

## The MBR for Industrial Effluent

*Presented to the CIWEM & Aqua Enviro Conference  
14<sup>th</sup> May 2003, Wakefield  
By Tony Robinson, Wehrle Environmental*

### INTRODUCTION

The use of MBR technology for wastewater treatment is now well established. However there is a range of process variations available, and it is important to select the system most suitable for the task.

The main reasons why MBR has come into focus for the treatment of industrial effluent are twofold,

- The final effluent is of a very high quality. The environmental agencies within Europe favour MBR because not only are discharges of bio-solids completely avoided, but also specific chemical contaminants, such as pesticides, etc. are removed.
- The MBR is now a favoured wastewater treatment option for industrial processors faced with ever increasing environmental demands and costs. MBR not only occupies far less space than conventional treatment systems but it is also affordable.

In many respects, the MBR is an extension of the activated sludge process. Conventional activated sludge processes suffer from several constraints, such as needing to operate with a low MLSS (range 4 g/l to 7 g/l) and the use of gravimetric tanks to separate sludge from the clean supernatant effluent. The efficiency of separation is governed by the quality of the biological process, which affects the settlement of the sludge. Changes to the plant biology can easily cause the sludge to bulk, in effect making it float, thereby increasing the solids level in the final effluent.

The fundamental difference with an MBR is in the method of separating sludge from the clean effluent. The conventional use of settlement tanks is replaced by an Ultrafiltration (UF) membrane system.

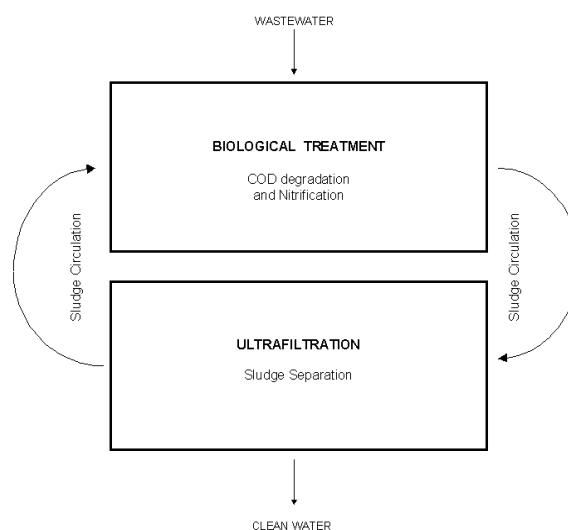
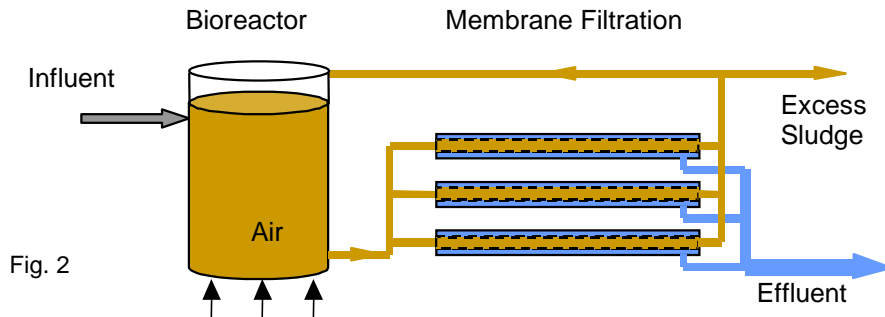


