Apply Membrane Biological Reactor (MBR) in Industrial wastewater treatment: A Mini Review

Samar A. Al-Khafaji	Civil Engineering Department, College of Engineering, University of Basrah *Email of corresponding author: wesam752014@gmail.com
Wisam S. Al-Rekabi	Civil Engineering Department, College of Engineering, University of Basrah *Email of corresponding author: wesam752014@gmail.com
Mohammed J. mawat	Civil Engineering Department, College of Engineering, University of Basrah *Email of corresponding author: wesam752014@gmail.com

ABSTRACT

As an economical option to create nutrient-rich, solids-free effluents with a significant level for pathogen removal, while taking up little space compared to other treatment units, membrane bioreactor technology for municipal and industrial wastewater treatment is rapidly being investigated in recent years. Numerous research has used a variety of reactor designs in conjunction with membranes in the past, particularly in the previous ten years. With an emphasis on several types of membrane-coupled reactors, such as submerged and external membrane types, this paper critically assesses the potential of membrane bioreactor technology for the treatment of industrial wastewater. Additionally, this review paper addresses the effects of numerous parameters, including benefits and drawbacks, on the biological and filtration performances of membrane bioreactors for two types external membrane and submerged membrane.

Keywords:

1. Introduction

Membrane bioreactor (MBR) activity dates back to as early as the 1960s. However, due primarily to low membrane flux, low permeability, short membrane life, and high membrane expense, commercial usage of the membrane in wastewater treatment have remained limited. A new generation of membranes emerged from the beginning of the 90s due to aggressive research in the field of membrane technology, which significantly overcame numerous of the above constraints and the costs of membranes began to decrease. This has drawn a significant amount of interest to the usage for commercial purposes of membranes in the treatments of wastewater. By then, it was popular to use membranes in other fields of industrial applications, including water treatment, and a lot of experience had already been acquired.

Limitations of typical biological methods have become more evident in the handling of industrial wastewater to reach the requirements of discharge. This has contributed to a large number of studies targeting alternative technology and enhancing current technologies. As a result, studies on MBR were collected and many of these were actively funded by industries. Previously, several works centered on the MBR treatment of domestic/municipal wastewater. Later and more recently, much focus has been drawn to the possibility of using MBR in various forms of industrial wastewater treatment.

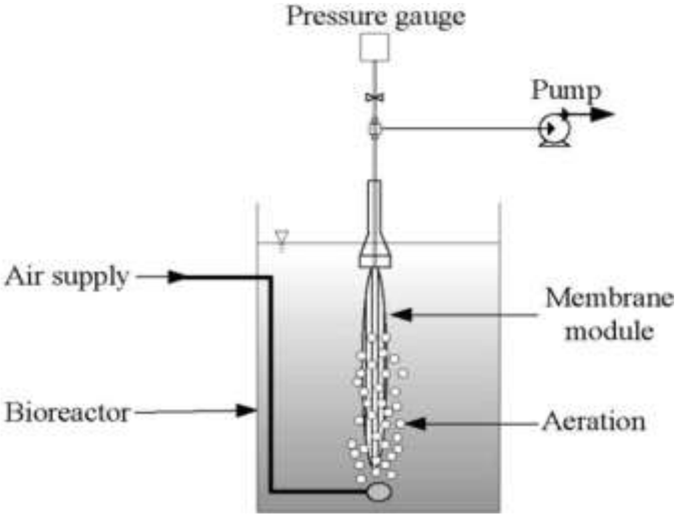

Figure 1 Schematic Arrangement of a typical Membrane Bioreactor

Several improvements (justifying the use of MBR in industrial waste water treatment) can be achieved as a result of replacing the secondary clarifier with a pressure-based membrane filtration process (Chettiyappan):

• Efficiency of solid-liquid separating performance is enhanced as a result of improved membrane filtration efficiency compared to separation by gravity;

The sensitivity of the operation of separation to inner and exterior parameters can be decreased, thus enhancing the system's validation.

Controls can be improved on many process-related variables, such as sludge retention time (SRT) or average time of cell residence, volume, organic loading and properties of waste sludge, etc., which can improve the biochemical reaction process' efficiency;

It is possible to enhance the removal of nutrients and refractory (biodegradation-resistant) substances.

