Web-based information system for controlling membrane bioreactor

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Abstract

The web-based membrane bioreactor (MBR) system is constructed to control MBR system remotely and automatically. Applying man machine interface system to existing MBR process enables this automated system. The pressure, influent and effluent flow-rates, temperature, pH, DO and water level variation are monitored in MMI system. All these data are transferred from a local MBR to remotely located center through the web-based PC to PC networking using Internet. In this study, this system is called web-based information system, presenting very effective control of membrane fouling. While the manually operated system shows the abrupt transmembrane pressure drop and the membrane fouling.

Key Words: Membrane bioreactor, fouling, pressure, remote control, monitoring, Internet

Introduction

Membrane filtration can be efficiently coupled with a conventional activated sludge process for wastewater treatment, which eliminates the final clarifier because a membrane provides almost perfect liquid-solid separation. This is so-called membrane bioreactor (MBR). MBR has no problem in a failure of biological system due to biomass loss and/or bulking, and the biological capacity to treat organic matters and nutrients also increases (Nagaoka, 1996; Chang 1998; Fan et al., 1996).

However, membrane fouling and its control is a major issue for an economically feasible MBR system (Stephenson et al., 2000). Fouling is the process in which variety species in water are convected and deposited onto membrane surface resulting in the increasing of the hydraulic resistance as well as membrane resistance. This has been a critical obstacle to more broad application of MBR to wastewater treatment.

The objective of this study is to build up the computer aided system to control membrane fouling. It is noted that this study cannot provide an ultimate solution on membrane fouling, but proposes the way how to operate the membrane optimally in given conditions, retard the fouling, handle an emergency situation automatically, and transfer information to a remotely located operator.

Applying MMI (Man Machine Interface) to existing MBR system makes this automated system possible. The TMP, influent and effluent flow-rates, temperature, pH, DO and water level variation are monitored in MMI system. All these data are transferred from a local MBR to remotely located center through the web-based networking system. Central computer compared monitoring TMP with the critical value in real time scale and decided to adjust the influent flow-rate, permeate flux, or membrane operating cycle to decrease TMP. In this study, the operation, performed automatically using web-based remote controlling system, is compared to the manual operation in terms of the transmembrane pressure.

Materials and Methods

Lab-scale MBR system

The lab-scale MBR consists of three commercial hollow-fiber MF membrane modules (Mitsubishi Rayon, Japan). The effective filtration area is 0.2m^2/module. The membrane is made of polyethylene with hydrophilic coating, and its nominal pore size is 0.4 ㎛. Each membrane is fully immersed and symmetrically placed in the reactor. The membrane flux is 15LMH (200L/day) and operated for 8 minutes and idled for 2 minutes. This reactor is installed in a suburban wastewater treatment plant. The municipal wastewater, which passes the screening and first-sedimentation process, is introduced. Food to microorganism ratio ranged from 0.1 to 1.0 kgCOD/kgMLVSS.

Monitoring and controlling the MBR system

In order to control and monitor MBR system automatically, a man-machine interface system (MMIs) is constructed using DAQ (Data AQuisition) board, PCI 6024E, manufactured by National Instrument, Co. This PCI board is the multifunction analogue, digital, and timing I/O boards for any personal computer. This is connected to the signal block which collects the electrical signal from the devices or delivered the output voltage.

The equipments for remote monitoring and controlling system with the web-based networking are listed in Tab. 2. The analogue output generates the voltage signal ranged from -10 to +10VDC, while analogue input detects electrical signal from any devices. Therefore, the output channels are connected to devices that an operator wants to control such as pumps. Input channels are linked to the device to be monitored such as flow meter. Operating factors such as flux, membrane filtration cycle, aeration and influent flow-rate are controlled. Among these factors, influent flow-rate, TMP, permeate volume and dissolved oxygen are monitored and recorded. All these operations are enabled in the control panel screen (Fig. 1), that is programmed using Labview 6.0i (National Instrument, Co., USA).

