
Treatment of Restaurant Waste Water with Al₂O₃ Ceramic Membrane

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Abstract: With the improvement of people's living standard, the phenomenon of waste on dinner table is becoming more and more serious, and the amount of waste produced by food and kitchen is increasing rapidly. At present, scholars at home and abroad mainly focus on the treatment of solid kitchen waste, and there are few reports on the treatment of catering wastewater. The characteristics of high concentration of organic matter, complex composition and high oil content in the kitchen wastewater determine that the degradation efficiency of the traditional treatment process will be very low, so it is very important to study different treatment processes for the treatment of kitchen wastewater. The self-made Al₂O₃ ceramic membrane was developed to treat the catering wastewater which is the pollution sources of high concentration causing great pollution to the water around the city. The effects of feed liquid content, feed liquid flow rate, operating pressure and feed temperature on membrane flux, oil droplets and COD removal rate were studied. The result shows that the optimized filtration condition was that the feed liquid was the raw material liquid, the volume flow rate of the feed liquid was 200 L/h, the operating pressure was 160 kPa, and the feed liquid temperature was 25°C. Under the optimized filter conditions, when the membrane was cleaned by homemade alkaline chemical cleaning agents, the regeneration performance of membranes was well and could recovered to more than 95% of original ones.

Keywords: Ceramic Membrane, Restaurant Waste Water, Operating Conditions, Regeneration Performance

1. Introduction

Ceramic membrane is a new force in membrane materials in recent decades. Compared with the membrane prepared by traditional membrane materials, ceramic membrane has good chemical stability, high mechanical strength, high temperature resistance, high flux and environmental friendliness in filtration applications [1-3]. In the process of water treatment, ceramic membrane has more advantages than other organic membranes [4]. Widely used in waste water treatment, pharmaceutical food manufacturing, seawater distillation, energy engineering and many other fields, it has become a new high-tech industry, which is predicted to bring "the third Industrial Revolution" [5-7]. Research on the preparation,

modification and process optimization of ceramic membrane in order to improve its filtration, separation and anti-fouling efficiency is the focus of research in the field of water treatment ceramic membrane [8].

With the continuous improvement of people's living standards, the catering industry is also springing up as a rapid development, followed by the discharge of a large number of restaurant waste water. According to statistics, in more than 100 large and medium-sized cities in China, the discharge of restaurant waste water accounts for 3 percent of the total urban sewage, but the contents of BOD₅ and COD_{Cr} account for about 33% of the total load [9]. However, the restaurant waste water is complicated containing a lot of animal and vegetable oils and various colloids, detergents, proteins, plant fibers,

inorganic- salts and so on, which make it difficult to purify the waste water. Untreated direct discharge of catering waste water can reach more than 100 million tons each year. And the untreated restaurant waste water is not allowed to be discharged directly into the municipal sewerage network [10].

Generally, restaurant waste water treatment includes floatation, sand filtration, coagulation, aerobic biological sludge process, MBR, biological turntable and so on, but these methods have their own shortcomings [11]. Due to the hydrophobicity of the inorganic ceramic membrane, it is widely used in the treatment of oily waste water [12]. The microfiltration membrane has been studied continuously in oil and water separation, but it is mostly used in petrochemical industry with high added value, while it is seldom used in catering industry.

2. Experimental Part

2.1. Waste Water Source

The restaurant waste water was collected from the washing tank of a school canteen. The collected waste water was statically set for 12 hours to remove the larger particles, and then stirred at high speed with a mechanical agitator for 10 hours to make the waste water stable in emulsifying state. The oil content and COD of the waste water were measured, and the oil concentration was 866 mg·L⁻¹, and the COD was 2775 mg·L⁻¹.

2.2. Device and Method

The experimental device is a self-made membrane filtration device, and the membrane module is a self-made Al₂O₃ flat ceramic membrane. The effective area of membrane filtration is 0.011 m², and the average pore size is 0.3 μm, as shown in figure 1.