Fig. 1

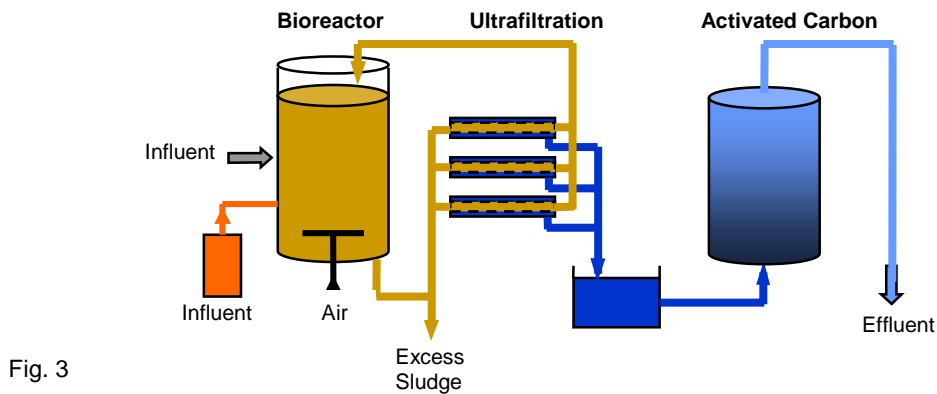
The key to a successful MBR is combining the two unit operations into a single process. Viewing the design of an MBR as two separate unit operations is not advisable.

**EXAMPLES OF INDUSTRIAL MBR SYSTEMS**

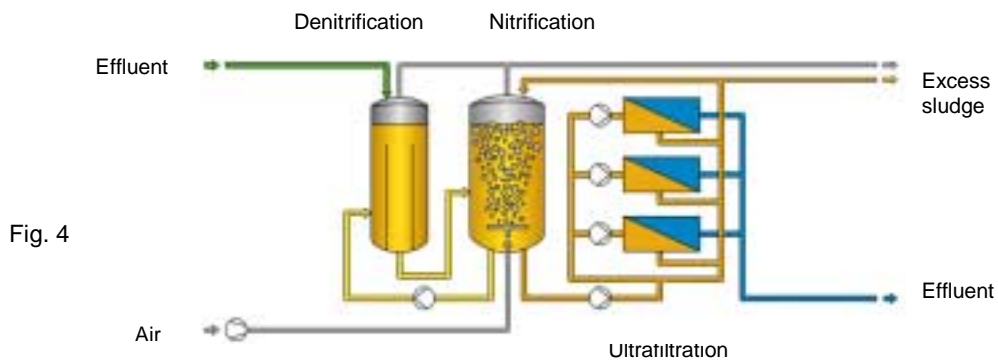
The simplest form of atmospheric MBR is shown in fig.2 and is applied to COD degradation and nitrification.



If the wastewater contains 'hard' COD or, for example a textile waste where residual dyes need to be removed, then a post activated carbon step is recommended (fig. 3). This particularly applies to landfill leachate, which normally contain an array of organic substances, which are difficult to biodegrade.



If the final effluent is being discharged to a watercourse where the local environmental authority is placing a nitrate or total-N consent, the solution is to include denitrification as a feature of the process. This can easily be achieved with a pre-denitrification step as shown in the fig. 4.



## The Pressurised MBR

The pressurised MBR is an alternative design and is an optimal solution for the treatment of highly contaminated industrial wastewater and landfill leachate.

The bioreactor can be operated at up to 35 kg/m<sup>3</sup> MLSS, which minimises reactor volume for a given F/M loading. The smaller aeration tanks can be pressurised at up to 3 bar (Wehrle BIOMEMBRAT Patent) to facilitate the provision of optimum dissolved oxygen concentration even at a high organic loading.

The pressurised tanks also minimise the airflow, reducing the risk of stripping out volatile compounds, and reducing the size of air scrubbers where these are required. The reduced airflow also reduces the risk of foaming, the latter being a feature with some industrial wastewater.



