Study the Effect of Temperature on the Performance of Hollow Fiber Membrane Bioreactor in Wastewater Treatment

دراسة تأثير درجات الحرارة في اداء مفاعلات الاغشية الحيوية لمعالجة مياه المجاري

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Abstract

A membrane bioreactor (MBR) is one of the modifications to the conventional activated sludge process, since it is the combination of a membrane module and a bioreactor. In the present study, 100 liters lab-scale aerobic MBR was seeded with 1.5 Liter activated sludge and municipal wastewater from AL-Rustumiya municipal wastewater treatment station, two hollow fibers sample (MI,MII) manufactured in the University of Technology/ Chemical Engineering Department, were used as biomembranes. Trans membrane pressure TMP was studied and it was found that the optimum value of TMP was 10 cm Hg vacuum which gave optimum effluent flux 400 ml/hr for MI and 350 ml/hr for MII. The experimental work involves the effect of temperature 25, 35, 45°C on the performance of the MBR fibers sample (MI, MII) and its effect on biomass growth and removal efficiency of the COD, BOD. Both samples show good performance in 25°C.

Key words: Hollow Fiber Membrane, Bioreactor, Wastewater

المستخلص

مفاعلات الاغشية الحيوية هي عبارة عن تحوير لمفاعلات الحمأة المنشطة التقليدية حيث انها تتألف من الاغشية الحيوية والمفاعل الحيوي في هذه الدراسة تم استخدام مفاعل حيوي مختبري مصنع محليا يبلغ حجمه 100 لتر . لقح باستخدام 1.5 لتر من الحمأة المنشطة من محطة الرستمية لمعالجة المياه وتم تصنيع نموذجين هما MII, MI من الاغشية المجوفة والذي تم تصنيعه محليا في الجامعة التكنلوجية قسم الهندسة الكيمياوية فرع التكرير . تضمنت الدراسة تأثير الضغط الفراغي ووجد انه افضل ضغط كان 10سم زئبق حيث كان يعطي افضل دفق خارج للنموذج MI الى400 مللتر/ساعة وللنموذج MII الى350 مللتر/ساعة . تضمنت التجارب العملية دراسة تاثير درجة الحرارة 25،35،45م على الاغشية الحيوية MII، MI وكذلك تأثيرها على نمو الكتلة الحيوية وكفاءة الخفض لل Chemical oxygen Demand, Biological oxygen Demand . اظهرت التجارب ان افضل كفاءة كانت عند درجة حرارة 25 مئوية .

الكلمات المفتاحية : مفاعلات الاغشية الحيوية ، مياه المجاري

Introduction

The first MBR were developed commercially by Dorr-Oliver Company in the late 1960's with application to ship-board sewage treatment [1]. Around the same time, other bench-scale membrane separation systems linked with activated sludge process were reported [2].

In the early 1970's, the technology was introduced in the Japanese market and the MBR had a rapid development targeting mainly to small and specific applications such as treatment of ship-board sewage, landfill leachate and industrial effluents [3].

These MBR systems were based on the so-called sidestream membrane configuration; i.e. the membrane separation step was employed in an external recirculation loop, exhibiting rather high energy demand for the recirculation of the mixed liquor [2].

Membrane bioreactor can be broadly defined as a system integrating biological degradation of waste products with membrane filtration [4]. Thus it can be regarded as a combination of two basic process of biological degradation and membrane separation into a single process. As a novel and promising technology, the combination of membrane with a bioreactor with more compact and less energy consumption, has increasingly received considerable attention in wastewater treatment and reclamation [5].

Membrane bioreactor system can be divided into two units according to the function. A biological unit (bioreactor) and a membrane filter unit. The biological unit is responsible for the biodegradation of the waste compounds, while the membrane filter unit is responsible for the physical separation of the treated water and biomass (solid-liquid separation) [6].