• It is possible to fully eliminate microorganisms and pathogens from the effluent, reducing the requirement for disinfection;

Less operational control can be accomplished during steady-state conditions as well as the fast initial start-up of processes;

• By substituting wide (clarifier) tanks with compact membrane modules, the footprint of a conventional wastewater treatment plant can be decreased;

Better effluent quality from MBR easily offers opportunities for wastewater reuse and recycling.

The MBR technology (Membrane Bioreactor) is an exceptional technology for advanced wastewater treatment Compared to traditional activated sludge methods, there are numerous advantages.

A mixture of traditional biological wastewater treatment plants and filtering via membrane is the membrane bioreactor (MBR) conception. With the exception of separating activated sludge from treated wastewater, the concept is theoretically identical to that of a conventional wastewater treatment plant. This separation is not achieved in an MBR installation in a secondary clarifying tank via sedimentation, but by filtering through membranes.

Relative to conventional settlement separation systems, MBR processes can be implemented at increased amounts of MLSS (mixed liquor suspended solids), thus reducing the volume of the reactor to attempt the same rate of loading.

There are two types of MBRs: internal and submerged, where the membranes are immersed in the biological reactor and are integral; and external/sidestream, where membranes are a separate unit process that involves an intermediate pumping stage.

As a product, the MBR method has now become an appealing choice for industrial and municipal wastewater treatment and reuse, as demonstrated by the ever-increasing numbers and capability of wastewater.

2. MBR System Design

The design of an effective system of MBR is based on the design of an acceptable membrane system of the membrane. Additionally, in the design of the reactor and other unit processes, the impact varies in the parameters of the (biochemical) process (such as organic and hydraulic loading, age of sludge, sludge recycling, etc.) due to changes It must be considered in the solid-liquid separation system.

2.1 Membrane System Design

Today, including proprietary models, there are numerous variants of the MBR scheme in commercial use. For both suspended growth and attached growth processes, MBR is created. More variants are emerging, with many studies and many manufacturers of membranes vying for the marketplace. Below, the two most popular kinds are discussed. The most typical kind of MBR is through which the membrane units are installed directly in the activated sludge reactor tank is by far the submerged MBR (sMBR), Figure 2. Using a permeate pump, the permeate or effluent is adsorbed out of the membrane unit and the suspended solids are separated back into the vessel. Wasting sludge is executed immediately from the reaction vessel. Due to their compactness and low demand for energy, sMBRs are very common. However, sMBRs need more area of the membrane and are more appropriate with good filterability for sewage.

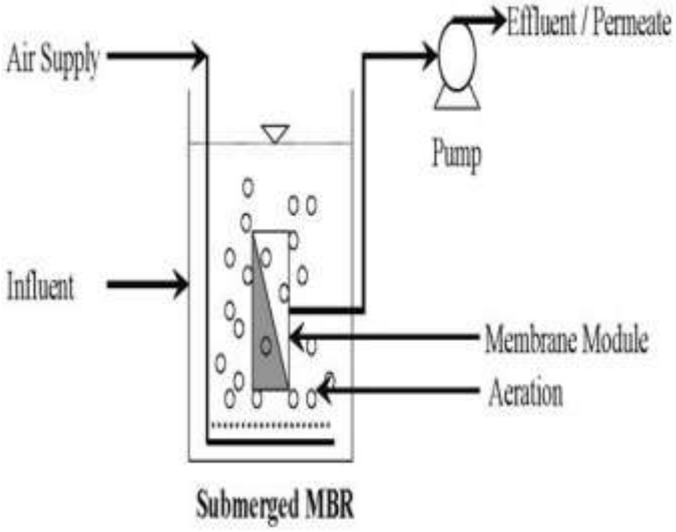

Figure 2 Submerged MBR for Suspended Growth Process

The membrane units have existed outside the reactor vessel in the outside Membrane (also referred to as Crossflow or Sidestream) MBR, Figure 3. The mixture liquid from the reactor is injected into the exterior membrane unit in this scheme. Compared with submerged MBRs, these require a smaller membrane area, exterior MBRs are often commercially utilized in industry sectors and function well for strong sewage with low filterability. These MBRs, however, exhausted so much energy and require area space and manifolds. The selection of a specific device formation is based on the specifications of the implementation and there is no simple base for choosing. After evaluating all the factors relevant to the application, designers should use engineering judgment to select a specific configuration. The main differences between the submerged and external membrane bioreactors to be considered in the adoption of a configuration are shown in Table 1.

