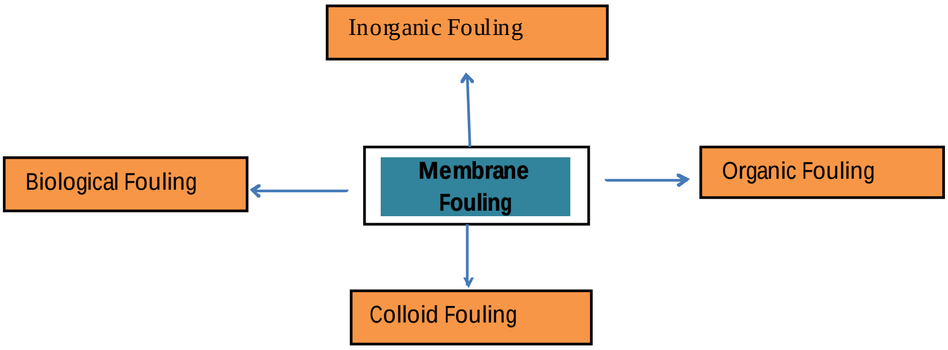


Figure 3. Types of membrane fouling

3.1.1 Colloidal fouling

Colloid fouling is also known as particulate fouling because it consist micro particles, microbes, algae, pathogenic bacteria, etc. these particles different from other colloids particles such as silts, sand and clay. These particles are biological colloids particles and not originated from physical and chemical weathering.

3.1.2 Biological fouling

Biological fouling is also known as Biofouling and microbial fouling. In which microbe's biofilms are formed on the surface of MBR membrane. These microbes and bacteria attached on the surface of membrane multiply microbes growth and produce extracellular polymetric substances (EPS) slimy, viscous hydrated gel. This EPS viscous gel protect bacterial cell from physical and chemical attack.

3.1.3 Organic fouling

Organic fouling is formed due to biopolymers such as polysaccharides, Starch and proteins.These biopolymers deposits on the membrane and block the permeability of MBR membrane. These organic foulants are formed due to metabolic activity of bacteria. Large particles, such as sludge floc, the deposition of organic foulants on the membrane surface are difficult to remove[6]. Organic foulants are

ISSN:0971-1260

Vol-22- Issue-14-December-2019

categorized in three compounds such as colloidal, soluble and particular. Membrane fouling is either reversible orirreversible as shown in fig 4.

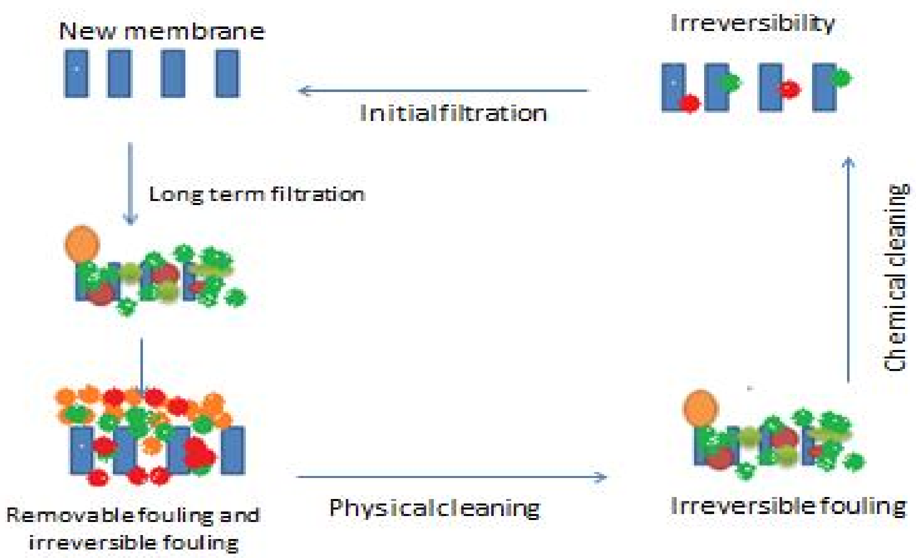


Figure4. Formation and removal of removable and irremovable fouling in MBRs [6]

3.1.4 Inorganic fouling

Inorganic fouling is formed due to accumulation of inorganic precipitates such as metals hydroxides and scale on the surface of MBR membrane. Precipitates are formed due to various chemical compositions present in the wastewater. Scaling is the major concern for various membrane technologies. Inorganic fouling is mainly formed due to polarization concentration.