BIOMEMBRAT treating landfill leachate at Lorrach

A further effect of using a smaller aeration tank is that the energy from the exothermic bioprocess and from the aeration and pumping is used to heat a relatively small volume of liquid. This enables the process to operate at an elevated temperature, usually 30 to 35°C, providing the following advantages:

### Biology

- Increased rate of bio-oxidation of pollutants
- Improved performance of 'hard' COD removal
- Higher rate of nitrification
- Lower sludge production

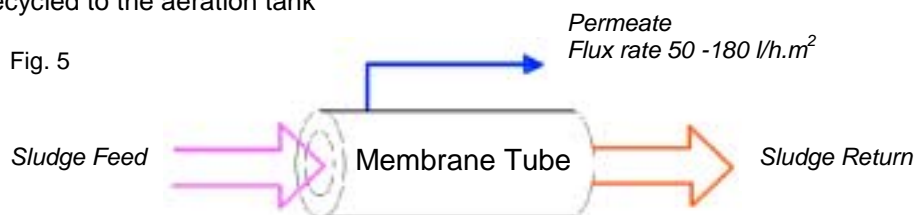
### Ultrafiltration

- Increased flux rates with increased temperature

## Cross flow Ultrafiltration

The key feature in these designs is the use of tubular **cross flow** membranes for the ultrafiltration process. For low strength-high volume wastewater, for example - sewage, low ultrafiltration energy costs per cubic metre are important. This requirement is usually best met by a **submerged membrane** process. However, for high strength-low volume wastewater the capital and operating costs for ultrafiltration are low relative to the total COD load, and **cross flow** MBR is often the best choice.

Most industrial wastewater falls into the second category. For the treatment of this wastewater, **cross flow** MBR has been found to have many advantages. In this system, the tubular membranes are housed in modules through which a side stream from the aeration tank is continuously pumped. Permeate (clean water) is discharged while the biological sludge is recycled to the aeration tank



## KEY DESIGN FACTORS

Whereas the biological element of an MBR and an activated sludge plant is similar in concept, it would be an error to assume the same design techniques could be applied for both processes. Poor operating MBR plants come about mainly because the designer has assumed that an MBR is two unit operations, *i.e. an activated sludge plant followed by an ultrafiltration process*. The MBR must be designed as one unit operation with an integrated biological and physical process.

The designer must take into account many parameters and these can be summarised as follows:

### Pre Treatment

As with the activated sludge process consideration of the pretreatment of industrial wastewater prior to the MBR process is very important. Primary screening out of suspended solids, flow balancing and pH control must be reviewed.

New environmental legislation, *e.g. The Landfill Regulations, 2002* has made sludge disposal a major issue. The use of chemicals to break down soluble COD must be reviewed with care. It is easier to dispose of solids and sludge into the agricultural sector if these are not chemically contaminated. The use of dissolved air flotation to remove small particulates must be considered.

One important pre-treatment feature is to ensure all the wastewater passes through a pre-filtration prior the main MBR process. Suspended solids such as fibres and hairs will tend to block the membrane plant.

### MBR Biological Treatment

The main advantage of the MBR is its small space requirement. This is achieved by using high levels of mixed liquor suspended solids (MLSS). The MLSS of an MBR can vary from 10,000 to 35,000 mg/l. However, the high concentration of bio solids does have a drawback in two particular areas.

Firstly, the ultrafiltration membrane flux rate tends to drop as the MLSS increases, which means the process will require the additional cost of more membrane area.

The second very important consideration is the rate of oxygen transfer. Most MBR processes use air as the means for supplying oxygen to the biology. This transfer can be restricted as highlighted below.

- Careful consideration should be given to the bioreactor tank geometry. Although MBR biological tanks are much smaller than their activated sludge counterparts, the biology still requires the same amount of oxygen transfer. There is a limit to the mass of air that can be injected into specific cross-sectional area of a tank.

All bioreactor tanks should be installed with roofs, preferably manufactured in GRP

- The type of aerators must also be reviewed. Jet aerators are favoured due to their high efficiency. However, foaming can be an issue preventing their use.
- The value of the  $\alpha$  factor used for calculating oxygen transfer for any specific aeration device will reduce with an increase in MLSS.
- The biology temperature used in the MBR process is normally more elevated. The higher temperature has a detrimental effect on the rate of oxygen transfer.

Incorrect consideration of the aforementioned factors can lead to a process with oxygen depletion, which could result in disastrous consequences.