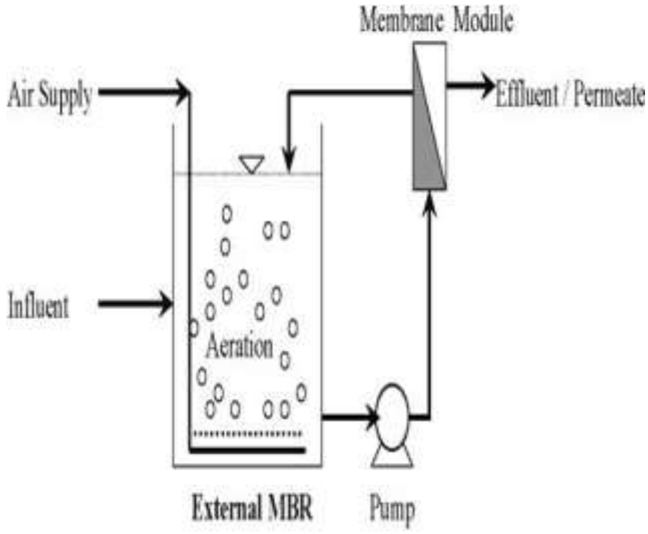

Figure 3 External Membrane Bioreactors for Suspended Growth Process

Table 1: Comparison of Submerged and External MBR Systems (Chettiyappan 2005)

	Submerged MBR	External MBR
Suitability	Low strength wastewater with good filterability	High strength wastewater with poor filterability
Membrane Flux	Lower membrane flux or lower permeate per unit area of membrane	Higher membrane flux or higher permeate per unit area of membrane
Transmembrane pressure	Lower TMP is required	Higher TMP is required
Power Requirement	Less power is required per $m^3$of wastewater treated	More power is required per $m^3$of wastewater treated
Sensitivity	Less sensitive to variations in wastewater characterstics and flow fluctuations	More sensitive to variations in wastewater characterstics and flow fluctuations
Membrane area requirement	More area is required	Less area is required
Economics	Generally less expensive at lower wastewater influent rate	Generally More expensive at lower wastewater influent rate
Membrane Backwashing and Cleaning	More frequent backwashing and cleaning required	Less frequent backwashing and cleaning required
Operation	Less operational flexibility	More operational flexibility with control parameters like SRT,HRTM and MLVSS
Extension of WWTP Capacity	Difficult to extend	Easier to extend

3. Membrane modules:

In MBR, two kinds of membrane units are utilized most commonly:

3.1 Hollow Fiber. A package of hundreds to thousands of hollow fibers consists of a hollow-fiber membrane module. In a pressure tank, the entire assembly is installed. The feeding may be applied to the interior of the fiber or the exterior of the fiber (inside-out flow) (outside-flow).

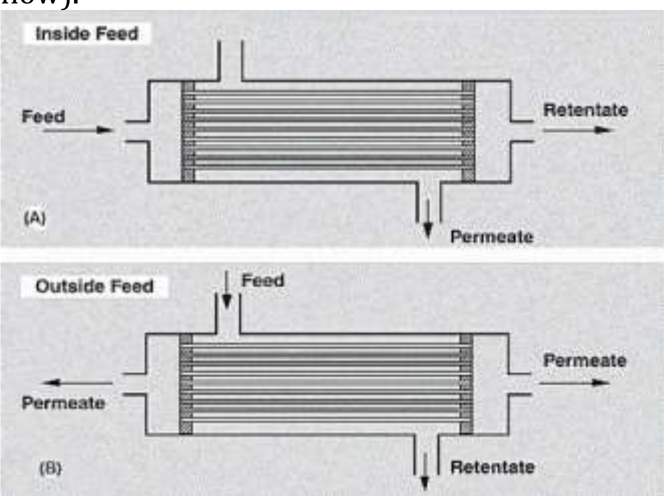

Figure4. (A) Bore side-feed hollow fiber membrane modules,
(B) Shell side-feed hollow fiber membrane module. Adapted from

3.2 Plat and Frame. A collection of flat membrane sheets and support plates are composed of plate and frame component modules. Between the membranes of two neighboring membrane assemblies, the water to be treated passes. The plate protects the membranes and allows the permeate channel to flow out of the device. The design of the plates and frames is most widely used for electro dialysis units, (Metcalf & Eddy. 2004).