The membrane separation process is based on the presence of semi permeable membrane. The principle is quite simple: the membrane acts as a very specific filter that allows water to flow through, while it catches suspended solids and other substances. There are two factors that determine the effectiveness of a membrane filtration process; selectivity and productivity [5]. Selectivity is expressed as a parameter called retention or separation factor, while productivity is expressed as a parameter called flux Permeate. Membrane materials can be organics (polyethylene, polyethersulfone, polysulfone, polyolefin, etc.) inorganic ceramic or metallic and they should be inert and non-biodegradable. Membrane materials should also be easily cleaned and withstand to cleaning chemicals, high temperature and pressure. Moreover, membrane surface must be neutral or negatively charged to avoid adsorption of microorganisms [6].

Experimental products and methods

Reactor system

Figure (1) shows a schematic diagram of MBR used which consist of reactor made of galvanized metastasis with an effective volume of 100 liter, 40 cm diameter, 100 cm high with a membrane submerging in it. The reactor contain three holes one at the bottom and two in the side situated 10cm and 70 cm from the bottom.

1-Reactor
2-Hollow fiber membrane
3-Heater
4-Bubble diffuser
5- Collecting tank
6- PVC structure membrane
7- Power supply
8- Air pump
9- Pressure gage
10-Vacuum pump
11- Manual valve

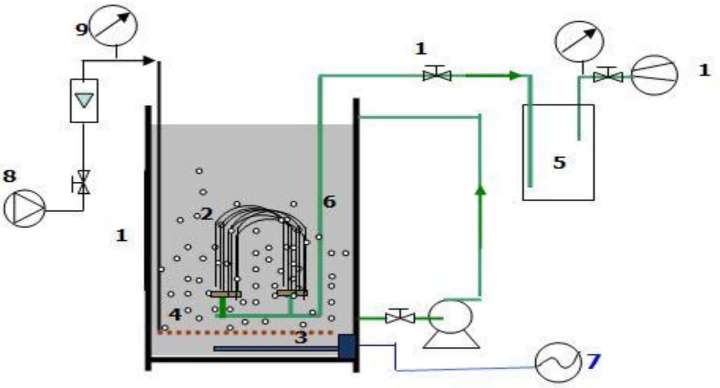

Fig. (1): A schematic diagram of laboratory scale submerges MBR system.

Two samples of hollow fiber cells were manufactured in chemical engineering department/ University of Technology**.** The characteristics of the hollow fiber membranes used are summarized in Table (1).

Table (1): Characteristics of the Poly vinyl chloride (PVC) hollow fiber membrane

Membrane characteristics	MI	MII
Membrane material and Composition ratio	PVC/PSR/PEG (16:1:2)	PVC/PSR/PEG (16:1:7)
Molecular weight cut-off	540Kda	500Kda
Mean pore size	0.38µm	0.33 µm
Porosity	82.53%	83.14%
Fiber length	30cm	30cm
Outer diameter	1.130mm	1.130mm
Inner diameter	0.610mm	0.710mm
Thickness	0.260mm	0.210mm
No. of fibers in module	20	20
Total membrane surface area per 20 fibers	$0.00142m^2$	$0.00142m^2$

PVC Polyvinyl chloride, PSR Poly Styrene, PEG Polyethylene glycol

Plastic pipes and fittings 3/4 inch were used in the piping of the system. Water was recycled by a pump from bottom to the side of the reactor.

The fiber cell of MBR connected to the plastic structure by union and submerged in the reactor**.** The open end of the cell pipe is connected to one end of a vacuum gage to adjust the vacuum pressure within the cell and to ensure not to damage the hollow fiber filter, the other end of the gage is connected to collecting container which connected by plastic tube to the vacuum pump. Air pump supplies the reactor with air and connected to diffuser to a diffuse the air in the reactor.

Determination of optimum Flux

In order to determine the optimum flux for the two different fibers MI, MII, the bioreactor was continuously fed with municipal wastewater. The Trans membrane pressure was increased gently from 0 to 50 cm Hg vacuum. During that, the effluent flux increased with increasing the vacuum pressure till it reached approximately 10 cm Hg, then the effluent flux began to decrease.

