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Application of hybrid coagulation–microfiltration process for treatment of membrane backwash water from waterworks

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Abstract

A coagulation–microfiltration (MF) system was studied to treat the discharged membrane backwash water (MBW) to meet the drinking water quality requirements. The values of dissolved organic carbon (DOC) and trihalomethanes formation potential (THMFP) in MBW were higher than those in Luan River water (LRW, the raw water for a pilot-scale membrane plant, which produced MBW used in this study), and organic matter enriched in MBW distributed mainly in molecular weight (MW) > 10k Da. When 15 mg $FeCl_3$/L and 15 mg/L powdered activated carbon (PAC) were added into the system, the average concentration of DOC was reduced from 5.731 mg/L in MBW to 3.377 mg/L in the treated water, and the average UV_{254} was reduced from 0.047 to 0.030 cm^{-1}. The removal of organic matter was main in the range of MW > 30k Da. Efficient organic removal by the hybrid coagulation–MF system resulted in significant reduction of THMFP in the treated water. Concentrations of trihalomethanes, turbidity, bacteria and coliforms in the treated water were below the limit value of the drinking water standards. The results show that the treated water from MBW is with satisfactory organic and microbiological quality.

Keywords: Backwash water; Coagulation; Microfiltration; Natural organic matter; THMFP

1. Introduction

The contradiction between water supply and consumption is increasingly severe because of the insufficient water resource. Water height of many reservoirs has been lower and many rivers have been intercepted in drought north areas of China as a result of the reduction of precipitation [1]. Drinking water standards have been improved and expenses of drinking water are increasing significantly [2], which make it more important to improve the productivity of drinking water treatment. The membrane technology has been considered as a substitute for conventional drinking water treatment for effectively retention of particulates, bacteria and some viruses [3–5]. Backwashing process is normally used in conventional drinking water treatment and membrane process to remove fouling on filtration materials and membranes [6,7]. Backwash water was often directly discharged into a sewer in the past, which resulted in the increase of raw water consumption and cost for waste discharge, and the loss of total productivity [6]. Therefore, recovering backwash water is an alternative to improve productivity of treating process and decrease the cost of water production.

Quality of recovered backwash water is of concern because of the possible natural organic matter (NOM), precursors for disinfection by-products (DBPs), and microorganisms, so guarantee the quality of recovered backwash water is necessary. Concerns about the recycling of microorganisms and/or DBPs have led to a significant reduction of the number of drinking water treatment plants that directly return clarified filter backwash water to the inflow of water treatment process [8]. It is well known that the treated water from membrane process is safer than that from conventional drinking water treatment [9,10]. So the feasibility of low-pressure membrane process for the recovery of backwash water was studied. A pilot-scale ultrafiltration (UF) plant with submerged membranes was reported for the recovery of filter backwash water from drinking water treatment, when a continuous maintenance disinfection was provided, the treated water from membrane was free of microbial contamination and could be reused without any safety concerns [8]. Dotremont et al. [11] demonstrated that UF is a reliable technique for the recovery of backwash water from sand filters. Membrane process for treating backwash water from conventional drinking water treatment was investigated, however, there were little studies on the

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recovery of MBW from drinking water treatment. It is necessary to investigate whether the recovered MBW can satisfy drinking water standards or return it to the inlet of water treatment process.

In China, new standards for drinking water quality were promulgated and the requirements for drinking water quality were stricter than ever [12]. For meeting the new standards, a pilot-scale coagulation–MF membrane system was set up in a drinking water treatment plant in Tianjin, China. The aim of the experiment was to offer the reliable experience for constructing new water treatment plant. The raw water was LRW. The capacity of the pilot membrane system was approximately 150 m^3/d and the pore size of the MF membrane used was 0.1 μm. When the filtration time reached 30 min, automatic backwash process was applied to scour the fouled membrane, and all MBW was discharged. Because of the MBW discharge at the end of each cyclic, the recovery rate of the system was only 90.9%. If MBW is discharged directly, around 9% of the raw water is wasted, so recovery of MBW is an effective way for improving drinking water productivity. The membrane system of filtration–backwash–filtration is a typical process used in drinking water plant. Therefore, recovery of backwash water is a prospective water treatment process.

