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# Application of Membrane and Adsorption Hybrid Processes for Industrial Wastewater Reuse

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## Introduction

Water demand and wastewater production is steeply increasing and the gap between water supply and demand is getting wider. Wastewater is considered a major water resource in many countries. Therefore, wastewater reuse has been considered as a promising solution to the shortage of water resources (Madwar and Tarazi, 2002; Fane, 1996; Bodalo-Santoyo et al., 2003; Mohsen and Jaber, 2002; Nicolaisen, 2002; Lawrence2002). There are many processes available for wastewater treatment such as chemical oxidation, foam flotation, electrolysis, biodegradation, adsorption, chemical coagulation and photocatalysis. Among them, membrane technology is widely used as a means of producing various qualities of water from surface water, well water, brackish water, sea water and industrial water. However, a problem in the application of membrane is sensitivity to fouling and the subsequent decrease in flux. It has been known that organics dissolved in wastewater cause membrane fouling, which leads to flux decline as well as shorten life-time of membrane. Powdered activated carbon is known to be an excellent adsorbent for removal of organics. However, the separation of powdered activated carbon particles from water make another problem to be solved in practical applications of the process. Therefore, the hybrid process consisting of powdered activated carbon for the removal of dissolved organics and submerged hollow fiber membrane for the separation of powdered activated carbon used, seems to be an excellent technique for the wastewater treatment. In this work, thus, we evaluated the performance of the hybrid process in terms of organic removal and flux decline. Moreover, the effect of coagulation on the removal of organics was investigated.

## Experimental

The characteristics of the treated wastewater are given in Table 1. The physical properties of three kinds of PACs used are given in Table 2. The jar test procedure was applied at room temperature and at various coagulant dosages and pH conditions. The coagulant used was alum chloride having a gram molecular weight of 241. The coagulant was added and mixed using magnetic stirrers at 300 rpm for 1 min. The pH was adjusted by adding HCl or $Na_2CO_3$ after coagulant addition. The stirring speed was controlled thereafter to 50 rpm for the next 20 min. The microfiltration hollow fiber membrane used was polyethylene hydrophilic membrane with 0.4㎛ pore size. The physical and chemical characteristics of the membrane used are given in Table 3. The hollow fiber membrane was obtained from the Korea Express Co., Korea. The membrane hybrid system was operated as a continuous stirred tank reactor (CSTR). The wastewater was continuously feed from the feed tack so as to maintain a constant level in the in fluent tank. Specific amount of PAC dose was added once at the beginning of the experimental run. Continuous mixing was provided in order to keep the PAC always in suspension and to facilitate the adsorption. The schematic of the laboratory scale experimental set-up is shown in Figure 1. Total organic carbon (TOC) using TOC analyzer(Dhorman, Pheonix 2000), absorbance at 254㎚ using UV Spectrophotometer (Varian FMS 100S) and turbidity using Turbidity meter (HACH 2100P) were measured constantly both in the influent tank as well as in the permeate. The permeate volume was monitored in order to calculate the permeate flux. Zeta potential was also analyzed using Zetasizer (Otsuka ELS 8000, Japan) and microscopic images of the membrane surface and the PAC coating on the membrane were obtained using scanning electron microscope (SEM) (Jeol, JSM-5400, Japan). All samples were analyzed as per the standard procedures.