ISSN:0971-1260

Vol-22- Issue-14-December-2019

Table 2 Comparative study of type of membrane and wastewater

S. No	Type	Type of Waste Water	Remark	Reference
1	MBR V/s Conventional	Sewage Waste and industrial waste	**Oliver TernaIorhemen et. al.** compared the performance of Membrane bioreactor (MBR) technology v/s conventional treatment process and found out that MBR is emerging as new innovations for wastewater treatment [7-8]which overcomes the drawbacks of the conventional / existing technology, including Reduction in foot print, Solid -Liquid separation issues, generation of excessive sludge [9]. Membrane technology can handle wastewater (Industrial and Sewage) treatment and reclamation [10-11] and have many advantages over Activated sludge process which produce reusable quality effluent with less sludge generation, less Retention Time (HRT) and high volumetric load and potential for simultaneous nitrification/denitrification in long SRTs [12,13and 14].	7,8,9,10, 11,12,13 and 14
2	sMBR	Industrial waste water	**Aly Al-Sayed et. al.** tested a bench scale with submerged membrane Bio reactor (SMBR) for waste water reclamation. Experiment was conducted atthree Hydraulic Retention time (HRT): 15, 10 and 06 hrs. COD value of Influent waste water ranged from 250 to 475 ppm, whereas after SMBR treatment the COD values of treated wastewater obtained were 14.06 ±5.2, 19.91 ±2.4 and 20.3 ±4 for HRTs of 15, 10 and 6h, respectively. BOD value of Influent waste water ranged from 213 to 240 ppm, whereas after SMBR treatment the BOD values of treated wastewater obtained were 2.58±1.2, 2.96±1.32 and 2.6±0.8 for HRTs of 15, 10 and 6h, respectively. Assessment of the results indicates that SMBR achieves efficient removals of suspended solids and organic contaminants.	15
3	MBR V/s Conventional	Sewage Waste and industrial waste	**N.I Galil et. al.** compared the performance between conventional treatment process and pilot scale with MBR system. The results show lower suspended solid concentration as 2.5 ppm in MBR as compared to 37 ppm in activated sludge. Similarly, Total organic concentration is 129 ppm in MBR and 204 ppm in conventional activated sludge process. BOD measured as 7.1 pp in MBR v/s 83 ppm thru conventional treatment.	16
4	sMBR	Domestic Waste	**Huang Xia et. al**.evaluated the performance of SMBRefficiency, for the treatment of Domestic waste water. The influent COD concentration was 95-362mg/L; NH_3-N was 14-27 mg/L and Suspended Solids 45-290mg/L and a polyethylene membrane having a pore size of0.1μm was used. The higher efficiency of the reactor has been confirmed by a higher COD, NH_3-N and Suspended Solids removal efficiency (i.e.60%).	17
5	MBR	Industrial Waste	**N.O. Yigita et al.** used a laboratory scale Zenon submerged hollow fiber membrane module made of polyethylene with pore size 0.04μm to treat a textile industrial wastewater. It is stated that with 14 h Hydraulic Retention time and a 25 d	18

