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Effect of the Pre-treatment on the Performance of MBR, Al-Kut WWTP, Wasit Governorate

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Abstract

Pilot scale experiments were carried out to examine the effect of the pre-treatment methods on the performance of MBR. The TITAN MBRTM module was used in this study. In order to investigate the effect of pre-treatment on the behavior of membrane, samples were collecting at different locations in Al-Kut WWTP, Wasite. The first samples group has been collected directly from the main source as raw sewage to determine its main characteristics of wastewater. The second group samples have been collected from outlet of Al-Kut WWTP (conventional treatment) and the third group and fourth group samples have collected from outlet of pretreatment of MBR system and finally treated wastewater from MBR system. The study showed that the membrane bio-reactor filters out nearly all solids, the pre-treatment has a positive effect on the MBR performance, and the pre-sedimentation is more effective than fine screening. Moreover, aeration is considered as one of the intrinsic parameters in both hydraulic and biological process performances because of its ability to maintain solids in suspension, scours the membrane surface, limits fouling, and provide oxygen to the biomass, which results in a better biodegradability.

Keywords: Flux; Membrane bioreactor; Membrane fouling; TITAN™ MBR module

Introduction

The membrane bioreactor is an activated sludge process coupled with membrane filtration instead of the settling process for liquid-solid separation. Because of the membrane filtration, the suspended solids are completely removed from the treated water to the extent that the effluent contains no bacteria in microfiltration or no virus in nanofiltration [1]. This very compact arrangement produces a MF/UF quality effluent that is suitable for reuse applications. Depending upon the membrane nominal pore size, the virus removal can consequently be attained by providing a barrier to certain chlorine resistant pathogens as *GIARDIA* [2]. The present study discusses the performance of the membrane bioreactor (MBR), which, in recent, is widely used for the municipal and industrial wastewater treatment and the effect of the pre-treatment on its performance. Main variable parameters as COD-pH-DO-MLSS-SVI-TKN-PO_4-P-Vacuum and flux obtained are accurately monitored and recorded.

Membrane Bioreactors (MBRs) have become a standard technology for wastewater treatment. However, understanding how to ensure sustained membrane permeability remains a key operational consideration. Several approaches have been introduced in order to reduce fouling including intermittent suction, back-flushing, module design improvement, or the optimization of aeration such as with the MBR aeration technology which has enabled dramatic reductions in operational energy cost to be realized. Nevertheless, membrane fouling remains important, particularly understanding how to respond to system perturbation, and as such it is suggested that MBR cost could be further reduced by better control of membrane fouling [3].

Membrane fouling is a consequence of the interaction between the membrane and a complex mixture comprising colloids, bacterial flocs and dissolved macromolecules. It has been widely reported that soluble microbial products which comprise mainly of proteins and polysaccharides are primarily responsible for the clogging and blocking of membrane pores. As these compounds are generally colloidal in nature, their transport is primarily controlled by Brownian motion and as such the shear forces applied either through pumping (in side stream) or aeration (in immersed) are insufficient to provide back-transport toward the bulk which results in preferential colloidal deposition at the membrane. Deposition of these high molecular weight compounds result in formation of a highly-hydrated gel matrix into which microorganisms are embedded, resulting in a significant resistance to permeate flow during membrane operation [4].

To ameliorate the potential impact of SMP on membrane fouling, several authors have introduced the use of coagulants, which enable the assimilation of SMP compounds into aggregates (or flocs), that are then more strongly influenced by inertial lift and shear induced diffusion, thereby promoting back-transport away from the membrane surface into the bulk [5].

Numerous chemical compounds have been trialed including metal salts, biopolymers, starch and organic polymers and have been considered particularly pertinent for reactive dosing of the coagulant to limit the impact of sudden SMP release in response to process perturbation, such as saline shock. Crawford [6] described the use of MPE50 which is a modified biopolymer with a net cationic charge that has been demonstrated to effectively reduce membrane fouling both at laboratory and full scale [7] suggested that the cationic structure of MPE50 enabled the neutralisation of the negatively charged colloidal biopolymers, thereby encouraging floc growth, which can be considered analogous to conventional coagulation-flocculation. However, in conventional application, coagulation and flocculation processes are generally configured in series. In the coagulation step,

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coagulant is added within a high shear zone with an average velocity gradient (*G*) exceeding 1500 s^{-1} to ensure the coagulant is distributed homogeneously to achieve particle destabilization and charge neutralization. Flocculation then proceeds in a secondary shear zone with a gentler average velocity gradient of around 100-200 s^{-1} to encourage successful collision of destabilized particles and is provided with a retention time of up to 60 min to ensure subsequent floc growth is complete.

