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Performance of Membrane Bioreactor in Removal of Heavy Metals from Industrial Wastewater

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Abstract

Membrane technology is one of the few non-pollutant choices when selecting a treatment process. A membrane with suitable pore size can remove almost all pollutants without using any chemicals. In this research, chromium, zinc and lead were removed from synthetic wastewater by a membrane bioreactor. The results showed that by using a membrane bioreactor, the COD removal efficiency was increased in all conditions in comparison with that of an activated sludge process system. According to the test results, in the case of having heavy metals; Chromium with a concentration below 50 mg/l , the removal efficiency was shown to be about 95% and at these concentrations, chromium has no toxic effect on micro-organisms. However, the Activated Sludge Process showed poor removal efficiency in the case of having zinc. But when ASP was used in conjunction with the membrane, the removal efficiency was increased to 76%. Membrane showed an improvement of efficiency from 44% to 65% in the case of having 50 mg/ l of lead.

Keywords: *Membrane bioreactor, Heavy metals, Wastewater treatment*

Introduction

In recent years the need for removal and recycling of metal ions from industrial wastewater has attracted more interest due to environmental protection and economical constrain. It saves cost and reduces heavy metal effects on the growth of micro-organisms which ultimately affects the food chain of bio-organisms including human beings [1]. The conditions of wastewater disposal to water body have become more restricted due to environmental protection laws, moreover, the companies are under pressure for the reduction of operational costs [2].

Membrane processes that are used for heavy metal removal are expensive. These processes could be used as a filtration unit and secondary treatment after various types of pre-treatments. In an activated sludge process, if membrane is used after the aeration pond, in fact the secondary aeration pond is replaced by the membrane [3]. In such systems complete decomposition and separation of influent organic matters could be achieved by maintaining high concentrations of microorganisms within the reactor, and also using the various types of membrane to prevent the discharge of heavy molecules. Due to membrane separation,

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solid retention time (SRT) is independent of hydraulic detention time (HRT) [4].

Application of membrane technology for the bio-treatment of wastewater was first reported by Brindle et al in 1996 [5]. In 1999, Thomass et al reported zero excess sludge production when using membrane with domestic wastewater treatments [6]. It has also been reported that aerobic membrane bio-reactors could treat industrial waste water on a large scale. A membrane bioreactor with an HRT of 24 hours could treat a concentrated metal electro plating unit wastewater with an organic loading rate of 6.3 kg COD m^{-3} d^{-1}. In the mentioned process a high removal efficiency of ammonia, fat, grease, heavy metals and phosphorus removal efficiency was achieved [7].

In this research a membrane combined with a bioreactor was used to remove heavy metals from a semi synthetic wastewater. It was concluded that the efficiency of this method was higher than that of the activated sludge process used alone.

Materials and Methods

A membrane bioreactor system was used for the purpose of this research. The membrane was to remove microorganisms, solids, and heavy metals. The total volume of the bioreactor was 6,900 cm^3. Initial sludge was taken from the Gheytarieh waste water plant. The membrane was tubular with a single channel made by the Pall Corporation (type T101070). It was a ceramic micro filter with a porous size of 0.1 μm, .The growth of the biomass has reduced the pore size, hence, it could only remove the heavy metal ions. The external and internal diameters and the internal area of the membrane were determined and are 10 mm, 7mm and 50.5 cm^2 respectively. The membrane was of hydrophilic type. A cooling system was used to prevent the temperature increase during the process.

