

## Testing the Applicability of Submerged Membrane and Moving Bed Bioreactor (SMBBR) Technology for Municipal Wastewater Treatment in Iraq

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### Abstract

In this work, development of the membrane bio-reactor has been investigated by combining a moving-bed biofilm reactor MBBR with a submerged ultrafilter membrane, 0.08  $\mu\text{m}$  pore size, biomass separator. The MBBR technology utilizes the whole reactor volume for biomass growth, without suffering from "dead" spaces or short-circuiting issues and no need for sludge recirculation. This is obtained by having the biomass grow on the surface of specially engineered plastic media (biomedia or biocarriers) in the form of thin biological layers (biofilms) and have a density of around 1  $\text{g}/\text{cm}^3$ . For that reasons, the HRT will be smaller than MBR. Treatment efficiencies were found to be high with the production of a consistent high-quality effluent, irrespective of loading rates on the bioreactor. Membrane performance (fouling) is a function of the membrane flux and varies with loading rates. Stable operation was found to correlate to the fate of the low flux, 15 – 20  $\text{L}/\text{hr}/\text{m}^2$  and HRT between 5 – 6 hr. Denitrification reaction efficiency to remove the TN was found to be optimum at 300% sludge circulation from biomass separator to anoxic tank.

**Keywords:** Moving bed, Biofilm Reactors, Biomass Separator, Membrane Fouling, Denitrification and Anoxic.

### اختبار وتطبيق المفاعل البايولوجي ذو الحشوة المتحركة والاعشبية الغاطسة لمعالجة

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#### الخلاصة

تم بحث وتطوير المفاعلات البايولوجية ذات الاغشبية الغاطسة النفاذة عن طريق استخدام المفاعل البايولوجي ذو الحشوة المتحركة لاغراض الهضم البايولوجي والاعشبية الغاطسة المتناهية الدقة لاغراض الفصل . تقنية المفاعل البايولوجي ذو الحشوة المتحركة توفر مساحة عالية للنمو البايولوجي على حشوات بلاستيكية خاصة وذات كثافة 1  $\text{g}/\text{cm}^3$  مما يجعلها عالقة بالماء . نتيجة لذلك ، فان هذه التقنية ذات وقت استبقاء اقل بالمقارنة مع المفاعلات ذات الاغشبية الغاطسة النفاذة مما يجعل حجم المفاعل اصغر كما انها لا تحتاج الى تدوير الاطيان . تبين من خلال هذا البحث ان كفاءة هذه التقنية عالية والمياه الناتجة عالية النقاوة بغض النظر عن الحمل العضوي للمياه الداخلة كما ان احتمال انسداد الاغشبية يتناسب طرديا مع معدل الجريان لوحدة المساحة من الاغشبية وعلى فترة التفاعل البايولوجي . لغرض الحصول على تشغيل مستمر وامين ( بدون مشاكل ) ، لوحظ ان معدل الجريان للمياه الخارجة لوحدة المساحة من الاغشبية يجب ان تكون بين 15 – 20 لتر / ساعة /  $\text{m}^2$  وفترة التفاعل البايولوجي بين 5 – 6 ساعة .

الكلمات المفتاحية : الحشوة المتحركة ، المفاعل البايولوجي ، الاغشبية الغاطسة ومياه الصرف الصحي.

## Introduction

a cake layer, pore plugging/clogging by colloidal particles, adsorption of soluble compounds and bio-fouling are some of the main forms of fouling that have been identified (Defrance *et al.*, 2000). Fouling is particularly a problem in MBR since the process deals with liquors having high concentrations of total solids as well as dissolved compounds such as extracellular polymeric substances (EPS). Fouling is defined as reversible, i.e. can be removed by backwashing strategies, or as irreversible, i.e. fouling which is only recoverable by chemical cleaning, where the dominating fouling mechanism subsequently determines the performance of the process. Optimizing fouling control and cleaning strategies is therefore an important aspect of developing and designing MBR processes. An alternative to the MBR is combining a bio-film reactor with membrane separation of the suspended solids which may reduce the effect of membrane fouling by high biomass concentrations (Leiknes and Degaard, 2001 and 2002). Although efficient in removing soluble organic matter, bio-film reactors designed as trickling filters or submerged filters using granular media are prone to clogging when the wastewater contains high loads of particulate matter. Consequently, there is a limit to the loading rate that can be applied to such processes, often necessitating a pretreatment step for particle removal prior to the bio-film unit. The moving-bed-bio-film reactor with immersed membrane (SMBBR) is an alternative process design which utilizes the advantages of a bio-film reactor, which at the same time can handle high loads of particles, with immersed membrane as biomass separator. The

objective of this work is to investigate the efficiency of COD and TSS removal in municipal wastewater at different HRT, membrane fouling and the quality of the effluent in SMBBR, and de-nitrification efficiency.