For comparison, there is no high shear zone specified within present MBR design to incorporate coagulant dosing. Furthermore, the average velocity gradient imposed by coarse bubble aeration in MBR is around 150-200 s^{-1}. Consequently, without a clearly delineated high shear zone to provide homogeneous distribution of the coagulant, and with gas mixing in MBR providing a velocity gradient which is equivalent to flocculation, it is suggested that coagulation-flocculation will be rate limited within MBR which will cause a delay in the time from which coagulant is reactively dosed to when colloids destabilize and form aggregates. As flocculators are generally designed with residence times of up to 60 min to enable sufficient time for aggregate growth, it is posited that with direct dosing of MPE50 into the MBR, the time at which coagulant is added during the filtration cycle could therefore be of significance to sustaining membrane permeability during filtration [8].

Organic matter in raw wastewater is partially converted to biomass, which is eventually used for biogas production (energy recovery) in some cases. However, the conversion rate to biomass is not high [9,10]. At present, a large portion of organic matter in wastewater is not recovered but is degraded into carbon dioxide and water with external energy input. A paradigm shift is necessary: organic matter in wastewater should not be degraded but recovered for energy production. Wastewater from domestic usage contains a significant amount of potential energy. Capturing this organic matter as a renewable energy source will be an attractive process. Wastewater treatment plants can be net energy producers by utilizing organic matter in municipal wastewater that is currently degraded with external energy input [11].

Anaerobic treatment processes are viable options for producing energy from organic matter in wastewater. Concentration of COD in municipal wastewater is in the range of 250-800 mg/L [12], whereas it is difficult to apply anaerobic processes to wastewater with COD concentrations of <1500-2000 mg/L. Concentrating raw wastewater can therefore facilitate application of anaerobic processes to produce biogas. Analysis of the particle size distribution of organic matter in raw municipal wastewater showed that 63-70% of total organic carbon (TOC) was associated with particles that were larger than 0.1 µm. Loose membranes such as microfiltration (MF) membranes can efficiently retain particulate and colloidal organic matter in wastewater. Concentrating organic matter in wastewater can therefore be carried out by membrane processes, facilitating recovery of energy from wastewater via anaerobic digestion. Direct Membrane Filtration (DMF) of wastewater has advantages including simplicity of design and maintenance. However, in DMF of municipal wastewater, severe membrane fouling is very likely to occur. Although several attempts have been made to concentrate organic matter in wastewater by using membranes, few studies have focused on membrane fouling in DMF. It is not clear whether long-term operation of a membrane process for recovery of organic matter from wastewater is feasible [13].

Materials and Methods

Lab-scale submerged membrane bioreactor

A cylindrical lab scale reactor of 25 cm diameter and 55 cm height with open top has been installed in the laboratory (Al-kut WWTP laboratory, Wasite). The capacity of the reactor is 251, in which a TITAN membrane module is submerged. The reactor is fed with wastewater from a 50 L polyethylene feeding tank via a dosing pump with feeding rate varies from zero to 100 mL/min. For generating permeate, filtration is induced by the vacuum pump. Thus, the trans-membrane pressure (TMP) of the membrane is monitored as a negative value ranging from 20 to 50 kPa. The system is aerated by diffused air. The HRT of the bioreactor is 6 h while the SRT was 8 days. The Figure 1 illustrates the schematic diagram of the bioreactor. Raw wastewater collected daily from the inlet of the primary sedimentation tank of Al-kut Wastewater Treatment Plant, Wasite, Iraq was supplied as feed water in this study. The sewer system connected to the treatment plant is a combined system and covers a population of 500,000.

Membrane filtration was carried out in the outside-in mode at constant membrane fluxes. Resultant trans-membrane pressure (TMP) was recorded automatically by digital pressure meters. Intermittent filtration (3 min pause for every 12 min of filtration) was performed with peristaltic pumps. To mix the tanks, aeration was also provided in both tanks at the flow rate of 4 L/min throughout the experiments.