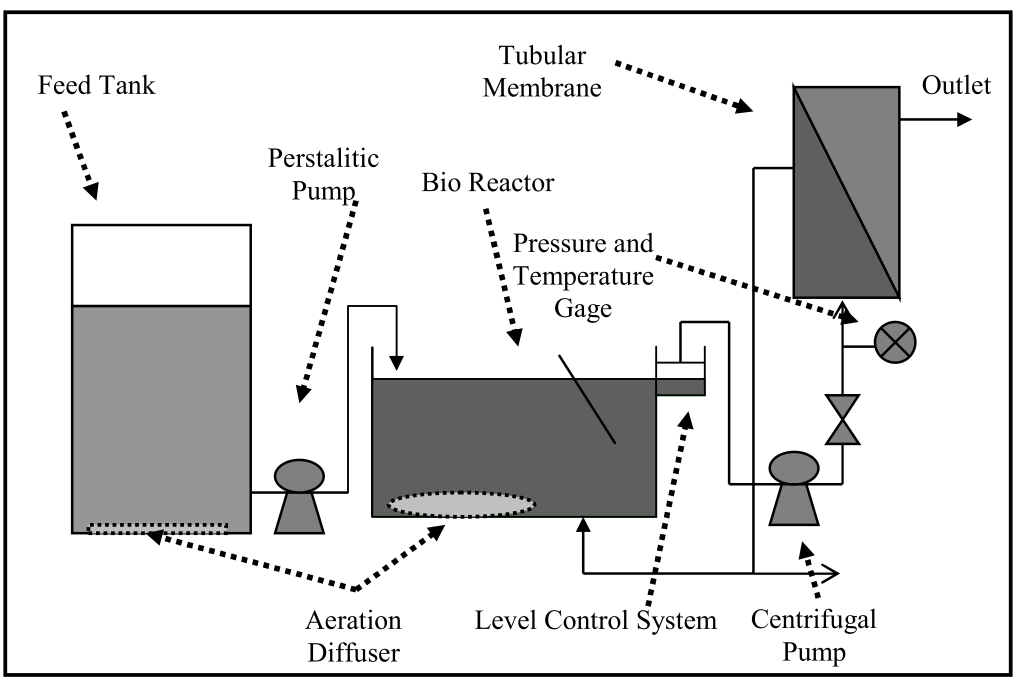

Figure 1. The experimental set-up

First we used the sludge from the Gheytarieh wastewater treatment plant as the seed.The mollusses for feeding COD/N/P was equal to 100/5/1. In the beginning the system was working continuously and after a month,it became ready for metal ions feeding and sampling. The waste water contained three metal ions of chromium (III), zinc (II), and lead (II). These three metals were selected due to their more negative impact and toxic effect on the micro organism.

In order to prepare a wastewater containing Cr^{3+} we had to use potassium de-chromate (35% weight chromium). When the objective was to produce a wastewater containing Zn^{2+}we had to use zinc sulphate (41% weight zinc). Ultimately, to produce waste-water containing Pb^{2+}, lead nitrate (63% weight lead) were used. The levels of ions concentration used in this experiment were 10, 25,and 50 mg per litre for each ion.

The process was continuous with a hydraulic detention time of 7 hours. The samples were taken from two points, one from the activated sludge tank effluent.This tank was labled AS or reference tank. The second sampling was done after the membrane and was named sample. The system characteristics are shown in Table 1. In this study all the measurements were carried out in accordance with standard methods [8]. To measure metal concentration an atomic absorptions type Varian model AA220 was used.

Results and Discussions

A_chromium During the first experiment, COD concentration in sample and reference tanks were approximately the same. However when 10 mg/l chromium was added, it was observed that COD removal efficiency increased.

It is presumed that at this concentration chromium has a positive effect on the growth of the micro-organism and increases the MLSS of the samples by 700 mg/l, relative to the reference. (Increase from 2,000 to 2,700 mg/l).

Low concentration of Chromium could be an effective agent in bio-organism mass, as chromium adsorbs and is metabolized by microorganisims, as well as having a positive effect on growth. Chromium concentration in the effluent of the activated sludge system was reduced considerably and its removal efficiency reached 92% and remained the same during the remaining process time. For the sample taken after the membrane the removal efficiency was increased to 98%. This was the same for COD removal, which was increased from 87% to 93% when membrane was introduced.

As shown in Fig. 2, the COD removal efficiency had no noticeable change; only with the 50 mg/l concentration did it have a very limited reduction. But chrome removal efficiency was reduced with the increase of the chromium concentration. Nevertheless, the reduction was very low and only from 98% to 95%.

Table 1. Characteristics of the Process

Parameters	Amounts
COD of Feed	900 mg/l
PH of the tank	7-7.5
Dissolved oxygen in the tank	4-5 mg/l
Temperature in the reactor	25 $°C$
Temperature in the membrane	30-32 $°C$
Mixed liquor suspended solid (MLSS)	2700 mg/l