Membrane bioreactors (MBR) are combination of membrane filtration and biological treatment using activated sludge (AS) where the membrane primarily serves to replace the clarifier in the wastewater treatment system (Gunder and Krauth, 1998 ; Van der Roest *et al.*, 2002). A disadvantage of the cross-flow side-stream membranes is the high energy required to generate sufficient sludge velocity across the membrane surface, and this process option was therefore considered nonviable for treating municipal wastewater. The development of submerged low pressure configurations in the period of 1980–1990, by immersing the membranes into the AS tank, was an important step in making viable commercial solutions for the MBR process (Bouhabila *et al.*, 1998 ; Davies *et al.*, 1998). Today a variety of process configurations exist where the membrane is installed either in an external unit or immersed in the aeration tank and where the systems are designed to be operated under low-negative pressure. Compared to conventional AS systems, several advantages of the MBR have been identified (Stephenson *et al.*, 2000) which have promoted the development of commercial MBR options. These include compact units with small footprints, complete solids removal, effluent disinfection, operation at higher suspended biomass concentrations resulting in long sludge retention times, low sludge production, and no problems with sludge bulking. One of the major drawbacks of MBR

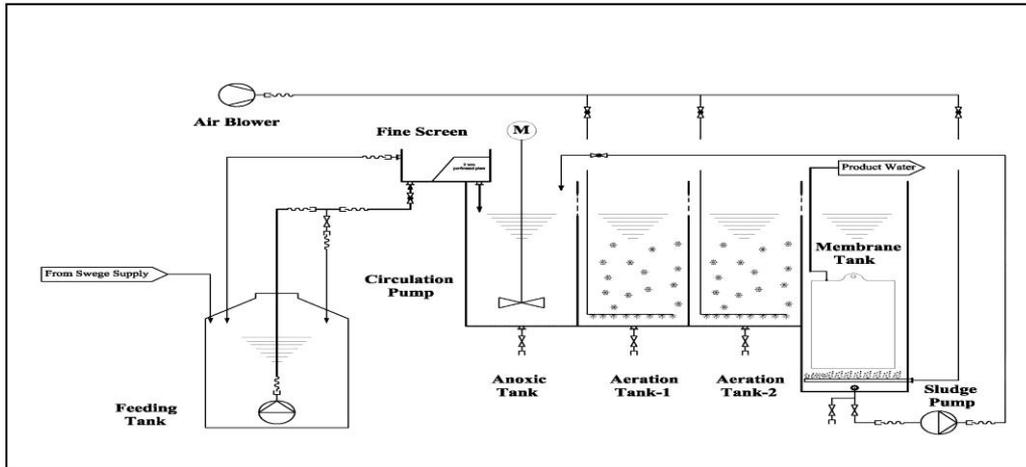


Fig. (1) Schematic Drawing of the MBBR and Immersed Membrane Process Used in the Steady



Fig. (2) Image of the MBBR and Immersed Membrane Unit

is fouling, which is common for all membrane systems, where the efficacy of the process is constrained by the accumulation of materials on the surface of or within the membrane resulting in a reduction in the membrane permeability. Membrane fouling is caused by different materials and the mechanisms are rather complex and interrelated. Deposition of solids as For the pilot plant investigated in this work, municipal wastewater from Al-Zafrania residential complex sewer system was pretreated using a small gravity settler and inclined screen, then pumped into the MBBR reactor. The outlet of the MBBR is

subsequently led into the membrane tank from where permeate is extracted through the membrane under vacuum using negative static head pump. A small volume of the concentrated sludge, , is removed as excess sludge or recycled to the anoxic tank for nitrogen removal . Fig. (1) show an image of the unit used for this work.

## Materials and methods

A schematic of the MBBR and immersed membrane process concept is shown in Fig. (2), where the treatment train consists of three sectors, the anoxic tank, MBBR

( aeration tanks-1, 2) followed by a membrane biomass separator with submerged modules and the process can therefore be defined as a biomass separation membrane bioreactor. By dividing the two sectors into separate entities, each process step can be designed and operated at optimal conditions.

The influent wastewater enter the first chamber and comes in contact with the carriers bio-media and air with large surface area provide by the carriers, helps the bacteria to form large colonies on the carriers. Each carrier slowly moves in a circular motion from the surface to the bottom and then upward again.