ISSN:0971-1260

Vol-22- Issue-14-December-2019

			Sludge Retention Time (SRT), the average concentrations of influent before treatment of color, turbidity, TSS, BOD_5, COD, NH_3-N, NO_3-N and TN were 2443 Pt Co, 294 NTU, 137 mg/L, 455 mg/L, 1411 mg/L, 11.2 mg/L, 42.6 mg/L and 49.2 mg/L. The results showed that the effluent of textile industry treated with submerged membrane bioreactor having the average value of color, turbidity, TSS, BOD_5, COD, NH_3-N, NO_3-N and TN were 53 Pt Co, 0.31 NTU, 0.6 mg/L, 15 mg/L, 37 mg/L, 1.0 mg/L, 9.6 mg/L and 10.5 mg/L respectively.	
6	sMBR	IndustrailWaste Water	Ganpat B More and Sanjay Kumar R Throat did review on Performance evaluation of Membrane Bio Reactor Technology for Treatment of Industrial waste water and reveals thatMBR represents a competent and cost effective process that handles excellently with the rising need for transforming wastewater into clean water that can be given back to the environment without harmful effects.the environment without harmful effect.	19
7	sMBR	Municipal Waste	**A. H. Mahvi et. al**. tested a performance of pilot-scale submerged MBR under the continuous inflow with synthetic municipal wastewater. Membrane used was made up of polypropylene with normal poresizeof0.1 μm and filtration area of 0.4 m^2. The performance of submerged MBR in order removal of organic compound and nitrogen. the performance was carried out for the different solid retention time i.e. 10, 20, 30 and 40 days. The results showed that the maximum removal rates of COD, total kejeldahl nitrogen removal, total nitrogen and phosphorous were99.3%, 98.1%, 85.5% and 52% respectively.	20
8	MBR V/s Conventional	Domestic Waste Water	**S. Kitanou et.al**didcomparative study on pilot-scale membrane bioreactor (MBR) using ceramic membrane with conventional activated sludge process (ASP) plant using domestic wastewater. Results obtained using MBR produced much better quality of treated waste water than the Activated Sludge Process (ASP) in terms of reduction in biological oxygen demand (BOD), Total Suspended solids (TSS), Chemical oxygen demand (COD), Total phosphorus (TP) and Total nitrogen (TN).	21
9	MBR V/s Conventional	Domestic waste	**Farshad Golbabaei Kootenaei** and Hasan evaluated the performance of MBR technology v/s conventional, processes like sedimentation and disinfection can be eliminated through MBR systems in a way that membranes are placed into or out of an aeration tank and the vacuumed wastewater created by the vaccum pump thru membranes and leaves the Mixed Liquid Suspended Solids (MLSS) inside the aeration tank. Membrane Bio Reactor (MBR) allows biological processes to work in a long Sludge Retention Time which increases the MLSS concentration even higher than 10000 mg/l,and removes BOD to 93-99%, COD to 85-97% Membrane filtration removes biological pollutants, particulate materials and colloid dilution, turbidity, microorganisms, suspension impurities and elements such as iron and manganese. The advantages of this system, smaller required space due to the omission of sedimentation tank, extra disposable sludge production reduction about 60-75	22

ISSN:0971-1260

Vol-22- Issue-14-December-2019

			percent, constant effluent quality and its independence from influent can be mentioned.	
10	MBR	Waste Water treatment	**Jain Jyoti et. al** did literature review on Application of Membrane-Bio-Reactor in Waste-Water Treatment. To overcome water scarcity, reuse and recycling of wastewater is an alternativesource of supplementing water supplies. In last 20 years, recent developments in membrane technology have made the recycling of wastewater a realistic possibility also the costs involved have reduced by 80%. In review main emphasis was given on comparing the principle, operation and performance of different types of MBRs membrane and effect on using different industrial effluent treatment.	23
11	MBR	Waste Water Treatment	Saima Fazal. et al. did literature review on various Industrial Wastewater Treatment by using Membrane Bioreactor Technology and demonstrated the importance of membrane, its process, treatment of waste water.	24
12	MBR	Anaerobic–aerobic treatment of industrial and municipal wastewater	Yi Jing Chan et. al evaluated the review of literature on Anaerobic–aerobic wastewater treatment systems. Earlier years many application for treatment of waste water has been carried out in conventional anaerobic–aerobic. In recent years, high rate membrane bioreactors and integrated anaerobic–aerobic bioreactors used for treatment of wastewater, advantages are minimal space requirements, low Operating and capital cost and excellent COD removal.	25
13	MBR	Municipal waste water	A. F. van Nieuwenhuijzen et. al did review on the state of science usingMembrane Bioreactors for municipal wastewater treatment and focused are follows: 1. Membrane fouling; 2. Effluent quality; 3. Energy consumption (aeration); 4. Cost considerations.	26
14	Anaerobic MBR	Waste Water Treatment	Meenu Jain *et al.* studied on Anaerobic Membrane Bioreactor (AnMBR), which is acombination of conventional anaerobic technologywith MBR.AnMBR technology provides improved effluent quality, reliability, and efficiency over the other traditional technologies.	27
15	MBR and RO	Industrial Waste Water	Majid Hosseinzadeh et al. evaluated the review of literature on membrane bioreactor for advanced treatment of industrial wastewater. The results of this study given using MBR technology generated a high quality permeate water. Chemical oxygen demand, Total nitrogen, Total suspended solid removal recoded was 98%, 75%, 74% and 99.9%	28
16	MBR and RO	Industrial Waste Water	Chin Hong Neoh et al. evaluated the review of literature on Green Technology in Wastewater Treatment Technologies: Integration for MembraneBioreactor using Various Wastewater Treatment Systems	29