Figure (2) show that the effluent flux reached a maximum values for both fiber samples MI, MII. These values were 400 ml/hr for MI and 350 ml/hr for MII

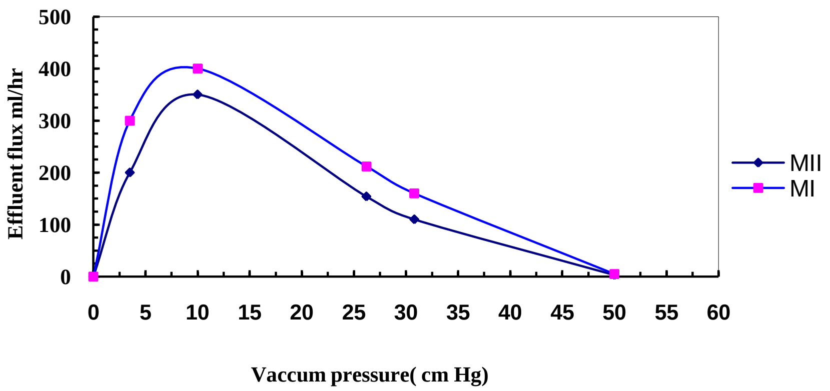

Fig. (2): Optimum effluent flux for two samples of hollow fibers filter at 25°C

The explanation of this behavior is that at the beginning the flow rate of effluent increases with increasing of the vacuum pressure. That is because of higher driving pressure force across the membrane barer till it reached to 10 cm Hg after that the flow rate of effluent began to decrease because of two main hindrance which were; first indentation of the fiber cell which resist the vacuum pressure, and the second is the sticking of the dirt on outer membrane surface in which the high vacuum pressure prevent both bubbling of air and recycling of water from removing it. COD and BOD were measured according to Standard Methods for the Examination of Water and Wastewater [7].

Results and Discussion

The following analysis focuses on characterization of the water quality and the effect of the membrane performance in different temperature

COD Removal Efficiency

Chemical Oxygen Demand COD was measured in the influent and effluent streams. In this study it was observed by the negative effect of temperature on the biomass activities, which appears in lower COD removal efficiency. Figures (3, 4) showed the COD removal efficiencies at temperatures of (25, 35, 45)°C, for MI**,** MII membranes fiber filter.

At 25°C, the COD removal efficiency for MI sample started with 8% at the first day and then increased to 50% in the 6th day and it reached to 91% at end of 14th day, while for sample MII the COD removal efficiency was also 8% in the first day, it increased till it reach to 93% by the end of experiment.

At 35°C, the COD removal efficiency value for MI reach to 21% in the 4th day and after that it increased to 40% and kept increasing to 64% at the end of 14th day. For MII, COD removal efficiency was increased from 8% to 60% at the end of 14th day.

At 45°C, the COD removal efficiency dropped to 45.5 % for MI while for MII it's dropped to 40% at the end of experiment.

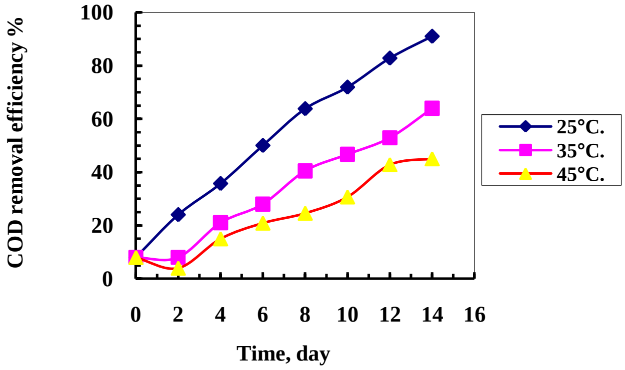

Fig. (3): COD removal efficiency for MI fiber filter at different temperatures

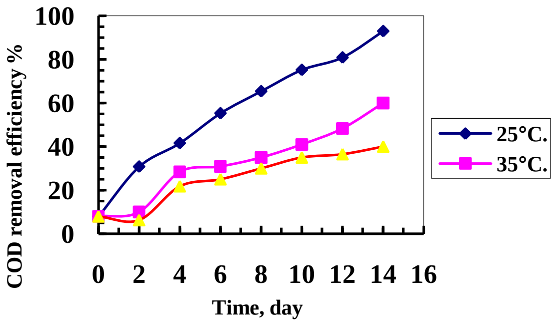

Fig.(4): COD removal efficiency for MII fiber filter at different teperature

The results imply that increasing temperature has notable influence on COD removal efficiency. It was an expected result since at high temperature; biomass is unable to oxidize the same variety of complex soluble components as compared to the capability of the mesophilic biomass.

