Effect of ultrasonic on the performance of concentrate in high loaded bioflocculation-membrane reactor

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Abstract. In this work, the performance of the concentrates such as settlability, particle size distribution and filterability at different ultrasonic treatment was investigated and compared in the high loaded bioflocculation-membrane reactor for actual municipal wastewater treatment. The results indicated that the ultrasonic treatment can effectively improve the settleability of the concentrate. Moreover, the concentrate treated with the different ultrasonic, the particles in the concentrate were broken and distributed in small size interval. What needed to be noticed that when the concentrate with ultrasonic intensity of 0.6 W/mL treatment, found that membrane filtration resistance was highest.

1. Introduction

High loaded bioflocculation-membrane reactor (HLB-MR), which operated at extremely short solid retention time (SRT) and hydraulic retention time (HRT), bioflocculate colloidal and suspended particles in the wastewater, realized the organic matter recovery. Compared with the conventional activated sludge process (CAS), membrane separation technology had some advantages, such as high effluent quality, operation stable, and small footprint and so on. Currently, membrane technology had been development rapidly and played an important role in wastewater treatment. However, membrane fouling was a key issue for all membrane process, because it can be had disadvantages on the membrane performance and operation cost [1]. In order to control the membrane fouling effectively, some researched had studied that using ultrasonic can mitigate membrane fouling [2, 3]. In addition, Li et al. reported that after the length ultrasonic treatment, the MLSS decreased [4]. While, the ultrasonic whether influence the concentrate performance and further effect the bioflocculation efficiency were not reported, thus need to further study to determine the relevant impact. The objective of this work is to investigate and compared the effect of ultrasonic on the performance (such as settleability, filterability, particle size distribution) of the concentrate.

2. Materials and methods

2.1. Experimental set-up

Four lab-scale high loaded bioflocculation-membrane reactors operated were in a parallel mode with constant flux configuration as shown in Figure 1, and the membrane flux was 6.0 L/(m²·d). The reactor equipped the homemade hollow fiber ultrafiltration membrane module with the polyvinylidene...
fluoride (PVDF) with the effective membrane area of 0.28 m² and the nominal pore size of 0.03 μm (obtained from Tianjin MoTiMo membrane Technology Co., Ltd, China). The effective volume of each reactor was 1.7 L. Dissolved oxygen in the reactor was maintained at 6-8 mg O₂/L by aeration. Aeration flow rate was maintained at 70 L/min by gas flow meter. The aeration sand tray put at the bottom of the reactor, not only provide oxygen for the microorganisms growth but also provide bubbles for flushing the membrane surface to mitigating the membrane fouling. Set stirrer in the influent tank to prevent sedimentation of particles. Keep the influent tank and reactors’ effective height were same to controlling the constant influent. In order to removal reversible fouling on the membrane module, the peristaltic pump which controlled the effluent was run mode with 8 min for on and 2 min for off. The experiments operated 25°C contained by water bath. When the reactors operated keep stable, take out a certain volume of the concentrate from each reactor, one of the samples did not ultrasonic treatment, the other three samples treated with ultrasonic, and the ultrasonic intensity was 0.60, 1.05 and 1.5 W/mL, respectively. The ultrasonic treated at the frequency of 40 kHz for 8 min.

![Figure 1. Schematic of experimental set-up.](image)

The experiments treated with the actual municipal wastewater which taken from local municipal wastewater treatment plant with the treatment capacity of 150,000 m³/d in Changchun, Jilin, China. The quality of influent was shown in Table 1.

| Items     | COD | TN | TP | NH₄⁺-N | NO₂⁻-N | NO₃⁻-N | TSS | VSS |
|-----------|-----|----|----|--------|--------|--------|-----|-----|
| Concentration(mg/L) | 247 | 26 | 0.95 | 26     | 0.75   | 0.449  | 362 | 244 |

2.2. Analysis of water

In general, the reactors run for three-fold SRT was tending to be stable, and in this study, the experiments run for 15 days.

Chemical oxygen demand (COD), ammonia nitrogen (NH₄⁺-N), nitrite nitrogen (NO₂⁻-N), nitrate nitrogen (NO₃⁻-N), total nitrogen (TN), total phosphorus (TP), total suspended solids (TSS) and volatile suspended solids (VSS) were determined according to the standard methods [5].

To measure the sludge settling velocity (SV), collected 100 mL treated concentrate, put into cylinder, settled for 30 min. The floc particle size in the concentrate was measured using a laser particle size analyzer (EyeTech) and the results were recorded as number particle size distributions.

2.3. Membrane fouling resistance
In order to measure the membrane fouling resistance, used the method of the dead-end filter cup experiment by described by Gong et al. [6]. The tested membrane was a hydrophilic PVDF plate membrane (RGE-10) with a pore size of 0.1μm, effective filtration membrane area was 41.8 m², the filtration pressure was controlled at 1bar, the stirring speed was 700 rpm, and the filtration temperature was controlled at 20 ± 1℃. The filtration resistance was calculated using the following equation (1):

$$R = \frac{\Delta P}{\eta J}$$  \hspace{1cm} (1)

Where R is the total filtration resistance (m⁻¹); ΔP is the transmembrane pressure (Pa); η is the dynamic viscosity of permeate (Pa·s) and the J is the flux (m³/m²/s).