Assessment of the distribution of fouling resistance

At the termination of each filtration run, fouled membranes were taken out from the tanks and subjected to dead-end filtration tests using

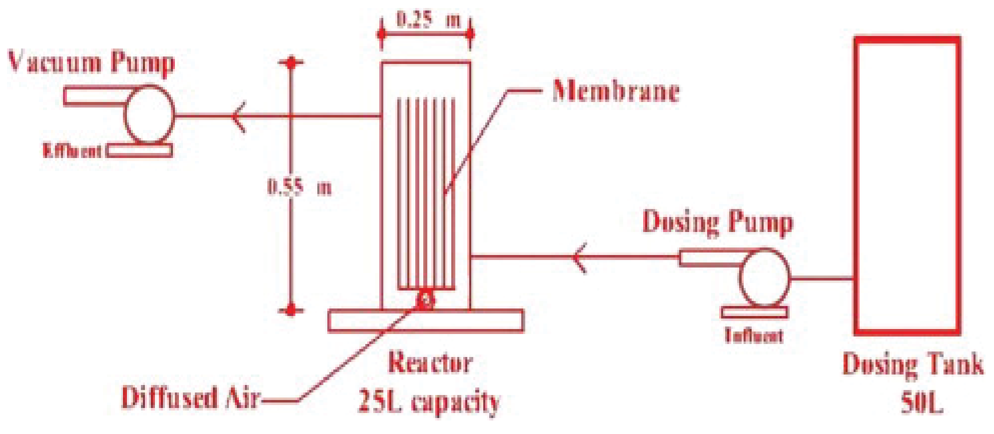

Figure 1: Schematic diagram of the MBR.

pure water. Pure water permeabilities of the fouled membranes were measured to investigate the distribution of fouling (i.e., reversible or irreversible fouling). The fouled membranes were gently wiped with a soft sponge to remove deposits from the membrane surface. Pure water permeability of the wiped membrane was then measured. Restoration of pure water permeabilities achieved by wiping represents the degree of reversible fouling, whereas filtration resistance that remained after wiping represents the degree of irreversible fouling [14]. Conversion from pure water permeability to filtration resistance was made based on Darcy's law:

$$J = \frac{\Delta P}{\mu R_t}$$

Turn Math Jaxon; where Rt is total filtration resistance (m^{-1}), J is permeate flux ($m^3/m^2/s$), ΔP is TMP difference (Pa), and μ is viscosity of water (Pa s).

Air diffusion

In a submerged MBR, Cross-Flow Velocity (CFV) is created by aeration, which not only provides oxygen to biomass, resulting in a better biodegradability and synthesis of the cells, but also, maintains the solid in suspension and controls the membrane fouling by hydraulic shear force and agitation. The air-induced cross-flow can efficiently remove or at least reduce the fouling layer on the membrane surface. The rate of air diffusion in this research was 15 l/h.

Start up

The reactor has been seeded with an activated sludge from the plant of Al-Kut WWTP for two weeks. The sludge is continuously aerated by diffused air. The concentration of the dissolved oxygen in the reactor was 5.8 mg/L at the ambient temperature (26.4°C).

Analytical methods

Analysis of MLSS, TSS, TKN, COD, DO, TP and NO_3-N for the influent and effluent was conducted using the procedures described in standard methods. These parameters were monitored and recorded continuously, all tests methods were conducted according to APHA [15].

Experimental evaluation of membrane fouling

The Flux is the quantity of material passing through the unit area of membrane per unit time $m^3/m^2/h$ (LMH) and is occasionally referred to as the permeate velocity m/h. The driving force for the process may be a trans-membrane pressure gradient. Since the flux and driving force are interrelated, either one can be fixed. In order to observe membrane fouling; the driving force was fixed according to the required vacuum by membrane manufacturer at the range between 20 and 50 kPa.

Results and Discussion

Al-Kut wastewater treatment plant treats about 65000 m^3/d. The primary treatment contains screens, aerated grit chamber and primary settling tank. The biological treatment consists of four activated sludge basins and final two sedimentation tanks. To start up, the reactor was seeded by an activated sludge which is withdrawn from the return sludge tank. The MLSS was 3600 mg/l and the SVI was 110 mg/l. Before studying the effect of the pre-treatment on the performance of the membrane, raw sewage samples were withdrawn and analyzed. The main characteristics of the raw sewage are determined and tabulated in Table 1.

The raw sewage has a ratio of C:N:P of approximately 139:4.1:1.0 so there is a surplus of nitrogen and phosphorus. Dissolved oxygen concentration indicates that the influent is in aerobic conditions. To investigate the performance of the MBR as compared to the activated sludge system, a comparison between the characteristics of the effluents of the membrane bioreactor and activated sludge system in Al-Kut WWTP should be carried out. For six months (Feb. to Jul. 2016) a complete analysis of the influent and the effluent was carried out in Al-Kut WWTP (Figure 2). The Table 2 summarizes the main characteristics of the influent and effluent in Al-Kut wastewater treatment plant. The given values are the mean values during the six months of measurements. The obtained results of the effluent indicate that the performance of the activated sludge system inefficient and the results didn`t comply with the environmental laws in Iraq (TSS, COD, TKN and PO_4-P values were exceeding the Iraqian permissible limit (Figures 3 and 4).