ISSN:0971-1260

Vol-22- Issue-14-December-2019

17	Conventional v/s MBR	Industrial Water	Manoj Kumar did study on Industrial Wastewater Treatment in comparison to Conventional Activated Systems (CAS) and Membrane Bioreactor (MBR) Systems	30
18	MBR	Industrial Water Water	ShyamKodape studied on Membrane Bioreactor performanceat various temperatures for Wastewater Treatment. The study on performance of side stream membrane bioreactor (MBR) was studied by varying temperature (30oC, 33oC and 40oC) along with crossflow velocity (1m/s, 1.5m/s and 2 m/s). CFV and temperature had significant effect on performance of side stream MBR. Performance was studied by analysing COD removal (%), flux declination, Transmembrane pressure, mixed liquor suspended solid concentration. Maximum COD removal was 93% is obtained at 30oC with CFV 1.5 m/s. Flux declination is large at 30oC as compared to flux declination at 33oC and 40oC temperatures for all CFVs. Sludge production in terms of MLSS, is large at 30oC and minimum at 40oC. This high concentration of MLSS is responsible for large COD removal as well as increased in membrane fouling which cause large flux declination. It is observed that high CFV causes less flux declination tends to large permeate flux. By visual perception it is observed that athigher temperature, bioreactor content was more turbid than at low temperature this means that, large bioflocs get segregated and cause fastscouring on membrane surface, it resultsslow down of permeate flux declination. Selection parameter (SP) was used to optimize the operational condition of MBR system. Largest value of SP was treated as optimum value for operation of sidestream MBR. Thus, condition T = 33oC, CFV = 2 m/s gave highest SP value 27 lit/m2-hr, and may be recommended for treating wastewater of COD 1092 mg/lit. Comparison of side stream MBR with submerged MBR system was carried out, and it is observed that sidestream MBR data is best suitable for wastewatertreatment.	31
19	MBR	Industrial Waste water	Shamim Ahmed Deowan evaluated the review of literature onDesigningand testingof a pilot-scale submerged membrane bioreactor (MBR) fortextile wastewater treatment.	32
20	MBR	Industrial Waste water	Er. Devendra Dohare and Er. Rohit Trivedi evaluated the review of literature on Membrane Bioreactors: An Emerging Technology for treatment of Industrial Wastewater Treatment.	33

ISSN:0971-1260

Vol-22- Issue-14-December-2019

4. Function and Advantages of Membrane Bio Reactor:

Bioreactor enhances the biological degradation with the help of microorganism and degrades organic contaminants. Membrane module helps in separation of microorganisms from the treated waste water. Membrane fouling rate can be controlled with regular recirculation of wastewater and same was noticed and proved highly efficient throughout the ecological characterization study:

Advantages of Membrane Bio Reactor:

1. Potential reuse of effluent water
2. High qualityeffluent and High degree of Waste Stabilization
3. Very Less biological sludge production
4. Low hydraulic retention time
5. High Organic load
6. Less bioprocess foot print area
7. Easy in operation

5. Conclusion:

Water is a natural resource and availability of fresh water will become bottleneck in many areas of the world. The recycling or reuse of wastewater is alternative source of supplementing available water supplies. Untreated contaminants like total solids; total organic solids and total dissolved solids are discharged into the water by municipal and industrial sector. Rapid increase in population leads to over exploitation of groundwater and fresh water. MBR technology most concern technology for treatment of wastewater in developed and developing countries. Rapid increase of population, industrialization leads to maximization of wastewater. MBR technology is becoming one of important configuration system for minimization of increasing wastewater and gives cost effective solution. In this review, we have analyzed MBR technology for management of sewage wastewater. MBR technology is advance technology for the management of sewage water sustainably.