The alternative is to employ direct oxygen transfer, especially with processes that will tend to foam.

The sludge loading or F/M ratio is also an important design parameter. Generally, the MBR process can operate at higher F/M ratios when compared to an activated sludge plant. However, for some industrial applications, notably in the dairy and food industry, there is F/M range to be avoided. The problem mainly relates to specific filamentous bacteria. Consequently, F/M ratios lower than 0.15 kg COD/kg MLSS\*day are used in this sector. However, the MBR employed in other industrial sectors can apply F/M ratios greater than 0.4 kg COD/kg MLSS\*day.

For industrial effluents where recalcitrant organic substances often occur it can be necessary to operate in a low F/M – long sludge age mode. The high MLSS in the bioreactor facilitates this mode of operation, which together with the retention of bacteria by the membranes maximises the biodegradation. This is reflected in the observed improvement in COD reduction when the treatment of landfill leachate using the pressurised system was compared with a conventional activated sludge process.

A low F/M loading is also necessary for nitrification, and minimises the production of surplus sludge.

**MBR Ultrafiltration**

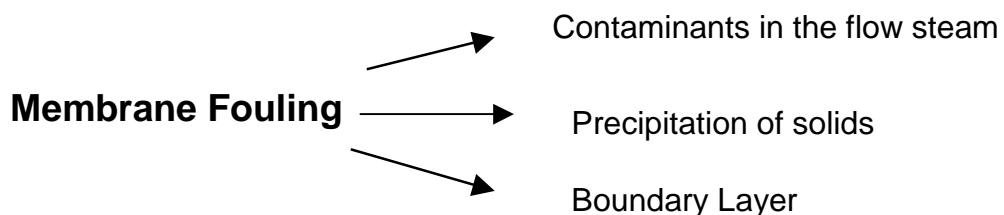
Most crossflow UF systems employed in an MBR design use tubular membranes. The diameters of the membrane tubes vary between 5 mm - 10 mm and these are assembled as bundles into modules. The module diameters vary between 1” – 8” and lengths up to 3 Mts.

Most membrane tubes are manufactured using a polyester support base covered with a thin polymer layer. The latter, used for industrial wastewater treatment can be Polysulphone (PS) or Polyvinylidene fluoride (PVDF). The use of ceramic membranes is becoming more prevalent.

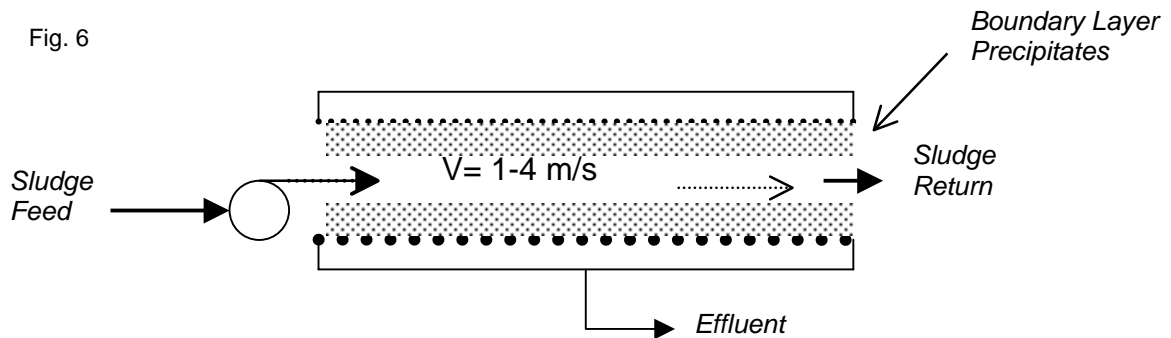
The term “horses for courses” is aptly applied to the selection of the best membrane type and configuration. It is worth noting that the performance of the same membrane type and configuration can vary considerably between different manufacturers. The choice must be based upon empirical data and pilot trials are advised before selecting a membrane for a specific wastewater treatment application.