What was needed to be noticed that since the dynamic viscosity of permeate is affected by temperature, the temperature is corrected using the following equation (2):

$$\eta = 0.479(T+42.5)^{1.5}$$  \hspace{1cm} (2)

Where T is the temperature (°C) of the concentrate.

3. Results and discussion

3.1. Settleability

Figure 2 shows the settlement curves of the sludge in the concentrate treated at different ultrasonic intensity. As can be see, when the concentrates settled for 30 min, the sludge settling velocities were all less than 18%. Compared with the un-ultrasonic, the concentrates treated with different ultrasonic intensity had better settleability, the when settled for 30 min, the SV were less than un-ultrasonic treated. In addition, ultrasonic intensity increased, the settleability improved. At first 4 min, the sludge decreased rate was faster, at the 18th min, the decreased tended to be gentle. The results indicated that ultrasonic can promote the sludge settleability significantly, the ultrasonic intensity larger, the settleability better.

![Figure 2. Settlement curve at different treatment.](image)

3.2. Particle size distribution

Figure 3 shows the particle size distributions in the concentrate after the concentrate treated with different ultrasonic intensity. The mean particles concentration in the un-ultrasonic treatment reactor was $1.0 \times 10^5$ mL, when the reactors treated with the ultrasonic intensity was 0.60, 1.05 and 1.50 W/mL, the corresponding concentration was $2.5 \times 10^5$ mL, $1.9 \times 10^5$ mL and $2.6 \times 10^5$ mL, respectively. As can be seen, compared with un-ultrasonic treatment, particles concentration increased b using treating with ultrasonic. The statistics data of D10, D50 and D90 in the concentrate particles with un-ultrasonic treatment was 0.62 μm, 4.03 μm and 13.01 μm, respectively, which in the concentrate particles with ultrasonic treatment was 0.62μm, 1.24μm and 5.26μm, respectively, which in the concentrate particles with ultrasonic intensity of 1.05 W/mL treatment was 0.62 μm, 1.39 μm and
6.18 μm, respectively, which in the concentrate particles with ultrasonic intensity of 1.50 W/mL treatment was 0.62 μm, 1.08 μm and 5.10 μm, respectively. The results showed that apart from the date of D10, dates of D50 and D90 at the different ultrasonic treatment were all larger than which without ultrasonic treatment. In other words, ultrasonic radiation breaks floc particles in the concentrate, the particle size distribution tended to smaller size.

In order to explain the effect of ultrasonic on the particle size, the size of the particles which in the concentrates at different ultrasonic treatment was statistically analyzed by interval, and the results were shown in Figure 4. As can be seen, in 0-10 μm interval, the percentage in the concentrate with un-ultrasonic, ultrasonic intensity of 0.6 W/mL, ultrasonic intensity of 1.05 W/mL, and ultrasonic intensity of 1.50 W/mL was 35.61%, 70.61%, 64.56% and 68.68%, respectively. In 10-20 μm interval, the percentage in the concentrate with un-ultrasonic, ultrasonic intensity of 0.6 W/mL, ultrasonic intensity of 1.05 W/mL, and ultrasonic intensity of 1.50 W/mL treatment was 40.07%, 20.33 %, 24.77% and 23.34%, respectively. In 20-40 μm interval, the percentage in the concentrate with un-ultrasonic, ultrasonic intensity of 0.6 W/mL, ultrasonic intensity of 1.05 W/mL, and ultrasonic intensity of 1.50 W/mL treatment was 17.75%, 7.96%, 8.23% and 6.47%, respectively. In 40-120 μm interval, the percentage in the concentrate with un-ultrasonic, ultrasonic intensity of 0.6 W/mL, ultrasonic intensity of 1.05 W/mL, and ultrasonic intensity of 1.50 W/mL treatment was 6.55%, 1.1%, 2.44% and 1.51%, respectively. The results showed that compared with un-ultrasonic treatment, the particles in the concentrate with different ultrasonic treatment were distributed in a small range (0-10 μm). Moreover, with the ultrasonic intensity increased, the particles concentration changed was mainly caused by the fine particles increased. When the concentrate treated with the ultrasonic intensity of 0.6 W/mL and 1.50 W/mL, the concentrations were larger, the percentage of particles in 0-10 μm interval were higher, which demonstrated that ultrasonic can affect the flocs particle disintegration further.
3.3. Filterability

Figure 5 shows the results of the membrane filtration resistances of concentrates with different ultrasonic treated as a function of the filtration time. As can be seen, with the filtration prolonged, more concentrate filtrated, the membrane filtration resistances increased. Compared with un-ultrasonic treatment, concentrates treated with different ultrasonic had larger membrane fouling resistances, may cause more severe membrane fouling. Filtrated the same volume concentrate, the sample without ultrasonic treatment required shortest time. When the concentrates treated with ultrasonic intensity of 0.6 W/mL and 1.50 W/mL had more time, moreover the membrane filtration resistances larger. This phenomenon was consistence with the results reflected by the particle size distributions, which had higher particle concentration and larger percentage of small size interval when the concentrate treated with ultrasonic intensity of 0.6 W/mL and 1.50 W/mL, more submicron particles in the concentrates leaded to block the membrane pore, thereby the membrane filtration resistances increased.

Figure 5. Membrane filtration resistances at different treatment.

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