Effect of pre-treatment on the performance of the membrane bioreactor

As mentioned before, the aim of this study is to investigate the effect of the pre-treatment on the performance of the membrane. Fine screening and pre-settling are proposed as the methods of pre-treatment. Fine screening screening must be in place to remove larger materials, but most waste products can be decomposed with the right bacterial composition. Effluent water is almost free of solids and larger particles. The raw sewage was screened via stainless steel screen meshes 1 and 2 mm size. Although a 1 mm screen is standard, a finer screen is required for some types of hollow fiber membrane modules. On the other hand, a coarser screen will suffice for some flat sheet membrane modules. Pre- settling tank Al-Kut WWTP contains a primary settling tank with a volume of 5500 m^3. It removes approximately 36% COD, 26% PO_4-P, 11% TKN and 52% TSS. The MBR is fed with the pre-settled wastewater from the effluent of the primary sedimentation tank.

Three groups of the experimental work are carried out. The first and second groups are to study the performance of the MBR for the fine screened influent while the third group studies the performance of the MBR for the pre-settled influent. Each set of experiments and analysis was carried out for two weeks. The average of the measured values is recorded and tabulated. The Tables 3 and 4 summarizes the main characteristics of the influent and effluent during the application of MBR in the laboratory after the pre-treatment. The MBR results show that there is no significant difference between the obtained results using 1 and 2 mm fine screening. The pre-settling has a higher effect than the fine screening on the performance of the MBR. This seems to be attributed to the high removal of the suspended solids in the primary settling tanks due to the HRT.

Parameter	Average value (six months data)
pH	8.15
D.O	1.1 mg/L
TSS	316 mg/L
COD	1640 mg/L
TKN	48.9 mg/L
NO_3-N	11.8 mg/L
PO_4-P	6.4 mg/L
Conductivity	1930 S/cm

Table 1: Results of raw sewage analysis.

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Parameter	Raw sewage	After primary treatment	After biological treatment
pH	8.15	7.74	7.38
TSS (mg/l)	316	112	44.8
COD (mg/l)	1640	844	82.6
TKN (mg/l)	48.9	46.1	12.6
PO_4-P (mg/l)	6.4	4.52	1.32

Table 2: The main characteristics of the influent and effluent in Al-Kut WWTP.

Parameter	Raw sewage	After fine screening (1 mm)	After primary settling (2 mm)	MBR effluent		
				(1 mm)	(2 mm)	Pre-settled
pH	8.12	8.06	7.98	7.56	7.44	7.36
TSS (mg/l)	265	213	117	2.12	0.92	0.77
COD (mg/l)	1560	1420	786	26.10	17.0	13.6
TKN (mg/l)	49.70	48.10	45.3	6.20	5.34	4.2
PO_4-P (mg/l)	11.2	11.1	6.34	0.84	0.43	0.31

Table 3: Wastewater quality of the influent and effluent during the application of MBR.

Parameter	Raw sewage	Removal (%)				
		After fine screening (1 mm)	After primary settling (2 mm)	MBR effluent		
				(1 mm)	(2 mm)	Pre-settled
pH	8.12	0.74	1.72	6.90	8.37	9.36
TSS (mg/l)	265	19.62	55.85	99.20	99.65	99.71
COD (mg/l)	1560	8.97	49.62	98.33	98.91	99.13
TKN (mg/l)	49.70	3.22	8.85	87.53	89.26	91.55
PO_4-P (mg/l)	11.2	0.89	43.39	92.50	96.16	97.23

Table 4: The removal percentages after MBR treatment.

Figure 2: Al-kut WWTP.