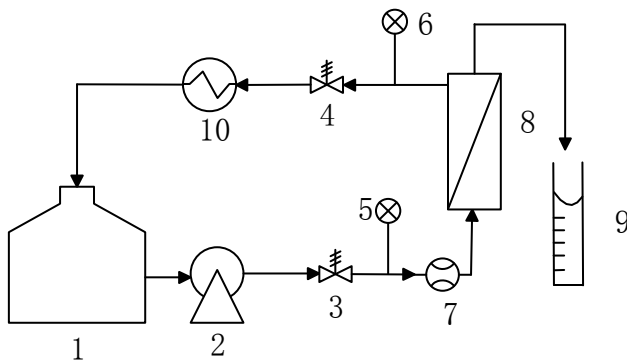


Figure 1. Equipments of filtration experiments.

- 1. Feed tank 2. Pump 3. 4. Valve 5. 6. Pressure gage 7. Flowmeter 8. Membrane module 9. Cylinder 10. Heat exchanger

The liquid is stored in the tank, and the filtration experiment is carried out by centrifugal pump in the membrane assembly

at the beginning of the filtration experiment. The filtration time is recorded by the timer, the operating pressure is calculated by the pressure difference between the inlet and outlet, and the filtrate is collected by the metering tube to calculate the membrane flux. The content of oil in filtrate and COD were determined by CJ/T51-2004 weighing method and GB11914-1989 potassium dichromate method respectively [13-14]. The membrane flux *J* and the removal rate *R* of its oil droplet or COD are calculated by the following formula:

$$J = V / (At)$$

$$R = 1 - \rho_p / \rho_b$$

In these formulas, *V* is the effluent volume, *A* is the filtration membrane area and *t* is the filtration time, ρ_p is the mass concentration of solute or COD in osmotic solution, ρ_b is the mass concentration of solute or COD in the feed solution. Membrane regeneration process: a self-made alkaline cleaning agent is used for chemical cleaning of the filtered ceramic membrane. The chemical cleaning agent is 1% SDS + 0.5% sodium citrate + 0.5% sodium carbonate + 1% sodium hydroxide respectively. The filtration experiment was carried out under the optimum conditions. After 30 min of filtration, the membrane was cleaned (continuous immersion for 3 h, continuous 3 times). The change of steady state membrane flux and the removal rate of oil droplet and COD after cleaning were recorded.

3. Results and Discussions

3.1. Effect of Material Content

The concentration and dilution of the feed solution were carried out at 25°C, 200 L / h feed volume flow rate and 0.12 MPa operating pressure. The effects of different feed content on membrane flux, oil droplet and COD removal efficiency were investigated. The results are shown in figure 2 and figure 3.

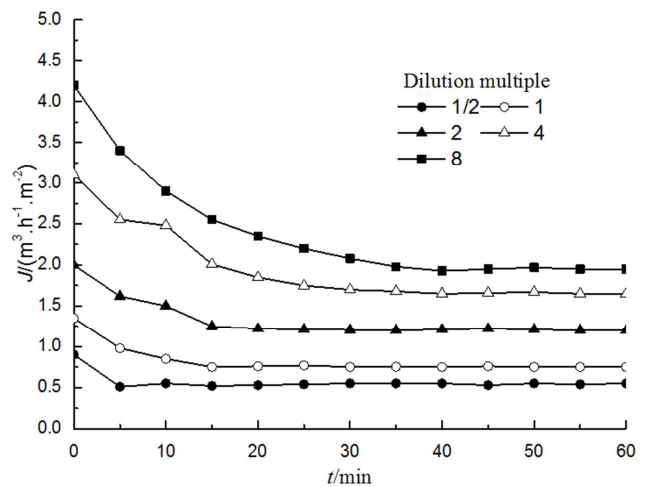


Figure 2. Effect of feed oil droplets content on the membrane flux.