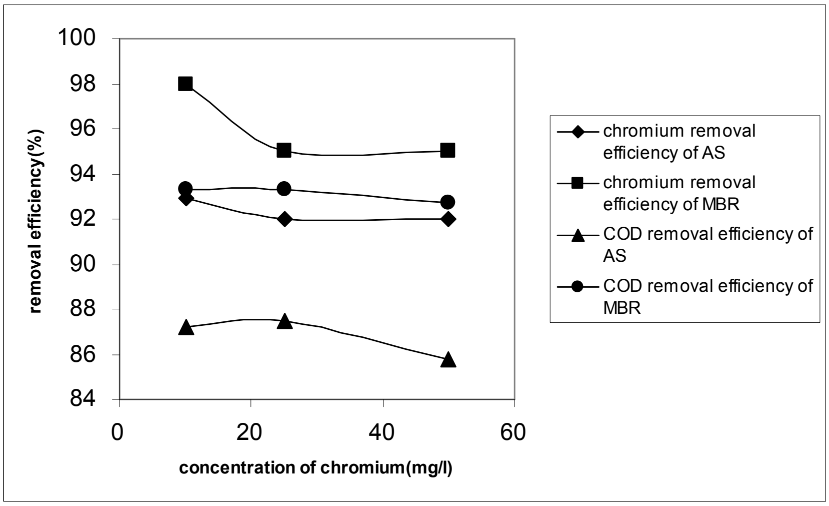

Figure 2.COD and chromium removal efficiencies diagram

In conclusion, for a chromium concentration of less than 50 mg/l the removal efficiency is always higher than 95% and COD removal efficiency is greater than 92%. And with such concentrations chromium have no toxic effects on microorganisms, and the MLSS remains at an average amount of 2700 mg/l.

B-Zinic As shown in Fig 3, in the case of having zinc, the COD removal efficiency in AS had a limited reduction by increasing metal concentration. The same was observed for the COD removal efficiency while having the complete system (bioreactor and membrane).

Studying the case of metal removal from AS and membrane, it was concluded that when zinc concentration was increased, its removal efficiency decreased noticeably and the removal efficiency of AS changed from 76% to 52%, while in the complete system from 86 % to 76 %.

Therefore, while using the activated sludge process the decrease in metal removal efficiency is not satisfactory, but when applying membrane with the activated sludge process, metal removal efficiency is determined to be higher than 76%.

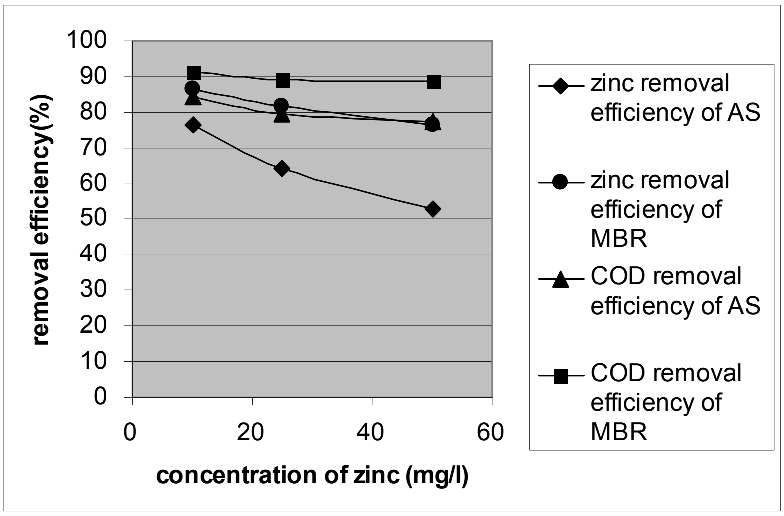

Figure 3. Zinc and COD removal efficiency diagram

Based on the results gained from using the activated sludge process and membrane for zinc removal, it is concluded that zinc removal with amounts below 25 mg/l show acceptable removal efficiency. In the case of higher concentrations the application of membrane is subject to the specific conditions of that case.

During the course of these experiments, the MLSS concentration was considerably reduced when the zinc concentration was increased. Therefore, it is concluded that a high concentration of zinc has toxic effects on microorganisms.

C-Lead As shown in Fig. 4, in the case of having 10 mg/l of lead, it was removed well by activated sludge process. However, by an increase in its concentration, the activated sludge process alone was not able to treat and remove lead because of the nature of the microorganisms, which could not adsorb and metabolize lead compounds. Also, lead has no toxic effect on micro organisms at concentrations below 50 mg/l, and therefore acts as a substrate for them. Hence, when the lead concentration was increased to 50 mg/l, the MLSS concentration was also increased in the activated sludge process.