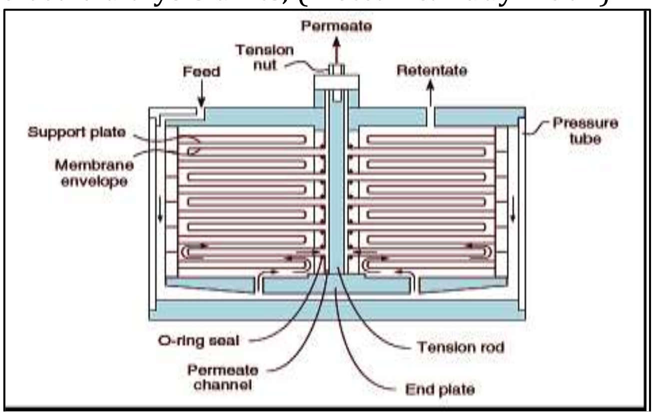

Figure5. Plate and frame membrane module. Adapted from.

3.3 Membrane behavior

In the treatment of high-strength industrial wastewater, the value of researching membrane behavior is to pick a good quality membrane. High-strength wastewater is made up of numerous pollutants that might eventually erode the membrane and contribute to the failure of the operation. Membrane performance often depends on the size of the pores, the type of materials to be handled, the type of treated wastewater, the solubility, and the retention time.

4. Advantages and disadvantages of MBR

4.1 Advantages

·MBR produces extremely good quality filtered effluent with smaller than 1 NTU turbidity and smaller than 5 mg/L BOD consistently.

· MBR increases biological process effectiveness by enabling it to function at a high concentration of solids and eliminating problems such as sludge bulking, sludge growing, Nocardia foam, etc.

· When utilized prior to RO, MBR will cancel the need for tertiary and secondary treatment devices. Despite this, the filtered water quality is acceptable to RO which operates smoothly.

· Single package unit with minimum civil construction.

· Low energy consumption.

· Filtration Up to 6 log (99.999%) removal of total coliform.

· No chemical is required during treatment.

· Usually, MBRs work at higher biomass concentrations than traditional processes of biological treatment. The benefit this offers is increased volumetric loading and less output of sludge, which in turn decreases the cost of capital expenditure for civil works and reduces the cost of sludge disposal.· Potential Reuse of effluent water.

· Higher rate of nitrification and gentrification.

·Optimum control of extended SRT allows for restricted and breakdown of slow biodegradable contaminants.

4.2 Disadvantages

· High investment and operation cost.

· Membrane lifetime and replacement.

· Membrane fouling problem.

Table2. MBR performance vs. conventional processes(Christelle Wisniewsk,)

	Raw water				Treated water			
	TSS (kg/m^3)	COD (kg/m^3)	Turbidity (NTU)	Germs (/100ml)	TSS (kg/m^3)	COD (kg/m^3)	Turbidity (NTU)	Germs (/100ml)
Trickling bed	0.2	0.7	120	10^8	0.035	0.125	10	10^6
Activated sludge	0.2	0.7	120	10^8	0.030	0.080	5	10^6
Physico-chemical process	0.2	0.7	120	10^8	0.060	0.130	20	10^7
MBR process	0.2	0.2	120	10^8	0	0.020	<2	$<10^2$

Table 3 MBR Applications in industrial wastewater treatment (Ref. Ciek, N. 2003)

Wastewater source	Membrane configuration	Size of operation	Treatment efficiency	Country of application
Various sources	Ultrafiltration external	Pilot scale 0.2-24.6 m^3/d	COD removal 97 %	Germany
Paint industry	Ultrafiltration external	Full scale 113 m^3/d	COD removal 94 %	USA
Tannery industry	Ultrafiltration external	Full scale 500-600 m^3/d	COD removal 93 %	Germany
Cosmetic industry	Ultrafiltration external	Full scale	COD removal 98 %	France
Electrical industry	Ultrafiltration external	Full scale 10 m^3/d	COD removal 97 %	Germany
Food industry	Microfiltration	Full scale 600 m^3/d	Effluent TSS 9 mg/l	USA

5. Applications in Industrial Wastewater Treatment

Two key features of industrial wastewaters that make alternate treatment methods like the MBR attractive are high organic loadings and being so complex and hard to treat contaminants. In the field of anaerobic treatment, wastewater with a high COD content has historically been used for industrial wastewater applications. Table 3 presents an overview of MBR applications in the industrial wastewater treatment area.