Tab. 2 Equipments needed for remote monitoring and controling the lab-scale MBR system

Item		Number	Product	Specifications
Pump	Suction	3	Pro-spense pump	0～5VDC input*
	Backwashing	1	Masterflex	1～5VDC input
	Feed	1		
Air Compressor		1	-	1.0 HP
Flow meter	Permeate	3	Mc-millian	0～5VDC output*
	Backwashing	1		
Air Flowmeter		1	AalBorg Alicat	1～5VDC output
Pressure transmitter		3	Cole-parmer	1～5VDC input
Thermal transmitter		1	Cole-parmer	4～20mA output
DO meter		1	YSI, Model 58, USA	1～5VDC output
Level sensor		2		Digital ON/OFF**
Personal computer		1	Samsung	Pentium III
PCI 6024E board		2	NI instrument	

* Input means the item can be controlled at the electrical signal and output generate the analogue signal

** Digital ON/OFF means the item provides the electrical switch

If the system faced emergency situation such as too high TMP or abnormal water level, warning signal is displayed and send this message automatically to the central computer that is located remotely. This MMI system also determines whether the permeate flux should be changed or not, automatically. Sometimes, the computer decided to halt the system and send emergency message to the central computer waiting for the first aid of an operator. Consequently, MBR system is operated to minimize the membrane fouling and system failure.

Web based networking

In order to monitor and control lab-scale MBR system remotely, web-based networking is constructed. This concept can be embodied in real time by transferring an order in form of electrical signal through Internet. In order to transfer the data, PC-to-PC connecting software such as PCANYWHERE (version 10.0, Symantec, USA) is applied in this research. Therefore, as far as an operator can access Internet, local MBR can be controlled regardless of the time and space. Fig. 2 shows the conceptual diagram of web-based networking system.

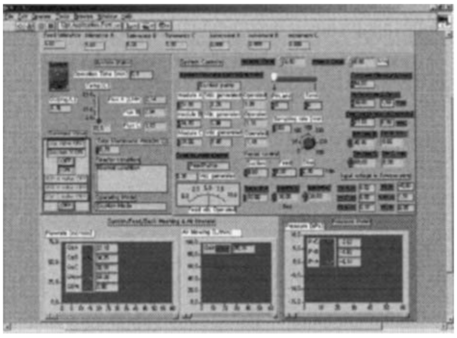

Fig. 1 Control panel programmed

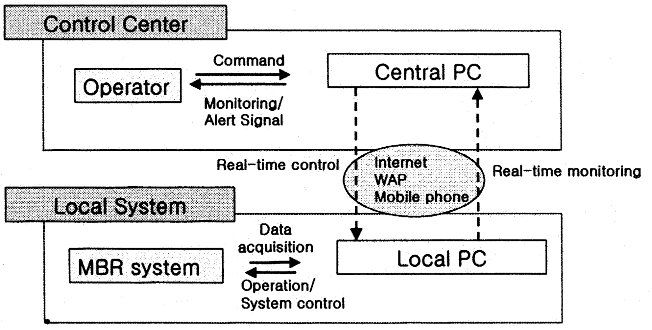

Fig. 2 Conceptual diagram of the web-based networking system

Results and Discussion

Permeate is produced at constant flux mode in lab-scale MBR process so that the TMP decreased as the membrane is fouled. Monitored TMP variation is expressed as specific flux decline curve presented in Fig. 3. Namely, the specific flux is calculated by dividing the monitored TMP into the initial TMP. Without any physical and chemical washing, the membrane could be operated for 60 days and the specific flux is maintained at about 0.7. This implied that the membrane is not fouled significantly, and still exhibited 70% of its capacity of the clean water flux. The specific flux variation for a week (circled period) is magnified in Fig. 3. The flux fluctuated like a waveform, repeating rise and fall. This pattern is attributed to the algorithm of the MBR information system. In order to find out the desirable point, at which the monitored value agreed with the simulation result, computer changed the operation factor such as suction flow-rate (permeate flux) by increasing or decreasing the signal output. For instance, if the monitored value were higher than simulated one, computer would diminish the signal output, by which the suction pump's rotation speed is controlled. Then again, newly monitored value is compared to the simulation result, and the increment or decrement of the signal output is decided. Computer repeated this procedure until the difference between the monitored and simulated value satisfied the tolerance. Therefore, in repeating this step, the specific flux fluctuated, but converged into some value. Web-based MBR system performed this iteration process automatically on behalf of an operator.