ISSN:0971-1260

Vol-22- Issue-14-December-2019

REFERENCES

1. Farshad Golbabaei Kootenaei and Hasan Aminirad (2014) Membrane Biological Reactors (MBR) and Their Applications for Water Reuse, International Journal of Advanced Biological and Biomedical Research, Int. J. Adv. Biol. Biom. Res, 2014; 2 (7), 2208-2216
2. Atkinson, S. (2006). Research studies predict strong growth for MBR markets. *Membrane Technology*, *2006*(2), 8-10.
3. Kynch, G. J. (1952). A theory of sedimentation. *Transactions of the Faraday society*, *48*, 166-176.
4. Judd, S. (2010). *The MBR book: principles and applications of membrane bioreactors for water and wastewater treatment*. Elsevier.
5. https://www.marketsandmarkets.com/Market-Reports/membrane-bioreactor-market-484.html
6. Buer, T., & Cumin, J. (2010). MBR module design and operation. *Desalination*, *250*(3), 1073-1077.
7. Yamanoi, I., & Kageyama, K. (2010). Evaluation of bubble flow properties between flat sheet membranes in membrane bioreactor. *Journal of Membrane Science*, *360*(1-2), 102-108.
8. Mutamim, N. S. A., Noor, Z. Z., Hassan, M. A. A., Yuniarto, A., & Olsson, G. (2013). Membrane bioreactor: Applications and limitations in treating high strength industrial wastewater. *Chemical Engineering Journal*, *225*, 109-119.
9. Stuckey, D. C. (2012). Recent developments in anaerobic membrane reactors. *Bioresource technology*, *122*, 137-148.
10. Iorhemen, O., Hamza, R., & Tay, J. (2016). Membrane bioreactor (MBR) technology for wastewater treatment and reclamation: membrane fouling. *Membranes*, *6*(2), 33.
11. Le-Clech, P., Chen, V., & Fane, T. A. (2006). Fouling in membrane bioreactors used in wastewater treatment. *Journal of membrane science*, *284*(1-2), 17-53.
12. Lin, H., Zhang, M., Wang, F., Meng, F., Liao, B. Q., Hong, H., ...& Gao, W. (2014). A critical review of extracellular polymeric substances (EPSs) in membrane bioreactors: characteristics, roles in membrane fouling and control strategies. *Journal of Membrane science*, *460*, 110-125.
13. Mutamim, N. S. A., Noor, Z. Z., Hassan, M. A. A., Yuniarto, A., & Olsson, G. (2013). Membrane bioreactor: Applications and limitations in treating high strength industrial wastewater. *Chemical Engineering Journal*, *225*, 109-119.
14. Brindle, K., & Stephenson, T. (1996). The application of membrane biological reactors for the treatment of wastewaters. *Biotechnology and Bioengineering*, *49*(6), 601-610.
15. Ueda, T., & Hata, K. (1999). Domestic wastewater treatment by a submerged membrane bioreactor with gravitational filtration. *Water Research*, *33*(12), 2888-2892.
16. Meng, F., Chae, S. R., Drews, A., Kraume, M., Shin, H. S., & Yang, F. (2009). Recent advances in membrane bioreactors (MBRs): membrane fouling and membrane material. *Water research*, *43*(6), 1489-1512.
17. Mutamim, N. S. A., Noor, Z. Z., Hassan, M. A. A., Yuniarto, A., & Olsson, G. (2013). Membrane bioreactor: Applications and limitations in treating high strength industrial wastewater. *Chemical Engineering Journal*, *225*, 109-119.
18. Grady Jr, C. L., Daigger, G. T., Love, N. G., & Filipe, C. D. (2011). *Biological wastewater treatment*. CRC press.
19. Judd, S. (2008). The status of membrane bioreactor technology. *Trends in biotechnology*, *26*(2), 109-116.
20. Al-Sayed, A., El-Senousy, W. M., Al-Herrawy, A. Z., Aly, M. A., & El-Gohary, F. A. (2017). Membrane Bioreactor Technology for Wastewater Reclamation.
21. 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.

ISSN:0971-1260

Vol-22- Issue-14-December-2019

22. Huang, X., Liu, R., & Qian, Y. (2000). Behaviour of soluble microbial products in a membrane bioreactor. *Process Biochemistry*, *36*(5), 401-406.