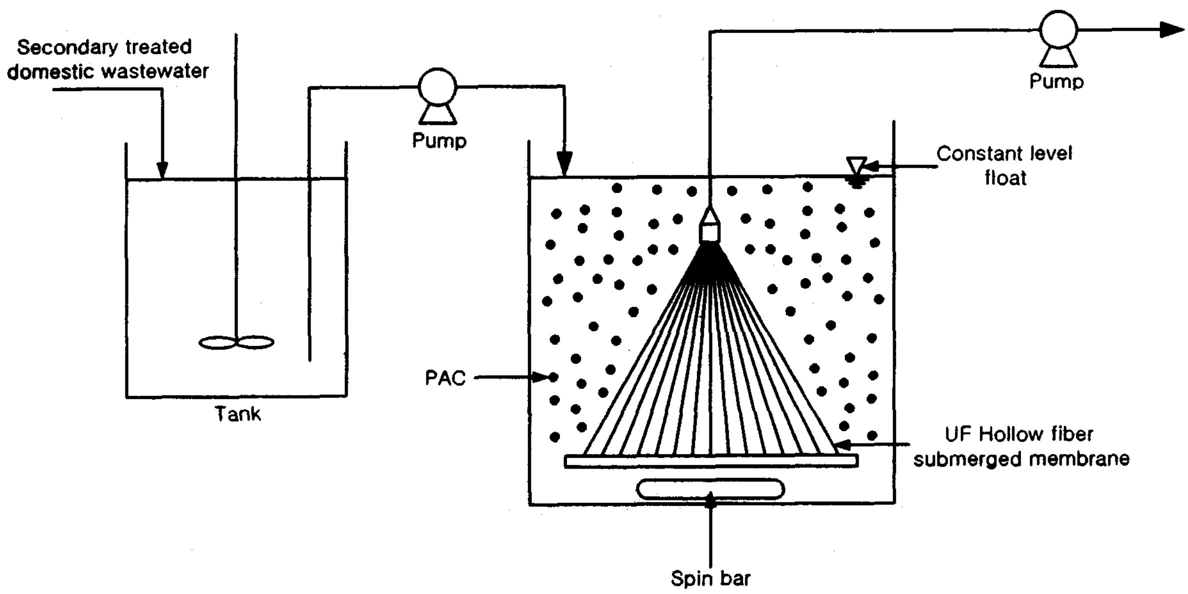


Fig. 1. Schematic diagram of submersed hollow fiber MF membrane hybrid system

Table 1. Characteristics of the influent wastewater

| Parameters | Average values |
|---|---|
| pH | 7.0-8.0 |
| Turbidity(NTU) | 1.0 |
| Suspended solids(mg/L) | 15.1 |
| Conductivity (ms/cm) | 700 |
| TOC(mg/L) | 5.1 |
| BOD(mg/L) | 15 |
| COD(mg/L) | 22 |
| T-N(mg/L) | 19.2 |
| T-P(mg/L) | 2.1 |

Table 2. Physical properties of three kinds of powdered activated carbon used

| Specifications | Wood Based PAC (WB) | Coal Based PAC (CB) | Coconut Based PAC(HA) |
|---|---|---|---|
| Bulk Density ($kg/m^3$) | 290-390 | 100-300 | 350-500 |
| surface area ($m^2/g$) | 882 | 915.2 | 1198.6 |
| Mean Pore Dia (Å) | 30.61 | 24.2 | 30.41 |
| Micropore Vol (cc/g) | 0.34 | 0.192 | 0.067 |
| Mean Diameter(mm) | 19.72 | 10.9 | 34.15 |
| Nominal Size | 80% finer than 75 micron | 50~65% finer than 45 micron | 75% finer than 75 micron |
| Iodine Number (mg/g min) | 900 | 800 | 900 |

Table 3. Physical and chemical characteristics of hollow fiber membrane

| Properties | Unit | Description/Value |
|---|---|---|
| Material | | Polyethylwnw |
| Type | | Hydrophilic |
| Total Surface area (30 modules 0.1 m length each) | $m^2$ | 0.00366 |
| Pore Size | μm | 0.4 |
| Internal Diameter | mm | 0.36 |
| External Diameter | mm | 0.54 |

**Results and Discussion**

The combined coagulation/adsorption and adsorption/coagulation processes for organic removal from wastewater were preformed as two-step processes. Chemical coagulation by alum chloride as a coagulant was shown to be highly effective for the removal of organics. On the other hand, the adsorption capacities of the three PACs were evaluated from the equilibrium and kinetic studies. The Freundlich isotherm was used to fit the equilibrium data well. It was found that WB gives the highest adsorption capacity of organics. Based on the kinetic experiments, faster kinetics for all PACs can be observed since they are fine particles. All PACs reached to equilibrium within 1 h. From the membrane hybrid system, the fouling of the membrane without PACs was severe. The performance of the hybrid system in terms of TOC, turbidity and flux for three PACs was investigated. There was a significant improvement in the performance of the hybrid system by adding PAC dose. The combined treatment process including coagulation, adsorption and membrane filtration, offers many advantages for potential industrial use such as high efficiency, high quality of treated water, possibility for the potential reuse of water, and a economic feasibility since it does not require high costs for chemicals and equipment. Moreover, this process will be applied for the drinking water treatment.

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