The influent enters the first chamber of the MBBR and from it flows to the second chamber, through a perforated plate. The same treatment will repeated in the second chamber and remaining biomass from the first chamber gets fully digested here.

Air flow is supplied to MBBR by a ring blower and distributed inside through perforated PVC pipe.

### The Membrane Biomass Separator

The membrane biomass separator was designed as an external submerged unit where the dimensions of the separator are adjusted to contain 5 flat sheet modules membrane. The type of membranes used are EK-08 from Ecologix (Taiwan) with pore size 0.08  $\mu\text{m}$ , effective area for each membrane module 0.8  $\text{m}^2$  and manufactured from PVDF. The permeate flow rate of the biomass separator is 80 L/hr (6 hr HRT) at low rate and 160 L/hr (3 hr HRT) at high rate.

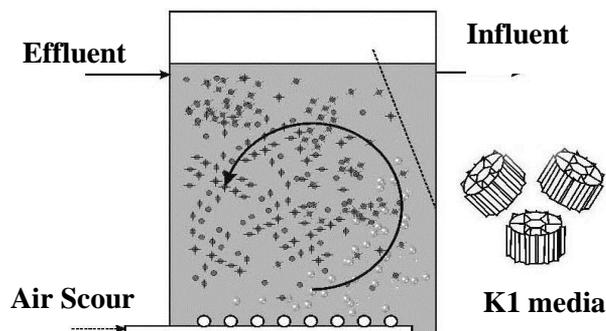


Fig. (3) The Moving-Bed Bio-Film Reactor (MBBR) Concept and Illustration of Carrier Types.

### Anoxic Tank

Anoxic tank 250 L is in capacity used for nitrate removal. It supplied with slow mixer to mix feed with the recycled sludge from the membrane tank. No carrier used in the anoxic tank(Fig.2)

### The Bio-film Reactor

MBBR consists of two chambers, aeration tanks-1, 2 as shown in Fig. (2) each of 250 L capacity. In the MBBR, the biomass grows on carriers that move freely in the water volume by aeration were kept within the reactor volume by a sieve arrangement at the reactor outlet as mentioned by (Vdegaard *et al.*, 1994). The biofilm carriers were made of high-density polyethylene (density 0.95  $\text{g}/\text{cm}^3$ ) and shaped as small cylinders with a cross on the inside of the cylinder and "fins" on the outside. The size of the carrier had lengths of 10 mm and diameters of 15mm. The carrier filling fraction percentage of reactor (volume occupied with carriers in empty tank) was normally 60–70%. The concept of the reactor and illustration of carriers was shown in Fig. 3. K1 media (supplied by EEC High Speed Bio TEC Co., Germany) was used in the pilot plant reactors at 70% filling-fraction giving an effective specific surface area of 500  $\text{m}^2/\text{m}^3$  tank

**Table (1) Average Treatment Efficiency of the Overall Process ( Min. and Max. Values Given in parenthesis) for Different HRT.**

	MBBR Inlet	MBBR Outlet	Permeate
<b>Low rate</b>			
<b>6 hr HRT</b>	450 ( 400 – 500 )	45 ( 50 – 40 )	20 ( 25 – 15 )
COD mg/L	300 ( 350 – 250 )	30 ( 35 – 25 )	0
FCOD mg/L	100 ( 120 – 80 )	120 ( 130 – 110 )	
TSS mg/L			40 ( 50 – 30 )
<b>High rate</b>			
<b>3 hr HRT</b>	450 ( 400 – 500 )	90 ( 100 – 80 )	0
COD mg/L	300 ( 350 – 250 )	60 ( 70 – 50 )	
FCOD mg/L	100 ( 120 – 80 )	100 ( 120 – 80 )	
TSS mg/L			

FCOD, COD in filtrated sample

fouling behavior of the bio-film effluent on the membrane.

Results showed that the operation of the plant is reliable in low rate, 5-6 hr HRT, and high rate, 3 hr HRT, and the overall treatment efficiencies were found to be more or less the same irrespective of how the membrane reactor was operated giving average values of 99.5% removal of suspended solids, and ~90% COD removal. Infact, the biodegradable constituents were removed in the MBBR while the particulate matter was removed in the membrane separator with no measurable biodegradation occurring in the membrane reactor. Performance and operation of the MBBR, however, varied as a function of loading rate.

The average values measured for COD, FCOD and SS for the operating conditions tested are given in Table (1). Fouling rates are determined by measuring the change in TMP ( trans-membrane pressures ) over time for constant flux operation. Fig. (4) shows examples of membrane performance for membrane biomass separators at different flux values.