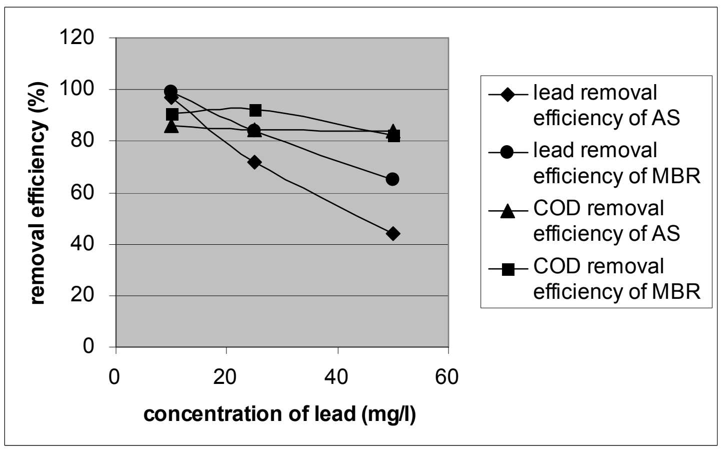

Figure 4. COD and lead removal efficiency diagram

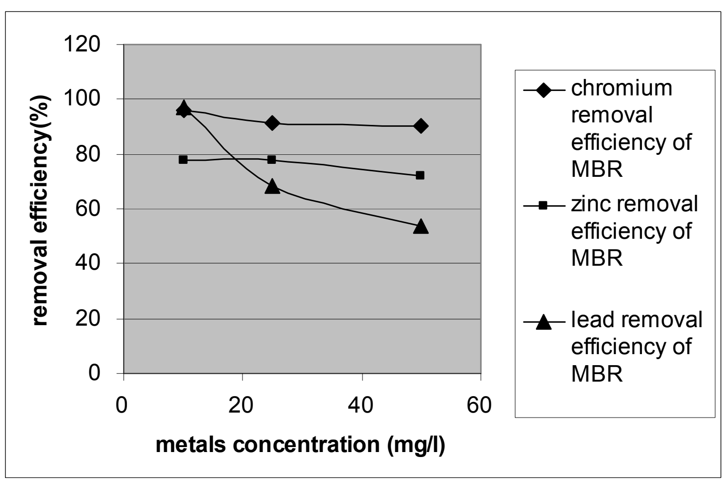

Figure 5. Removal efficiencies of metals vs. metals concentrations

D-three metals When10 mg/l concentration of each of the three metals was used at the same time, the COD of the sample was decreased relative to the reference tank, whereas the amount of MLSS of the sample was increased relative to the reference tank. Hence, at such levels of concentration these three metals act as useful substrates for microorganisms. With the increase in concentration of the three metals, the removal efficiency of the ions was decreased. However, in the case of lower concentrations they were removed with relatively better efficiency, except for zinc. However, this may be due to the type of micro organisms present in the sludge of the plant, which were more engrossed in removing chromium and lead rather than zinc. Therefore, zinc removal was decreased compared to the situation when on its own in the solution.

The removal efficiency of the three metals is decreased as concentrations of metals increases. However at lower levels of concentrations, all three metals would be removed at relatively acceptable rates of efficiency with the exception of zinc. The reason for the lower removal efficiency of zinc compared with lead and chromium, is assumed to be due to the type of microorganisisms present in the plant sludge, which is more engrossed in the removal of lead and chrome, as opposed to the situation when zinc is present in the solution on its own.

Conclusions

By applying membrane technology in bioreactors, COD and metals removal efficiencies will increase. Therefore, when we have an acceptable reduction of 60% to 95% we could conclude the following:

1- By applying MBRwith chromium levels below 50 mg/l concentrations, chro-mium was removed with efficiencies higher than 95%.

2- Zinc with a concentration level below 50 mg/l concentrations was removed only when membrane was applied with the activated sludge process, and the removal efficiencies could be expected to be higher than 76%.

3- Lead with a concentration below 50 mg/l concentrations could reach removal efficiencies of higher than 60% only by using membrane.

Therefore, it is proposed to use membrane bioreactors for removing three metals of chromium, zinc and lead.

References

1. Cowan, J., “The Development of Management Strategies and Recovery System for Heavy Metal Wastes”, Water Research Commission Report No 589/1/98 Pretoria, south Africa, pp 27-32, (1998).
2. Pugnanelli, F. and Beolchini, A., “Effect of equilibrium models in the simulation of heavy metal biosorption in single and two-stage UF/MF membrane reactor systems” Biochemical Eng, journal Vol 15(1) pp 27-35, (2003).
3. Enegess, D., Togna, A. P. and Sutton, P., “Membrane separation application to biosystems for wastewater treatment” filter separate 40 (1), pp 14-17, (2003).
4. Fane, A. and Chang, S., “Membrane Bioreactors: Design and operation al option” Filter separate 39(5), pp 26-29, (2002).
5. Brindle, K. and Stephenson, T., “The Application of Membrane Biological Reactors for the Treatment of Wastewater” Biotechnology and Bioe-ngineering Vol 49, pp601-610, (1996).
6. Thomass, H., Jodd, S. and Morrer, J., “Fouling Characteristics of Membrane Filtration in Membrane Bioreactors” Membrane Techno-logy No 122, pp10-13, (1999).
7. Stephenson, T. and Brindle, K., “Membrane Bioreactors for Wastewater Treatment” IWA publishing London U. K (2002).
8. APHA Standard Methods for the Examination of Water and Wastewater” 10th edition American public Health Association Washington DC, (1995).