In this study, a bench-scale coagulation–MF system was operated from April to June in 2007 to treat the discharged MBW from the pilot system. The overall recovery rate of the system was increased to 98.0% with MBW recovery. MF was integrated with $FeCl_3$ as coagulant and PAC as adsorbent for the treatment of MBW to meet the drinking water quality requirements. The differences in quality between MBW and LRW were compared, and the characteristics of DOM including MW distribution and THMFP were investigated. The removal efficiencies of organic matter, THMFP formed by organic matter with various sizes, total bacteria, coliforms and turbidity by the coagulation–MF process were studied.

2. Materials and methods

2.1. Membrane module

The characteristics of the membrane module used in the experiment are shown in Table 1.

Table 1
Membrane characteristics

Type	Hollow fiber
Material	Polyvinylidene fluoride (PVDF)
Surface property	Hydrophilic
Inner diameter of fibers (mm)	0.5
Outer diameter of fibers (mm)	1.0
Surface area (m^2)	0.4
Nominal pore size (μm)	0.22
Manufacturer	Motian Membrane Engineering and Technology Co., China

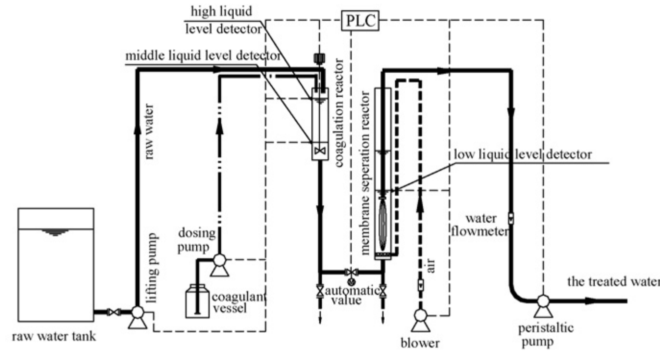

Fig. 1. Schematic diagram of experimental equipment.

2.2. Experimental system

The experimental scheme of the coagulation and MF units is shown in Fig. 1. MBW and the coagulant solution were pumped into a coagulation reactor, and then the mixed liquor flowed into a membrane reactor by gravity after the coagulation. A peristaltic pump was used to provide the trans-membrane pressure and controlled the constant membrane flux at 15.0 L/h m^2. The peristaltic pump worked as intermittent mode, worked for 8 min and shut off for 2 min. Operation of the system was controlled by a programmable logic controller (PLC). Liquid level probes, including a high level, a middle level and a low one were placed in the reactors. Automatic values and pumps were interconnected with PLC via the liquid level probes. For increasing the shear stress at the membrane surface and mixing the mixed liquor in the reactor, air was continuously supplied into the membrane reactor, and the volume ratio of gas to treated water was 15:1. The hydraulic residence time (HRT) of coagulation and membrane reactor was 27 and 40 min, respectively. The system worked continuously, and the concentrate from the membrane reactor was discharged at the end of each cyclic of 24 h. Aeration was operated for 5 min at airflow rate of 0.10 m^3/h before the concentrate was discharged.

2.3. DOM isolation

MW distribution of the organics in water samples was determined by a series of UF membranes filtration (Amicon YM, Milipore, USA) with MW cut-off 30k, 10k, 3k and 1k Da. Samples were filtered through the 0.45 μm membranes, then were applied to the UF membranes as a parallel mode. Available volume of the UF cup (Shanghai Institute of Nuclear Research of the Chinese Academy of Sciences, China) was 30 mL, and the available filtration area was 3.32×10^{-3} m^2. High purity nitrogen from a pressurized bottle provided driven force for filtration with consistent pressure 0.1 MPa. Prior to the operation, de-ionized water was used for the membranes cleaning to remove the residual contaminants. During of the experiments of 60 d, DOM isolation tests were carried out 5 times and the average results were reported.