

## **A taste of waste**

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**Membrane filtration (MF) and membrane bioreactors (MBRs) are well established technologies. Although developed in the 1960s, MF and MBRs have been used primarily in municipal drinking water and wastewater applications since the 1980s. Their use in the petroleum and chemical industries today, however, is only now beginning to take hold.**

### **Market drivers**

Economics, regulatory issues, or a combination of the two, ultimately affect changes that are implemented in existing facilities or the design of new plants. In many countries, the costs of raw water and/or wastewater discharges have rapidly increased over the years. Stricter environmental regulations are forcing refiners across the globe to upgrade their wastewater treatment plants to avoid higher fines for non-compliance. Limitations on raw water availability and degrading quality further motivate refineries to evaluate existing raw water treatment upgrades or alternative raw water sources. Many refineries and chemical plants are turning to wastewater reuse as a solution to all of the above.

MF and MBR are two treatment technologies that are increasingly being installed in refineries and petrochemical plants. The financial benefits of using these technologies include reduction of net raw water intake by using recycle; optimisation of boiler feedwater systems; compliance with discharge regulations to avoid fines; and sale of treated wastewater for irrigation purposes.

Over the past few years, more and more refineries in the Middle East have realised the economic and environmental motivators behind reusing wastewater. Refineries employing reuse treatment methods use significantly less raw water than their counterparts, resulting in cost savings on the front end of the treatment process. The same holds true for the back end, with many refineries in Saudi Arabia selling their treated wastewater for irrigation purposes.

The story is very similar for many refineries and petrochemical plants in western

USA: scarce raw water sources, poor quality intake water, higher purchase costs and wastewater discharge limitations. However, unlike their Middle Eastern peers, many US facilities are only now beginning to look at other raw water sources and water reuse treatment technologies.

### **Technology barriers**

Recovering and reusing wastewater is not rocket science. However, understanding the wastewater source and the processes that treat it are critical. A petroleum refinery's wastewater effluent can vary drastically in composition and flow rate, and even after tertiary treatment, it could be unacceptable for many of the refinery's water uses. Clarifiers and media filters are traditional technologies frequently used to treat raw water and wastewater. Such technologies have limited use in recycle applications. Fortunately, MF (as an add-on or replacement system) can help overcome the limitations of these and other conventional technologies, further expanding the possibilities for reuse.

### **Membrane filtration (MF)**

Membranes are polymer based materials with controlled microscopic pores in the sub-micron range. Common bacteria are several microns in size, which is the reason MF has been so successful at providing safe and reliable municipal drinking water. Common polymers used for these membranes include polypropylene, polyvinylidene fluoride and polysulfone. Most membranes today are hollow fibres with outside diameters of 500 - 1500 microns. As water flows through the membrane, it retains any suspended solids larger than its pores. Feedwater can flow either from the inside to the outside of the hollow fibres, or (preferably) from the outside to the inside, to prevent plugging the inside of the hollow fibres.

MF has many advantages over conventional clarifiers and sand or media filters, in certain applications, for removing suspended solids. First and foremost, the membrane acts as a physical barrier to microscopic suspended solids, colloidal particles, cysts, bacteria and biomass. By contrast, media filters rely on macroscopic collisions and bridging mechanisms to capture suspended particles with granular media. Water treated by an MF process produces a filtrate of less than 1 mg/L total suspended solids (TSS), a turbidity typically below 0.1

nephelometric turbidity units (NTU) and a silt density index (SDI) below 3. This makes MF an ideal candidate for either raw water treatment or recovery of wastewater for reuse.

The majority of MF systems today operate similarly to cartridge filter systems, removing suspended solids from the feedwater and retaining them within the system as filtered water is withdrawn. As the operating pressure of MF systems is similar to that of cartridge filters, the energy costs are roughly the same. However, unlike cartridge filters, membranes are not discarded, but rather backwashed at regular intervals to maintain performance. In fact, many facilities have cost justified installing MF systems solely based on no longer having to replace cartridge filters.

Most downstream petroleum facilities use a surface water source, and as a result, clarifiers or lime softeners, followed by media filters, are typically used for conventional treatment of raw water. However, the use of MF is becoming more prevalent for filtering incoming plant water for the petroleum industry.

Conserving plant space and improving efficiency in the entire water treatment process are the key drivers for using MF on incoming plant water. MF can be an economical alternative for new construction or existing plants due to its small footprint and the superior water quality produced for the boiler feedwater system. For example, many refineries in the Netherlands, South Korea and Brazil, as well as on the Gulf Coast, have opted to abandon conventional surface water treatment for MF. Since installing MF, several of these plants have taken advantage of reverse osmosis (RO) and realised an increased efficiency in their existing boiler feedwater systems. Only MF can reliably provide the extremely high quality feedwater that RO requires.