At the General Motors industrial company in Mansfield, Ohio, a fully operational aerobic MBR technology was run for the wastewater treatment containing artificial metalworking fluids and high concentrations of oil and fat. The average of 115 m^3/d of sewage (all wastewater plants) with an organic loading rate of 6.3 kg cod/m^3 /d was treated with an organic load rate of 15. On average, 94% of COD removal and significant oil and fat reductions were accomplished (Knoblock et al. 1994). A membrane bioreactor further decreased the biological hazardous of the effluent by ten times and reduced the total quantity of toxic waste by 3 times in another study involving oily wastewater for a metal processing facility (Zaloum et al. 1994). Elsewhere, high-efficiency biodegradation of synthetic wastewater including lubricating or fuel oils, as well as chemicals, was performed utilizing a reactor combined with ultrafiltration membranes. Up to 99.99 percent, removal rates were achieved at a hydraulic retention period of 13.3 hours (Scholzy and Fuchs 2000). The implementation of an MBR method for the treatment of ice-cream processing waste was studied by Scott and Smith (1996). Given the higher initial cost, due to improved durability and previous experience in industrial applications, a 0.2 μm ceramic membrane was used. For both filtration and aeration, the ceramic membrane was used. The waste stream had COD levels in the range of 8,000 Levels of-10000 mg/L and BOD between 2000-4000 mg/L at 22-32 °C temperature. Depending on the machine setup, COD removals ranged between 83 and 97 percent and BOD removals ranged between 90 and 98 percent. The system's ability to maintain a steady pH of 6-8, even at feed concentrations over 10, was another benefit of the MBR system. The existence of lactic acid bacteria has been attributed to this.

The application of MBR treatment to beverage manufacturing waste was proposed by Murray et al. (2005). Due to its ability to handle a highly variable, high temperature, high-strength waste without the need for settlement, the MBR method was selected. MBR was the perfect alternative because of the limited space available and the high-quality water for reuse. There was an irregular nutrient profile of the bottling wastewater high in H, O, and S. The control of nutrients had a significant influence on process efficiency within the MBR. The device had a flux rate of 26 gal/ft2d upon start-up and needed cleaning every 2 to 7 days. Nutrient deficiency adjustment increased the flux rate to 53 gal/ft2d and lowered the criteria for cleaning to once every 30 days.

Noor Sabrina 2013, There are different operational conditions during MBR service according to the amount of wastewater with high strength constituents. Behaviors of sludge (e.g. DO, MLSS, HRT, and SRT) and behaviors of the membrane are covered by operational conditions (e.g. pore size and membrane structure). Due to the difference in the biodegradability ratio, there are two categories of industries selected (textiles and food). Table 4 demonstrates the categorization of effluent from both sectors as high-strength wastewater, but in terms of biodegradability, they vary. Because of the presence of hazardous or slowly biodegradable organic materials [Ganjar Samudro], compared to the food industry, the biodegradability of the textile industry is weak. The food industry is identified as high-strength organic wastewater, and because of the high content of readily biodegradable or organic matter, high levels of biodegradability are present. (N. Cicek's).

Table 4. High strength wastewater characteristic.

Industry	COD (mg/L)	BOD_5 (mg/L)	BOD_5/COD	NH_4–N (mg/L)	TSS (mg/L)	SO_4^{2-} (mg/L)	PO_4^{3-} (mg/L)	Oil (mg/L)
Tannery [19]	16,000	5000	0.313	450	–	–	–	–
Textile [28]	6000	700	0.117	20	–	–	120	–
Textile [29]	4000	500	0.125	4.8	–	200	2	–
Dyeing [30]	1300	250	0.192	100	200	–	–	40
Textile [31]	1500	500	0.333	50	140	–	7	–
Wheat starch [2]	35,000	16,000	0.457	–	13,300	–	–	–
Dairy [19]	3500	2200	0.629	120	–	–	–	–
Beverage [19]	1800	1000	0.556	–	–	–	–	–
Palm oil [16]	67,000	34,000	0.507	50	24,000	–	–	100,000
Pet food [32]	21,000	10,000	0.476	110	54,000	–	200	–
Dairy product [33]	880	680	0.773	–	2480	–	–	–
Pharmaceutical [34]	6300	3225	0.512	–	1679	–	–	–

Table 5 MBR operational parameters for industrial wastewater.