Fig. 4 presents the specific flux when the lab scale MBR is controlled manually without computer. In manual operation, TMP pressure drop is checked once per day, and membrane is operated only by operator's knowledge, intuition, and experience. As shown in Fig. 4, the operation mode could be divided into 4 periods. In first period, no washing is performed. The specific flux is maintained at around 0.5. However, it decreased rapidly to become 0.2 at the end of the first period. The membrane seemed to be fouled seriously, so that the membrane surface is physically flushed by clean water. Although physical washing, the flux decreased to 0.2 again in the second period. So, the chemical washing using 300 ppm NaOCl solution is carried out. In this cleaning step, the fouled membrane is detached from the reactor, and fully submerged into the chemical solution for 3 hours. The cleaned membrane is re-installed and operation started again (Period III).

However, as shown in the figure, the specific flux after the chemical cleaning is 0.5. This implied that the cleaning efficiency is about 50% and not good enough to recover the membrane capacity into the initial flux. The specific flux became 0.1 after 30 days operation in period III. Therefore, the more intensive cleaning is performed at the end of period III. However, at the beginning of period IV, the fouling rate is so fast that the membrane is fouled seriously only for a week.

Once a membrane is fouled too seriously, it is almost impossible to recover its capacity of filtration (Yusuf and Murray, 1993; Ueda and Hata, 1999) and the fouling rate became faster compared to the healthy membrane. The membrane filtration capacity is irreversible (Kuberkar and Davies, 2000). Fig. 4 presents this irreversible behavior of the fouled membrane, clearly (period IV). Therefore, in order to prolong the life span of a membrane, an operator should prevent the abrupt membrane fouling and sudden flux decrease or TMP increase and maintain steady state as possible. Some researchers expressed this kind of membrane operation as critical flux operation in crossflow type filtration. However, it is so difficult to operate the membrane at the critical flux by an operator manually, as shown in this experiment.

Consequently, Web-based MBR system shows the more stable transmembrane pressure, while the manually operated system shows the abrupt transmembrane pressure drop and the membrane fouling. However, there is no significant difference in the effluent quality between two systems due to the high biomass and the complete retention of the solids by the membrane filtration.

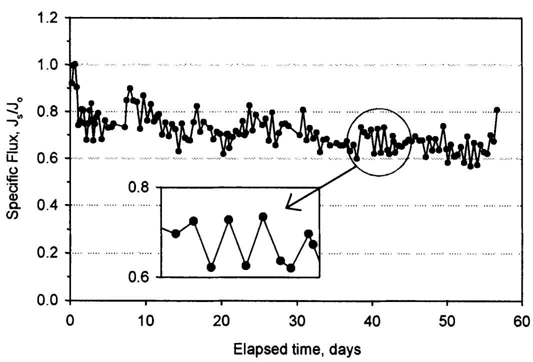

Fig. 3 Monitored TMP variation expressed as specific flux decline curve. The flux variation for a week (circled period) is magnified

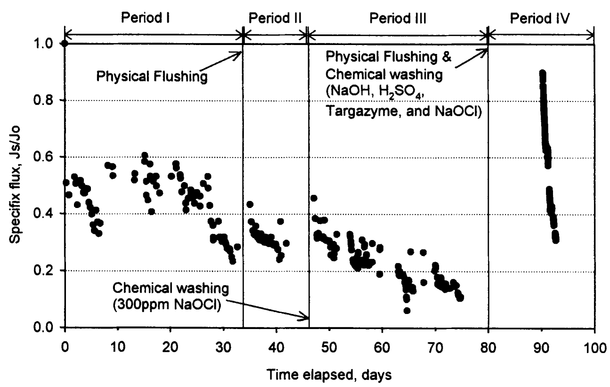

Fig. 4 Specific flux decline curve controlled by manual

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