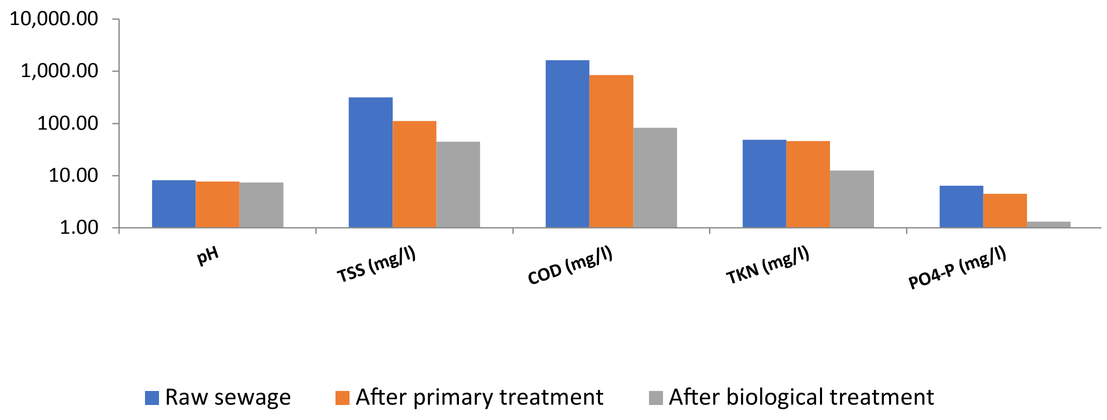

Figure 3: The main characteristics of the influent and effluent in Al-kut WWTP.

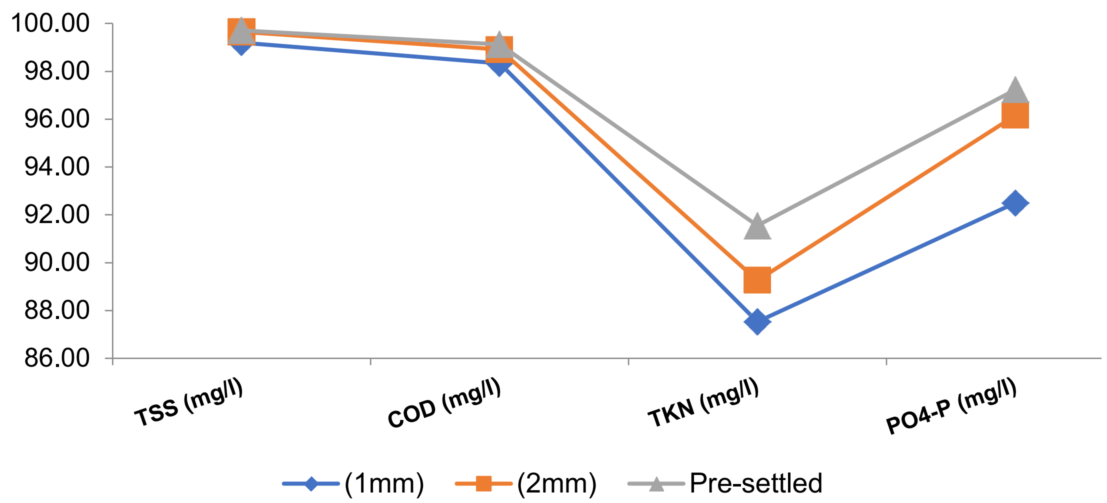

Figure 4: The removal percentages after MBR treatment.

Comparison between the effluent of the activated sludge in Al-Kut WWTP and the effluent of the membrane bioreactor

COD, TKN, PO_4-P and TSS of the effluent of the activated sludge system and membrane bioreactor. As a consequence, the comparison between the activated sludge system and membrane bioreactor is established. It can be seen that the difference between the characteristics of the effluent resulting from activated sludge treatment in Al-Kut WWTP and the effluent resulting from membrane bioreactor is significant due to suspended solids concentration, COD and PO_4-P exceed the Egyptian permissible limits (40, 80 and 1 mg/l, respectively) while the effluent treated water from MBR is complying with Iraq regulation. The obtained results of the two pre-treatment methods (1 & 2 mm pre-screened and pre-settled) in the MBR system meet the requirements of the environmental legislations for reuse [16].

Since the membrane acts as a barrier to bio solids and microorganisms, the effluent quality is much better than that produced by a conventional plant. Also, the membrane barrier eliminates the secondary clarifier and allows the activated sludge to be more highly concentrated. This reduces the capacity needed for biological tanks, saving space and money.

Conclusion

This study aims at investigating of the effect of the pre-treatment on the performance of the membrane biological reactor for six months. A TITAN MBR module from PALL Membrane Systems was used in this study. The obtained results reveal that the pre-sedimentation is more effective than the fine screening (1 & 2 mm fine screening), in this case study, as a pre-treatment method. Additionally, the membrane bio-reactor filters out nearly all solids and satisfies the environmental requirements of reuse. The TITAN MBR module employs a unique air scour nozzle, delivering air in the center of each membrane fiber bundle to effectively shake the membrane and scour the entire fiber length. The advanced air scour nozzle design minimizes power consumption by delivering air efficiently in a cyclical fashion while eliminating sludging. Moreover, aeration maintains solids in suspension, controls the membrane fouling by hydraulic shear force and agitation and provides oxygen to the biomass, leading to a better biodegradability and synthesis of the cell.

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