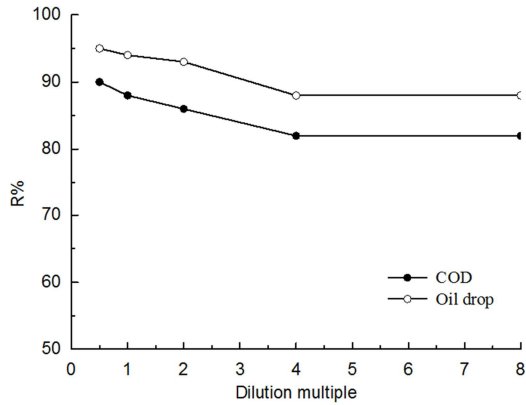


Figure 3. Rejection of oil droplets and removal rate of COD under different feed content.

It can be seen from figure 2 that steady membrane flux decreases with time under the same feed oil droplet content. And the steady membrane flux decreases with the increase of feed oil droplet content. The main reasons are the increase of oil droplet content in two aspects: the thickening of the dynamic membrane layer (cake layer) on the membrane surface, the increase of filtration resistance, the decrease of the membrane flux and the increase of the oil drop content and the solution osmotic pressure. At the same operating pressure, the driving force of solvent passing through the membrane surface is weakened, which leads to the decrease of water flux.

It can also be seen from figure 2 that the time required to enter the steady state membrane flux decreases with the increase of the oil droplet content in the feed solution. The reason is that the increase of oil droplet content in feed liquid increases the amount of solute flowing to the surface of membrane in unit time, which makes the thickness of dynamic film (cake layer) increase faster and reach steady state quickly. At the same time, the oil droplet content has a direct effect on the thickness of the film layer (filter cake layer), and the time required to enter the steady state membrane flux can be determined by determining the oil droplet content.

As can be seen from Figure 3, as the content of oil droplets in the feed liquid is reduced, the retention rate of oil droplets and COD are all descending, but the interception rate of two times concentration and the retention rate of the raw material are all higher.

3.2. Influence of Material Flow Rate

The effect of feed flow rate on membrane flux, oil droplet and COD removal rate was investigated at 25°C, feed solution as raw material solution and operating pressure of 0.12 MPa. The results are shown in figure 4.

The results are shown in figure 4. It can be seen from figure 4 that the steady state membrane flux increases first and then decreases with the increase of feed volume flow. Before the volume flow reached 200L/h, with the increase of feed flow rate, the flow rate of membrane surface increased, which reduced the concentration polarization and increased the membrane flux. After the volume flow reached 200 L / h, the membrane flux decreased rapidly with the increase of feed

flow rate. The reason is that the membrane surface flow velocity is increased, the large particles attached to the membrane surface are taken away, the proportion of the fine particles of the dynamic film layer is increased, so that the resistance of the dynamic film layer is increased, and the membrane flux is rapidly reduced; On the other hand, the increase of the membrane surface flow velocity will increase the membrane surface pressure, make the dynamic membrane layer more compact and increase the filtration resistance.

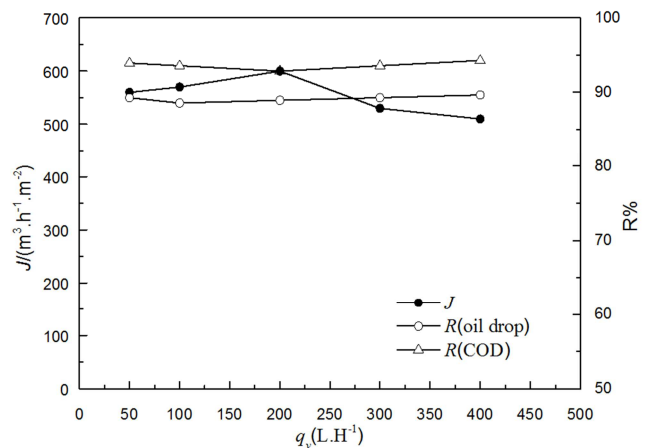


Figure 4. Membrane flux, oil droplet and COD removal rate in steady state under different feed flux.