23. Yigit, N. O., Uzal, N., Koseoglu, H., Harman, I., Yukseler, H., Yetis, U., ...& Kitis, M. (2009). Treatment of denim producing textile industry wastewater using pilot-scale membrane bioreactor. *Desalination*, *240*(1-3), 143-150.

24. Alberti, F., Bienati, B., Bottino, A., Capannelli, G., Comite, A., Ferrari, F., & Firpo, R. (2007). Hydrocarbon removal from industrial wastewaterby hollow-fibre membrane bioreactors. *Desalination*, *204*(1-3), 24-32.

25. Naghizadeh, A., Mahvi, A., Vaezi, F., & Naddafi, K. (2008). Evaluation of hollow fiber membrane bioreactor efficiency for municipal wastewatertreatment. *Journal of Environmental Health Science & Engineering*, *5*(4), 257-268.

26. Kitanou, S., Tahri, M., Bachiri, B., Mahi, M., Hafsi, M., Taky, M., & Elmidaoui, A. (2018). Comparative study of membrane bioreactor (MBR) and activated sludge processes in the treatment of Moroccan domestic wastewater. *Water Science and Technology*, *78*(5), 1129-1136.

27. Jain Jyoti, Dubey Alka and Singh Jitendra Kumar (2013) Application of Membrane-Bio-Reactor in Waste-Water Treatment: A Review, International Journal of Chemistry and Chemical Engineering. ISSN 2248-9924 Volume 3, Number 2 (2013), pp. 115-122

28. Fazal, S., Zhang, B., Zhong, Z., Gao, L., & Chen, X. (2015). Industrial wastewater treatment by using MBR (membrane bioreactor) review study. *Journal of Environmental Protection*, *6*(06), 584.

29. Chan, Y. J., Chong, M. F., Law, C. L., & Hassell, D. G. (2009). A review on anaerobic–aerobic treatment of industrial and municipal wastewater. *Chemical Engineering Journal*, *155*(1-2), 1-18.

30. Van Nieuwenhuijzen, A. F., Evenblij, H., Uijterlinde, C. A., & Schulting, F. L. (2008). Review on the state of science on membrane bioreactors for municipal wastewatertreatment. *Water Science and Technology*, *57*(7), 979-986.

31. Jain, M. (2018). Anaerobic Membrane Bioreactor as Highly Efficient and Reliable Technology for Wastewater Treatment—A Review. *Advances in Chemical Engineering and Science*, *8*(2), 720-726.

32. Hosseinzadeh, M., Bidhendi, G. N., Torabian, A., & Mehrdadi, N. (2013). Evaluation of membrane bioreactor for advanced treatment of industrial wastewater and reverse osmosis pretreatment. *Journal of environmental health science and engineering*, 11(1), 34.

33. Neoh, C. H., Noor, Z. Z., Mutamim, N. S. A., & Lim, C. K. (2016). Green technology in wastewater treatment technologies: integration of membrane bioreactorwith various wastewater treatment systems. *Chemical engineering journal*, *283*, 582-594.

34. Manoj Kumar T, Nilavuneasan D, Thiruvengadaravi KV, Baskaralingam P, Sivanesan S (2016), Study of Industrial Wastewater Treatment Comparison between Conventional Activated Systems (CAS) and Membrane Bioreactor (MBR) Systems, *International Journal for Research in Applied Science and Engineering Technology*, Volume 4, Issue II, 587-594

35. ShyamKodape, V.S.Sapkal and R. S. Sapkal (2014) Study on Performance of Membrane Bioreactor (MBR) system at various temperatures for Wastewater Treatment, *International Journal of Innovative Research in Advanced Engineering (IJIRAE)*, Volume 1, Issue 7, 108-116

36. Deowan, Shamim&Korejba, Wladimir&Hoinkis, Jan &Figoli, Alberto &Drioli, Enrico & Islam, Rakib& Jamal, Lafifa. (2019). Design and testing of a pilot-scale submerged membrane bioreactor (MBR) for textile wastewater treatment. *Applied Water Science*. Volume 9. 59.

37. Er. Devendra Dohare and Er. Rohit Trivedi (2014) A Review on Membrane Bioreactors: An Emerging Technology for Industrial Wastewater Treatment, *International Journal of Emerging Technology and Advanced Engineering*, Volume 4, Issue 12, 226- 236