This inability could be ascribed to the reduction in microbial richness and diversity which caused by sudden changes in operational conditions (biomass shock). It is also attributed to the bacteria decay which releases soluble microbial products (SMP) to the solution, which increases the COD removal efficiency in the supernatant. Moreover, the low COD removal efficiency could be attributed to the short retention time (insufficient contact time) of the system, since the biomass needs longer retention time at higher temperatures due to the low variety and richness. Moreover, the biodegradation process is slower at higher temperatures rather than at mesophilic condition. However it was observed that removal efficiency was improved with the time indicating the ability of removing with the adaption progress of the biomass to the operational condition. Otherwise, the COD removal efficiency was comparatively high at the end of the 14^{th} day.

BOD Removal Efficiency

Figures **(**5,6) show the effect of the temperature on the Biological Oxygen Demand BOD removal efficiency for both MI, MII membranes fiber.

At 25°C the BOD removal efficiency at the first day of experiment was 9% by the time it reached to 90% at the 14^{th} day for both fiber sample MI, MII, while at 35°C there is notable decline in the removal efficiency. For the MI hollow fiber filters it started at 9% until it increased to 74% and for MII it started with 9% to 77% at the end of 14 days.

At 45°C BOD removal efficiency show drastic declined in the both MI and MII and the BOD removal efficiency will not cross over 40% at the end of 14^{th} day.

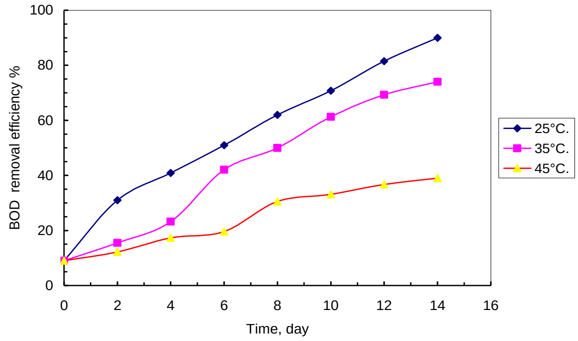

Fig.(5): BOD removal efficiency for MI fiber filter at different temperatures.

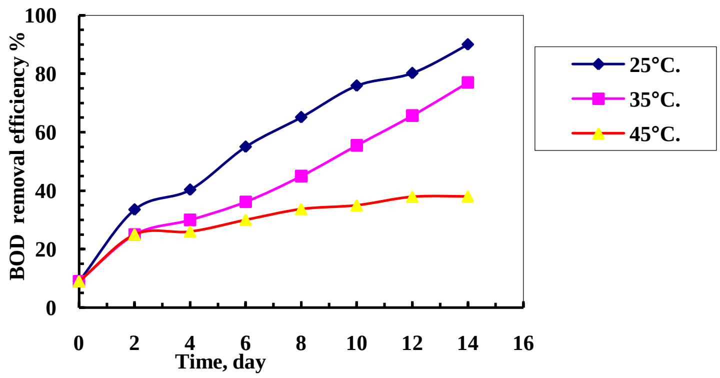

Fig. (6): BOD removal efficiency for MII fiber filter at different temperatures

Decline the value of BOD removal efficiency due to of difficult adaption of the biomass to the new condition temperature. The lowest BOD removal efficiency was observed when the temperature was at 45°C. This finding was in agreement with that mentioned by [8].

Conclusions

1. The maximum effluent flux reached to 400 ml/hr for MI and 350 ml/hr for MII.
2. The maximum COD removal efficiency for MI reached to 91% at end of 14th day, while for sample MII the COD removal efficiency was reaching 93% by the end of experiment.
3. The best temperature for treatment waste water by using membrane bioreactor was 25°C.

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