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IMPROVEMENT ON FILTERABILITY IN THE AEROBIC TREATMENT OF CARBOXYMETHYL CELLULOSE (CMC) WASTEWATER

Article Highlights

- The aerobic treatment of saline CMC wastewater is discussed for the first time
- For the aerobic treatment of CMC wastewater, the filterability of mixed liquid is much worse during exponential and stationary phases, and much better during death and lag phases
- For the aerobic treatment of CMC wastewater, the filterability of mixed liquid is effectively improved by mixing filtered natural water with the wastewater. The filtered natural water is simulating distilled water with proper micronutrients dosed
- For the treatment of CMC wastewater with CAS, the F/M to maintain biomass is approximately 0.4 kg COD/kg MLSS

Abstract

CMC is chemically modified from natural cellulose and widely applied in various industries. CMC wastewater consists mainly of sodium glycolate, sodium chloride and water. With extremely high COD and salinity, high concentration CMC wastewater cannot be biologically treated, but with COD and salinity around 15000 and 30000 mg/L respectively, low concentration CMC wastewater can be aerobically treated. In a CMC factory, the treatment of low concentration wastewater with aerobic MBR was successful except for one serious problem: poor filterability. Two trial solutions: adding micronutrients and applying MBBR were expected to improve the filterability. In the experiment, adding micronutrients was achieved by mixing filtered natural water into the wastewater, rather than dosing chemicals into it. The treatment efficiency of both solutions was close, but adding micronutrients showed distinguished performance in improving filterability, which includes higher filtration flux and slighter membrane fouling. Adding micronutrients also effectively improved the filterability under severe salinity shock.

Keywords: carboxymethyl cellulose, filterability, membrane fouling, micronutrients, saline wastewater.

What is CMC?

CMC is chemically modified from natural cellulose. It is a cellulose derivative with carboxymethyl groups substituting hydroxyl groups. Natural cellulose is not soluble in water, but most CMCs dissolve rapidly in cold or hot water, forming a viscous, smooth, flavourless, odorless, nontoxic, transparent and neutral solution. With such property, CMCs have various functions of bulking, firming, gelling, thickening, glazing, lubricating, emulsifying, humidifying, water-holding, colloid-holding and so on, and have various applications in food, daily chemical, pharmaceutical, oil, and many other industries. In fact, they are nowadays the most abundantly produced and the most widely applied cellulose products globally. Incidentally, CMCs are mostly applied as sodium salt – sodium carboxymethyl cellulose.

CMC production and CMC wastewater

CMC is synthesized through two reaction steps [1]. The first is alkalization reaction, which generates

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alkali cellulose; the second is etherification, which generates CMC:

$$[C_6H_7O_2(OH)_3]_n + n\text{NaOH} \rightarrow \rightarrow [C_6H_7O_2(OH)_2\text{ONa}]_n + nH_2O \quad (1)$$

$$[C_6H_7O_2(OH)_2\text{ONa}]_n + n\text{ClCH}_2\text{COONa} \rightarrow \rightarrow [C_6H_7O_2(OH)_2\text{OCH}_2\text{COONa}]_n + n\text{NaCl} \quad (2)$$

Meanwhile, there is one side reaction step that generates the byproduct, sodium glycolate:

$$\text{ClCH}_2\text{COONa} + \text{NaOH} \rightarrow \text{HOCH}_2\text{COONa} + \text{NaCl} \quad (3)$$

The reaction medium can be water or organic solvent. The former is for low-grade products, while the latter is for top-grade products. Ethanol is a most commonly utilized organic solvent.

Consequently, CMC wastewater is composed of water, sodium glycolate ($HOCH_2COONa$), sodium chloride as the majority, and cellulose, sodium hydroxide, ethanol, CMC as the minority. The relation between the water quality parameters and the wastewater composition is established: the SCOD is mostly attributed to sodium glycolate; the salinity is attributed to sodium chloride; the SS is attributed to the raw material – natural cellulose and some impurities. Sodium glycolate is a readily biodegradable; natural cellulose is slowly biodegradable; sodium chloride is the greatest obstacle to biological treatment, as saline wastewater is a hypertonic solution, in which cells undergo plasmolysis.

The concentration of CMC wastewater is highly variable among different product lines. The COD and salinity of high concentration CMC wastewater is up to around 70000 and 140000 mg/L, respectively; the COD and salinity of low concentration CMC wastewater is down to around 15000 and 30000 mg/L, respectively.

CMC wastewater treatment and its problems

Biological treatment is economical and practicable nowadays. However, high concentration CMC wastewater is far too saline for microorganism to treat. Only physicochemical treatment, such as distillation, incineration and filtration is supposed to be able to treat high concentration CMC wastewater, but at high operation costs.