MF can also be used in the petroleum and chemical industries to filter wastewater prior to discharge. However, the cost of MF in this case is uneconomical unless certain regulatory requirements need to be satisfied by a higher degree of filtration. An economical case can be made for final filtration using MF in the recovery, recycle and reuse of the wastewater, especially when RO is employed in the recycle scheme. For example, West Basin Municipal Water District in El Segundo, California, treats municipal wastewater using, among other technologies,

continuous microfiltration technology as pretreatment to RO. The facility processes 30 million gal./d of wastewater, and sells approximately 20 million gal./d to such nearby refineries as BP, Chevron/Texaco and ExxonMobil, for use in cooling towers and/or as boiler feedwater. The remaining 10 million gal./d is used to irrigate nearby golf courses and prevent seawater intrusion through aquifer re-injection.

Common petroleum refinery wastewater treatment consists of primary and secondary oil/water separation, biological treatment, clarification and filtration. In an article recently featured in Hydrocarbon Engineering<sup>1</sup>, several problems associated with the biological process manifested themselves in the clarifier, and thus in the final discharge. Filamentous and zooglea bacteria, high polysaccharides and poor BOD conversion, all resulted in 'poor secondary clarifier sludge compactions and environmental non-compliance on TSS.' If MF had been used instead, sludge composition and/or floating solids could have been completely removed.

### **Membrane bioreactors (MBRs)**

Combining biological treatment with a membrane filter for biomass separation yields a MBR. MBRs have a smaller footprint, efficiently use bacteria to better remove contaminants, and lower sludge volumes to reduce dewatering costs. Separating biomass sludge from the effluent is a key concern in the design and operation of biological processes. Another article to recently feature in Hydrocarbon Engineering noted that advances in biological contactors focus on the sludge characteristics, as '...sludge particles settle much better than sludge from conventional suspended growth systems, causing fewer sludge settling issues in the final clarifier.'

Even with these advances in biological contactors, problems such as carryover of suspended solids still occur when separating sludge from effluent water. MF provides a physical barrier to suspended solids, thus eliminating carryover. Much lower in suspended solids than conventional media filtration effluent, MBR effluent provides better quality water for potential recycle and reuse in cooling tower makeup and other utility purposes without requiring additional treatment.

MBR operation is simple. Oxygen fuels the bacteria's ability to multiply, and keeps the biosolids suspended. Membrane modules are submerged in an open tank that receives mixed liquor from the biological process. As filtrate is withdrawn through the membranes, the concentrated mixed liquor returns to the biological process. Conventional bioprocesses' mixed liquor suspended solids (MLSS) concentrations are generally 2000 - 4000 mg/L in typical refinery applications. Using a membrane for the biosolids separation makes it possible to operate the bioprocess at 8000 - 15 000 mg/L, allowing microorganisms to decompose organic material faster and more efficiently. This efficiency translates to a shorter hydraulic residence time (HRT), which, compared to a conventional bioprocess, can reduce the bioprocess footprint by up to 80%. Higher MLSS also results in a more stable operation, complete nitrification and a higher sludge concentration that is easier to dewater.

In a typical petroleum refinery, an MBR would be installed in one of two ways downstream of the secondary oil/water separator. The first installation consists of simply adding a membrane operating system to the existing biological process with minor, if any, modifications to the existing bioprocess. A US refiner is in the process of installing such a system to treat process wastewater and groundwater. Although the treated effluent will be used for re-injection, it will also be suitable as it is for some internal reuse applications. Installing the system will also eliminate the facility's clarifier and increase the wastewater treatment plant's capacity and reliability.

The second and more robust approach is used in designing new plants or major upgrades to existing plants. It consists of installing a completely engineered bioprocess and membrane system, each controlled and optimised separately to obtain all the benefits of an MBR. As noted above, higher MLSS makes microorganisms more efficient at removing contaminants, and shorter HRT reduces equipment size.

A pre-engineered, packaged MBR plant is a proven and preferred method for segregating sanitary waste from process waste. These integrated bioprocesses and membrane systems are specifically designed for sanitary waste treatment. Treating the wastes separately saves capital and operating costs as well as required floor space. Sanitary waste is more consistent than process waste and

does not contain the hydrocarbons, petrochemicals or other constituents that require a specialised biological process. To date, packaged MBR plants have been used primarily in municipal applications, although their small footprint and ease of operation makes them attractive to refineries and petrochemical plants. Any of these MBR applications is suitable for recovering refinery wastewaters. The recovered water can be reused directly for general utility uses in the processing of crude, as cooling tower makeup, or in land applications such as irrigation.

## **Conclusion**

The petroleum and chemical, as well as other industries, are beginning to capitalise on the worldwide acceptance and deployment of MF and MBR in the municipal sector. Although the industrial sector is not necessarily concerned with producing drinking water, the benefits of MF for incoming water or recovery of wastewater are readily apparent, and include:

- Saving valuable land space with high rate treatment in a compact footprint.
- Simplifying expansion and upgrades with modular construction.
- Providing reliable treatment through superior and consistent water quality.
- Making recycle and reuse economically feasible.
- Creating alternative water sources with economic advantages.

MF and MBR technologies are economical methods of addressing increasing raw water costs, declining raw water quality, or availability and rising costs due to non-compliance with wastewater discharge limits. Highly treated wastewater can be recycled within the facility for use as cooling tower makeup, boiler feedwater or other utility purposes. The treated water can even be turned into a profitable business when sold as irrigation water.

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