	Textile			Food		
	Textile [28]	Textile [29]	Textile [31]	Pet food [32]	Palm oil [16]	Dairy product [33]
Reactor volume (L)	500	20	230	20	20	20
Reactor type	Aerobic, side-stream	Aerobic, side-stream	Aerobic, submerged	Aerobic, submerged	Aerobic, submerged	Aerobic, submerged
Membrane configuration	UF, (7 tubular modules), PVDF	UF, external tubular cross-flow, PVDF	HF	2 modules	FS, 1 module	MF, 34 strands of a HF
Membrane surface area (m^2)	–	0.28	–	0.047	0.1	0.00162
Pore size (μm)	0.025	–	0.04	0.04	0.4	0.4
Flux (L/m^2h)	–	30	20	–	10	Horizontal: 5.03 Vertical: 2.27
MLSS (mg/L)	5000–15,000	–	13,900±	–	5000±	4000–10,000
MLVSS (mg/L)	–	–	–	47,000±	–	–
DO (mg/L)	1–3±	2–3±	–	3±	8±	–
HRT (day)	2	0.7–4	0.58	2.9±	0.8±	–
SRT (day)	–	11	25	50	–	–
COD removal (%)	97±	90±	97	97±	94±	–
Colour removal (%)	70±	98±	98	–	–	–
TSS removal (%)	–	–	99	–	–	99

Constant permeate flux (9.5 $L.m^{-3}.d^{-1}$(LMH)) is used for the treatment of dairy wastewater at 15 hours of hydraulic retention time (HRT) and 40 days of sludge retention time (SRT), Hanife Sari 2016, it was done in an aerobic submerged membrane bioreactor (sMBR). The removal efficiencies of COD, (NH_3-N), and orthophosphate (PO_4-P) was 98.2 percent, 95.4 percent, and 88.9 percent respectively. The findings have shown that sMBR is an adequate and reliable treatment for the removal of nutrients and organic matter for the treatment of milk wastewater.

In pulp and paper wastewater treatment, MBR processes are used by Ali Izadi et al 2018 to produce high-quality effluent to comply with strict regulations and also to reuse the effluent. The efficiency of treatment processes for various forms of pulp and paper wastewater is shown in Table 6.

Table6. Performance of Different Processes in the Pulp and Paper Wastewater Treatment

Treatment Process	Source of Wastewater	Contaminants Removal Efficiency (%)		
		COD	Color	Other Compounds
Aerobic Systems				
Activated Sludge	Kraft pulp mill	60	40	36 (Tannin and Lignin)
	Integrated pulp mill	60-70	-	60 (TOC)
Multiple stage	Black liquor	65	-	-
ASB	Kraft pulp mill	67	-	-
	Kraft pulp mill	40	-	-
SBR	Paper mill	75	-	-
	Hardwood Kraft mill	69	-	>80 (TSS)
Bio-filter	TMP	52	-	-
Membrane bioreactor	Paper mill	80	-	>90 (TSS)
	Paper mill	92	-	84 (Ammonia), >99 (TSS)
Facultative stabilization basin	Kraft mill	62	-	51 (AOX), 69 (Chlorinated compounds)

There is an unending list of applications of membrane technology in wastewater treatment. The key ones used were summarized in the paper of (Obotey Ezugbe et al 2020), citing examples of their use, their advantages, and drawbacks, as well as some membrane-related areas such as fouling and module structures. This paper is hopefully helpful in providing a good knowledge for more research into applications of membrane technology in wastewater treatment. This study looks at the advantages and drawbacks of trendy membrane systems in wastewater treatment. Membrane fouling, membrane washing, and membrane modules are also discussed.

6. Conclusion:

MBRs have the capability to consistently achieve the following effluent quality:

BOD_5: less than 3 mg/L
TSS: less than 1 mg/L
NH_3-N: less than 0.5 mg/L
TN: less than 3 mg/L
TP: less than 0.05 mg/L
Turbidity: less than 0.2 NTU

The consistently high-quality effluent generated by MBRs can be used in environmentally sensitive areas and for a range of municipal, industrial, and commercial reuse uses. Reverse osmosis applications using MBR effluent can provide water of better quality for groundwater recharging or industrial clear water reuse.

In order to preserve our natural water resources and develop new water sources, market trends predict MBR technique will be used more frequently in wastewater treatment and water reuse activities. There are roughly 600 operating plants in the U.S. and 6,000 worldwide. From small, point-of-use plants to large 40 MGD municipal plants, MBR technologies are now universally acknowledged as the best solutions available and are regarded as mainstream.

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