#### Analysis

All analyses were performed according to national or international standards. Chemical oxygen demand COD, according to method 8000, HACH spectrometer Dr-2800. Suspended solids TSS, according to the 2540D standard method. For the filtered chemical oxygen demand (FCOD) samples were first filtered through a Whatman GF/C glass microfiber filter.

#### Results and Discussion

The work was conducted using pilot plant consisted of a MBBR reactor followed by membrane separator unit. A variety of operating modes were investigated to evaluate overall treatment efficiencies and to determine Variations of operating modes tested for the membrane reactor consisted of operation at different flux values for

fouling control. The membrane unit was capable of operating with a maximum flux around 40 L/m<sup>2</sup> hr with a relatively high fouling rate, i.e. permeability decline and at 20-15 L/m<sup>2</sup> hr with low fouling rate.

De-nitrification efficiency for nitrate removal was measured at different circulation rates from membrane tank to anoxic tank. Fig. 5 shows TN

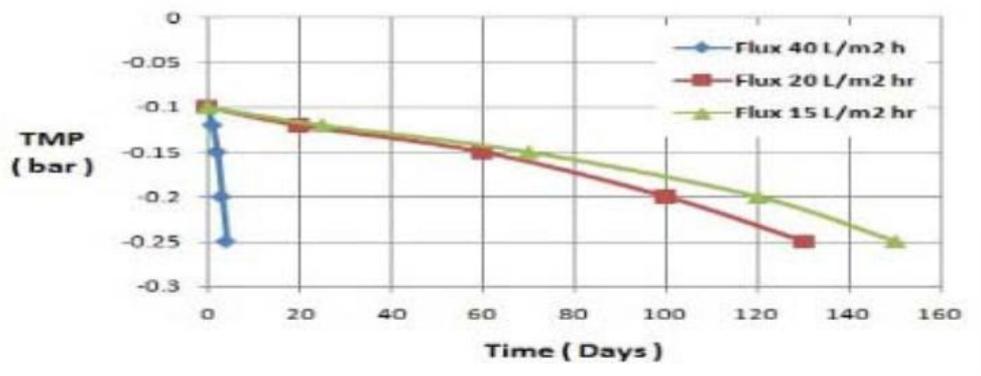


Fig. (4) Typical Variation Trans-Membrane Pressures (TMP) with

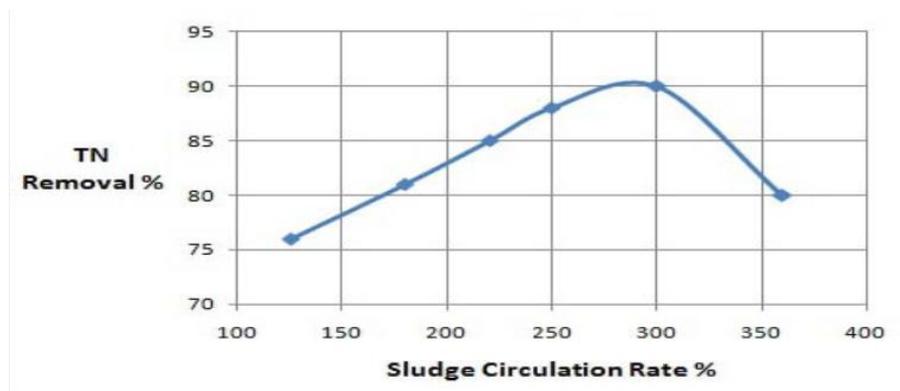


Fig. (5) Total Nitrogen (TN) Removal Rate as a Function of Sludge

removal efficiency is optimum at 300% sludge circulation. membrane fouling. MBBR process treatment efficiencies and produces a consistent high-quality effluent, irrespective of loading rates. Membrane performance, however, is dependent on wastewater quality and

correlates to the submicron particle size fractions in the suspended solids. During the nitrification process in the bio-film reactor Nitrate is formed, but sludge circulation from membrane anoxic tank will change it to Nitrogen by de-nitrification process

**conclusions and Recommendations**

SMBBR process has the potential of operating with different HRT, from 6 to 3 hrs. Sustainable process operation with membrane fluxes around 15 – 20 L/m<sup>2</sup> hr have been achieved under the conditions tested. This alternative strategy is to reduce the effect of Leiknes, T. and Degaard, H. (2002). Combination of Moving Bed Biofilm Reactor and Membrane Filtration, Membrane Filtration Technology for Water Treatment, Proceedings, Japan/Norway Workshop NTNU, Trondheim, Norway. Stephenson, T.; Judd, S.; Jefferson, B. and Brindle, K. (2000). Membrane Bioreactors for Wastewater Treatment, IWA Conference, London.

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