It can also be seen from figure 4 that the removal rate of oil droplets and COD increases with the increase of feed flow rate, but the change is not significant.

In conclusion, the membrane flux, oil droplet removal efficiency and COD removal efficiency are relatively high when the volume flow rate is 200L / h, so 200L / h is selected as the optimized feed volume flow rate in the experiment.

3.3. Influence of Operating Pressure

The effect of different operating pressure on membrane flux, oil droplet and COD removal rate was investigated at 25°C, feed liquid as raw material liquid and feed volume flow rate 200L / h. The results are as shown in figure 5.

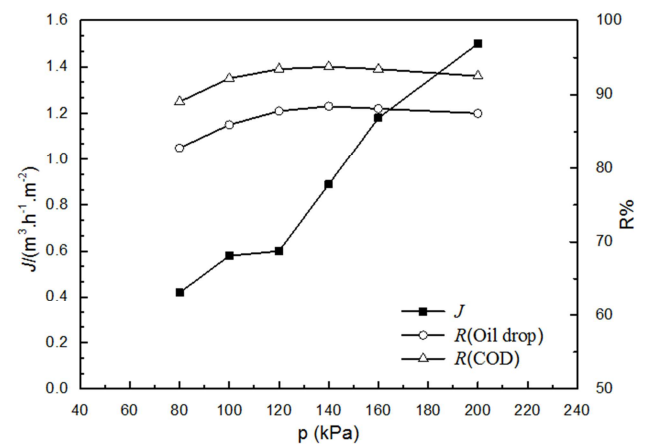


Figure 5. Membrane flux, oil droplet and COD removal rate in steady state under different operating pressure.

It can be seen from figure 5 that the steady membrane flux increases with the increase of operating pressure. The increase of operating pressure provides greater driving force for water and micro particles in the waste liquid, which makes these water and tiny particles faster through the ceramic membrane, thus increasing the flux of the membrane greatly.

It can also be seen from figure 5 that the removal of oil droplets and COD increases first and then decreases with the increase of operating pressure. When the pressure increased from 80 kPa to 120 kPa, the removal rate of oil droplets and COD increased rapidly. The reason is the increase of the operation pressure, which makes the dynamic film layer (filter cake layer) densified, to a certain extent, reduce the pore size, thus the retention rate is increased by [15]. When the pressure increased from 120 kPa to 160 kPa, the removal rate of oil droplets and COD increased slowly, because although the densification degree of the dynamic film layer was higher, the ultrasmall particles and water molecules in the waste liquid could still pass through the filter layer, which made the removal rate increase slowly. When the pressure increases from 160 kPa to 0.20 kPa, the removal rate of oil droplets and COD decreases gradually, which is caused by the increase of operating pressure, which makes more oil droplets deform through the film layer.

Considering the cost, retention effect and water flux, 160 kPa was selected as the optimal operating pressure.

3.4. Effect of Temperature of Feed Liquid

The experimental feed liquid was used as raw material, the volume flow rate of feed liquid was 200 L/h and the operating pressure was 160 KPa. The effects of feed temperature on membrane flux, oil droplet and COD removal efficiency were investigated. The results are shown in figure 6.

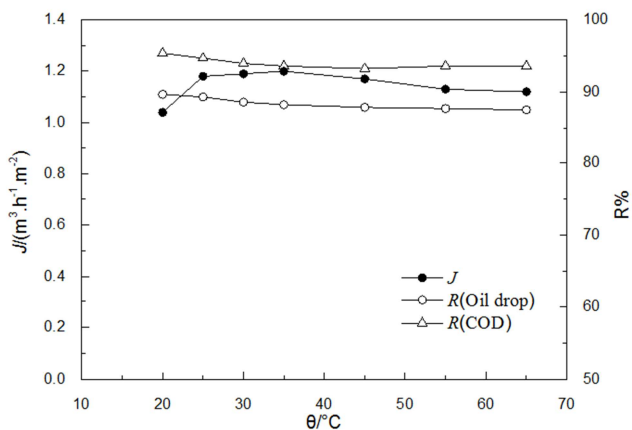


Figure 6. Membrane flux, oil droplet and COD removal rate in steady state under different feed temperature.