Membrane Fouling

In comparison with municipal sewage, the biological treatment of higher strength industrial wastewater is a far more complex matter. Generally, the levels of COD and ammonia to be treated are much greater but, more importantly, the membrane surface can foul very quickly if the wastewater contains a high amount of dissolved solids, which precipitate as organic salts during biological treatment.

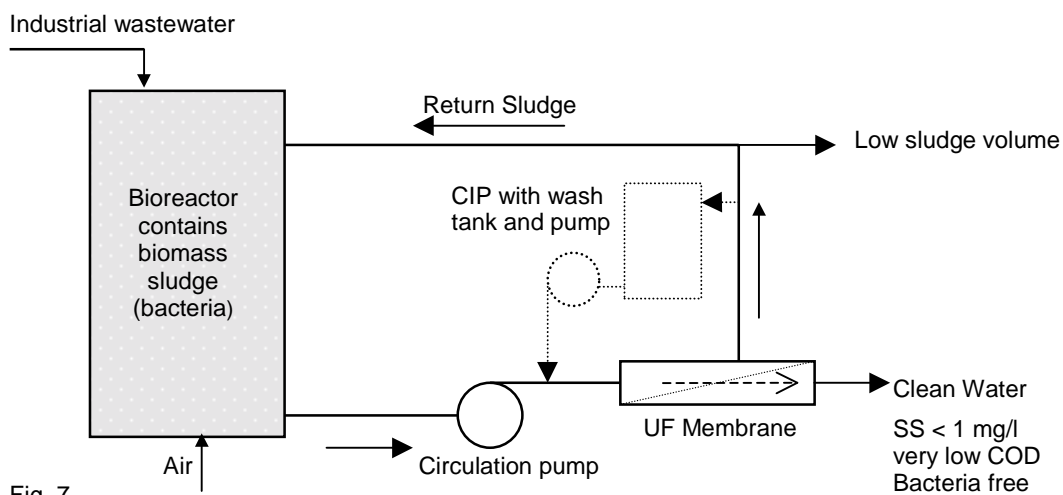


A 'boundary layer' of solids (sludge) forms on the surface of the membrane and its thickness is a function of the wastewater being treated and the liquid flow velocity. This 'boundary layer' in itself can act as an additional filter medium thereby reducing the fluxrate



The self-scouring action of tubular systems allows the membrane surfaces to remain relatively clear of the fouling material. This is achieved by increasing the sludge flow velocity. However, there is a limit to the practical use of increasing the flow velocity, since the energy costs can become prohibitive. It is at this point that the real advantage of tubular membranes is fully appreciated as using simple CIP techniques can easily clean them.

This can easily be achieved by standard *in situ* cleaning, using well established CIP techniques.



Membrane Flux rates

There are several important issues the designer of an MBR plant must review when considering membrane flux rates.

- The flux rate will drop as the boundary layer builds up. This will result in a reduction of wastewater flow passing through the ultrafiltration system and at the critical point the membranes must be washed. The period between two consecutive membrane-cleaning cycles can vary from two to ten weeks depending upon the characteristics of the wastewater being treated.

- Even with excellent washing (CIP) the overall membrane fluxrate will drop as a function of time and this will determine the overall membrane life span. Again this is dependent upon the wastewater being treated and the life span of the membranes can vary from two to six years.
- Membrane fluxrates can be adversely affected by certain contaminants within the wastewater such as oils, proteins, ant-foaming agents, etc.
- Membrane flux rates are temperature dependent. The designer should consider summer and winter conditions.

### Pilot Trials

No two wastewater streams are alike and, as mentioned before, a successful MBR design must be based upon previous experience and empirical data. The use of a pilot trial covering several weeks of operation is strongly recommended before finalising a process design for an MBR.

