# Membrane bio-reactor (MBR): Effect of operating parameters and nutrients removal

by

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## Certificate of authorship

I certify that the work in this report has not previously been submitted for any degree nor has it been submitted as part of requirements for a degree except as fully acknowledge within the text.

I also certify that this report has been written by me and the help that I have received in my research work and the preparation of the report itself has been acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

Signature of Candidature

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Sydney, September 2015

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## Nomenclature

| | | |
|---|---|---|
| A | = | The membrane surface area ($m^2$) |
| ASTM | = | American Standard Testing and Methods |
| BOD | = | Biochemical Oxygen Demand |
| BTSE | = | Biologically treated sewage effluent |
| BOM | = | Biodegradable Organic Matter |
| COD | = | Chemical Oxygen Demand |
| Da | = | Dalton |
| DOC | = | Dissolved Organic Carbon |
| DOM | = | Dissolved Organic Matter |
| kDa | = | Kilo Dalton |
| EfOM | = | Effluent Organic Matter |
| GAC | = | Granular Activated Carbon |
| EPS | = | Extracellular Polymeric Substances |
| HPSEC | = | High Pressure Size Exclusion Chromatography |
| kPa | = | Kilo Pascal |
| m.bar | = | Millibar |
| MWD | = | Molecular Weight Distribution |
| MF | = | Microfiltration |
| UF | = | Ultra filtration |
| NF | = | Nanofiltration |
| NOM | = | Natural Organic Matter |
| NTU | = | Nephelometric Turbidity Unit |
| PAC | = | Powdered Activated Carbon |
| $R_m$ | = | Membrane resistance |
| RO | = | Reverse Osmosis |
| SEC | = | Size Exclusion Chromatography |
| SS | = | Suspended Solids |
| t | = | Time |
| TDS | = | Total Dissolved Solid |

| | | |
|---|---|---|
| TMP | = | Trans-membrane Pressure |
| V | = | Total permeate volume (l) |
| $\Delta P$ | = | Applied trans-membrane pressure (Pa) |
| $\eta$ | = | Water viscosity at $20^0$C (N s/$m^2$) |
| $\alpha$ | = | The specific resistance of the cake deposited |
| $\rho$ | = | Polydispersity |
| $^0$C | = | Degree Celsius |

## Abstract

Membrane bio-reactor is an efficient, cost effective and reliable treatment process to produce high quality water from wastewater. In this study, a number of submerged membrane bio-reactors (SMBRs) experiments were conducted at different organic loading rates (OLRs) and fluxes (ranging from 2.5 - 40 L/m$^2$.h and corresponding hydraulic retention time of 10 - 1.5 h) to investigate their influence on organic and nutrient removal and on membrane fouling. A second set of experiment was also carried out with gradual increase of salt concentration in continuous MBR to assess its performances in this particular scenario (which may occur in coastal areas and in certain industries). The operation of MBRs at low HRT resulted in sudden rise of trans membrane pressure (TMP). The sudden development of TMP was minimized by introducing granular activated carbon (GAC) in MBR as suspended medium. The incorporation of GAC reduced TMP or total membrane resistance by 58% and also helped to remove an additional amount of dissolved organic matter. Further, a set of ion exchange adsorption study was conducted for the removal and recovery of the nutrients from the effluent of high rate MBR. The major findings are summarizes below.

The increase of OLR, flux and salt concentration resulted in lower removal of organic and nutrients and also caused higher membrane fouling (i.e. increased transmembrane pressure (TMP) development). The removal efficiency of DOC decreased from 93 – 98 % to 45 - 60 % when the OLR increased from between 0.5 – 1.0 to 2.75 – 3.0 kg COD/m$^3$d. Similarly the removal of ammonia decreased from 83–88% to less than 67% when the OLR was increased to 2.0 – 3.0 kg COD/m$^3$d. The increase of flux (i.e. reducing of HRT) also resulted in 30 - 40 % lower removal of organics and nutrients. The removal of organic and nutrient decreased when the salt concentration was

increased from 0 to 35 g/L. Based on the operating conditions of this study, the suspended media had less effect on nitrification but had an influence on organic removal. However, changing the operating parameters (such as increase of SRT) may improve nitrification rate.

The increase of OLR and salt concentration resulted in higher membrane fouling. Similarly flux and aeration rate also played a major role in membrane fouling reduction. However, the effect of flux on the reduction of membrane fouling was much higher than that caused by aeration rate. A lower flux of 20 $L/m^2$ h produced 75 times more water than a higher flux of 40 $L/m^2h$ with an aeration rate of 0.6 $m^3/m^2{}_{\text{membrane area}}$.h. The reduction of aeration rate from 1.5 to 1.0 $m^3/m^2{}_{\text{membrane area}}$.h caused a sudden rise of TMP. The sudden rise of TMP can be minimized by incorporating the medium in suspension in the reactor (to induce surface scouring of the membrane). The incorporation of suspended medium prevented a sudden rise of TMP (total membrane resistance reduced by ~ 58%) by creating an extra shearing effect onto the membrane surface produced by suspended media. It reduced the deposition of particles on the membrane surface by scouring. The addition of GAC also adsorbed some organic matter prior to its entry to the membrane. Nevertheless it is also important to apply a sufficient aeration rate (in our case 1 $m^3/m^2{}_{\text{membrane area}}$ h) to maintain a good functioning of suspended media in MBR. The aeration helped in scouring and provision of oxygen to microorganisms and maintained the media in suspension. Additionally, the amount and sizes of the suspended medium played major role in fouling reduction. In this study, we found the concentration of suspended media of 2 g/L and GAC size of 300-600 µm was effective in reducing membrane fouling. Therefore a suitable amount and size of suspended medium needed depends on the flux and aeration (or air scour) rate used.

The characteristics of organic matter of SMBRs effluent showed that a range of organic matter (such as amino acids, biopolymers, humics and fulvic acids type substances) was removed by the GAC both by scouring and adsorption mechanisms. A detailed organic matter characterization of membrane foulant, soluble microbial product and extracellular polymeric substances showed that bio-polymer together with humic acid and lower molecular neutral and acids were responsible for membrane fouling along with the deposition of floc particle onto the membrane surface.

MBR usually removes both organic matter and nitrogen from water. However, the removal of nitrogen and phosphorus using a high rate MBR system is not sufficient. It is equally practical to remove nitrogen and phosphorus by physico-chemical processes as post-treatment such as ion exchange/ adsorption. In this study, different ion exchange materials such as purolite (A520E and A500P), hydrated ferric oxide (HFO) and zirconium (IV) hydroxides were used to remove nitrogen and phosphorus from MBR effluent. They all showed ~ 90% removal of nutrients. The nutrients captured on the ion exchanger were later recovered when the ion-exchange was regenerated.