From figure 6, it can be seen that the steady flux of the membrane increases with the temperature of the feed solution rising from 20°C to 30°C. However, when the temperature is over 30°C, the membrane flux increases slowly with the increase of feed temperature. And the maximum flux is 1.196 m³ / (m²·h) at 35°C, and then decreases gradually. The reason

is that the increase of feed temperature will make the viscosity of liquid become smaller, the diffusion coefficient of mass transfer become larger, the Brownian motion intensifies, and the polarization phenomenon of concentration difference becomes weaker, thus promoting the increase of membrane flux, but at the same time, the increase of membrane flux also intensifies the concentration polarization. The fouling rate is accelerated, the dynamic membrane layer is thickened, and the membrane flux is decreased. The interaction of these two aspects leads to the nonlinear relationship between the increase of the feed temperature and the membrane flux as shown in the diagram.

It can also be seen from figure 6 that the oil droplet and COD removal rate decrease with the increase of feed temperature, but the decrease is very slow after 35°C. The reason is that before 35°C, with the increase of temperature, the viscosity of the liquid becomes smaller, the diffusion coefficient of mass transfer increases, and the Brownian motion intensifies, which results in the drop of oil and the removal rate of COD decrease by 35°C. After 35°C, although the viscosity of the material becomes smaller, the increase of membrane flux leads to the increase of membrane fouling, the thickening of dynamic membrane layer (cake layer), and the increase of oil droplet and COD removal rate, which can counteract the interaction between the two. The downward trend is very slow after 35°C.

Considering the steady membrane flux, oil droplet and COD removal efficiency, cost and other factors, the feed liquid has ideal filtration parameters at 25°C.

3.5. Performance Analysis of Membrane Regeneration

The change of steady membrane flux, oil drop rejection rate and COD removal rate after cleaning are shown in Table 1.

Table 1. Effects of cleaning operation on membrane filter indicators.

Cleaning mode	J/(m ³ ·h ⁻¹ ·m ⁻²)	R/%	
		Oil drop	COD
(New membrane)	1.161	94.61	89.24
Branch water	0.927	94.64	89.31
Cleaning agent 1 time	1.109	94.63	89.28
Cleaning agent 2 times	1.113	94.65	89.30
Cleaning agent 3 times	1.105	94.63	89.18
Cleaning agent 4 times	1.110	94.52	89.23

Table 1 shows that the steady-state membrane flux of chemical cleaning is much larger than that of clean water only. After 4 consecutive chemical cleaning, the membrane regeneration performance is very good, the steady state membrane flux decreases slowly and is very stable. At the same time, the removal efficiency of oil droplet and COD is ideal, which is basically the same as the original membrane, and the regeneration rate of the membrane is more than 95%.

4. Conclusion

With the increase of oil droplet content, the steady flux of the membrane decreases, and the time to reach the steady flux of the membrane decreases. Finally, it is determined that 20

min is the time to enter the steady state, and with the increase of the content of the feed solution, The removal rate of oil droplets and COD gradually increased, but the rising trend slowed down gradually.

With the increase of feed flow rate, the steady flux of the membrane increases first and then decreases, and with the increase of oil droplet content, the removal rate of oil droplet and COD decreases first and then increases, but the change range is not large.

With the increase of the operating pressure, the steady-state flux of the membrane increased greatly. At the same time, with the increase of the operating pressure, the removal rate of oil droplets and COD increased first and then decreased, but after the increase of 120kPa, Both of the removal rate increase is very small, basically remain the same state.

Under the optimized filtration condition, the membrane body was cleaned with self-made alkaline chemical cleaning agent, and its regeneration performance was good, reaching more than 95%.

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