In summary the advantages of the tubular cross flow membranes are as follows:

- The membranes are separate from the aeration tank and cannot affect the efficiency of the aeration
- The '*self scouring*' action created by the velocity of the sludge along the surface of a tubular membrane, in fact, considerably reduces the fouling factor.
- The membranes can also be easily back washed, chemically cleaned '*in situ*' (CIP) or removed for servicing after switching to a parallel module.
- Some wastewaters containing high inorganic dissolved solids precipitate salts during biotreatment these can cause problems with cleaning for submerged membranes.
- It is possible to operate the plant at a higher MLSS when compared with most alternative systems
- It is not necessary to use additional aeration for cleaning the membranes in situ



**CASE STUDIES**

<b>End User</b>	<b>Dairygold</b>	
Application	Dairy	
Flow, m <sup>3</sup> /day	2,000	
Bioreactor, m <sup>3</sup>	2,315	
Denitrification, m <sup>3</sup>	516	
Membrane, m <sup>2</sup>	636	
	<u>Input</u>	<u>Output</u>
COD, mg/l	3,600	<50
BOD, mg/l	2,250	<3
Ammonia, mg/l	75	<1
TKN, mg/l		<15
Total P		<0.5



<b>End User</b>	<b>Argent</b>	
Application	Rendering	
Flow, m <sup>3</sup> /day	400	
Bioreactor, m <sup>3</sup>	813	
Denitrification, m <sup>3</sup>	277	
Membrane, m <sup>2</sup>	265	
	<u>Input</u>	<u>Output</u>
COD, mg/l	5.200	<100
BOD, mg/l	3.600	<5
Ammonia, mg/l	700	<50



<b>End User</b>	<b>Bordas Chemicals</b>	
Application	Chemical	
Flow, m <sup>3</sup> /day	42	
Bioreactor, m <sup>3</sup>	2 x 150 pressurised	
Membrane, m <sup>2</sup>	32	
	<u>Input</u>	<u>Output</u>
COD, mg/l	60,000	<6,000



<b>End User</b>	<b>Bayern Leder</b>	
Application	Tannery	
Flow, m <sup>3</sup> /day	600	
Bioreactor, m <sup>3</sup>	2 x 200 pressurised	
Denitrification, m <sup>3</sup>	175	
Membrane, m <sup>2</sup>	240	
	<u>Input</u>	<u>Output</u>
COD, mg/l	5,200	<250
BOD, mg/l	2,500	<10
Ammonia, mg/l	600	<10
TKN, mg/l		<15
Total P		<0.5



<b>End User</b>	<b>Bosch</b>	
Application	Groundwater	
Flow, m <sup>3</sup> /day	10	
Bioreactor, m <sup>3</sup>	13	
Membrane, m <sup>2</sup>	12	
	<u>Input</u>	<u>Output</u>
COD, mg/l	700	<20
Phenol, mg/l	160	<1



**CONCLUSION**

Ten years ago industrial processors would not consider installing on site treatment of their wastewater. However, the increased charges being imposed for treating effluent at the local municipal sewage plant, or the increased constraints for discharges to a water course, is forcing industrial processors to consider on site treatment. Many industrial processors are 'first time buyers' of wastewater treatment plant and the MBR is an optimum solution.

The cross flow MBR is a robust wastewater treatment process providing it is well designed. In summary, the advantages of cross flow MBR are as follows:

- Virtual zero solids discharge in the final effluent.
- The application of a very high MLSS (mixed liquor suspended solids) within the bioreactor which equates to smaller tanks and lower investment cost
- The ability to handle wastewater in which salts and other solids will tend to precipitate.
- The membranes can be easily cleaned *in situ* (CIP)
- The use of low sludge loading (F/M ratio) results in extended sludge age and, by definition, less generation of excess biological matter.
- Very small foot print required when compared to conventional biological treatment plants
- Cross-flow membranes can be retrofitted onto existing activated sludge plants
- The membranes are separate from the biological aerated tank (bioreactor) and will not affect the aeration efficiency. They can be easily removed for inspection.