The concern of this paper is the biological treatment of low concentration CMC wastewater, whose salinity is hopefully tolerable for microorganisms. However, there is regretfully little or no reference to this field. Given that sodium glycolate is biodegradable and sodium chloride is the inhibitor of bacteria, studies in biological treatment of saline wastewater can enlighten the biological treatment of CMC wastewater.

Regarding the biological aspect, inoculating halotolerant or halophilic strains into oligohalobic activated sludge [2-5] and acclimatizing oligohalobic activated sludge to the salinity [6] have been applied separately or combinedly to abate the retarding effect of salinity on microorganisms. In general, the acclimation strategy may work when the wastewater Salinity is below 30000 mg/L, while the inoculation strategy is applied when the wastewater salinity is above 30000 mg/L [7].

Regarding the operational aspect, the biofilm processes, which can provide a dual biological treatment system, and the membrane technique, which can provide longer HRT and SRT, have been applied to improve the efficiency of treating saline wastewater [7-9].

In addition to the known inhibiting effect on microorganism, salinity can also cause poor oxygen transfer, turbidity, viscosity and salt precipitation during biological treatment. Furthermore, salinity can reduce the flux and exacerbate the fouling during membrane filtration [7].

There is one case of CMC wastewater biological treatment – in a specialty chemicals factory located in Jiangsu, China, low concentration CMC wastewater has been treated with acclimation strategy and MBR process. Under an average salinity about 30000 mg/L, the average influent COD is about 15000 mg/L and the effluent COD is mostly below 500 mg/L, which is compliant with the Grade III (effluent discharged to sewage treatment plants for further treatment) of the Chinese National Standard "Integrated wastewater discharge Standard" [10]. By applying the acclimation strategy and membrane technique, the biological treatment was basically successful, except for a serious problem: the poor filterability of the mixed liquid. In the membrane tank, there were 120 DOW® FLEXELL-20 hanging-floating hollow fiber ultrafiltration membrane units immersing in the mixed liquid. The membrane is made of PVDF, with a nominal pore size of 0.1 μm. The design membrane flux is 6-8 L/(m^2·h) by means of vacuum filtration, so the design flow rate is supposed to be 14.4-19.2 m^3/h, while the real flow rate was around 10 m^3/h. According to the operational manual tailored for this type of wastewater by the membrane manufacturer, a two-min water-air backwash and scouring is conducted every 30 min, and a chemical wash is conducted every two months. Actually, the water-air backwash and scouring was poorly effective on mitigating the membrane fouling, while the chemical wash had an immediate

but fugitive effect. Right after a chemical wash, the filtration capacity had been recovered to above 25 m^3/h, but just after one week, it dropped back to around 10 m^3/h. The problem had been unexposed during the acclimation period, but as the influent Salinity became high during the operation period, the problem became much more obvious and serious.

As the maximum wastewater production capacity of this factory is 16.7 m^3/h, the in-plant wastewater treatment plant was always overshadowed by insufficient wastewater treatment capacity. Actually, on a global scale, CMC wastewater treatment plants that apply membrane technique have been facing the same problem. The objective of this study is to seek a solution to this problem.

THEORETICAL

Micronutrients

Industrial wastewaters are always lacking in numerous nutrients that are essential for microbial metabolism. The macronutrients required are carbon, oxygen, hydrogen, nitrogen, phosphor and sulphur; the micronutrients required include a wide range of elements and vitamins. Adequate micronutrients are necessary for all the genera present in activated sludge, so as to maximize population diversity and to enhance co-metabolism function. Abnormal activated sludge status, such as bulking, foaming, poor flocculation, poor settleability and so forth are associated with an unbalanced community, which is further ascribable to micronutrition deficiency [11-13].

Even so, micronutrients dosing is still very uncommon, unlike the prevalence of nitrogen and phosphor dosing, probably because there is still no acknowledged formula for the micronutrients required for activated sludge, and an excessive dosage might even backfire. As municipal sewage or natural water contains sufficient micronutrients, it is supposed to improve the performance of activated sludge by mixing it with industrial wastewater.

Given the composition of CMC wastewater analyzed in the previous chapter, it is easy to conclude that part of macronutrients and most of micronutrients are lacking in CMC wastewater. As nitrogen and phosphor have been regularly dosed at an appropriate C-N-P mass ratio during the treatment, adding micronutrients is expected to be one trial solution to the problem of poor filterability.

MBBR

MBBR is an ideal alternative process in addition to CAS. The process is based on “floating” biofilm carriers, which distinguish MBBR from traditional fixed-medium biofilm processes. MBBR carriers are normally made of various plastic materials, and their densities are designed to be slightly lower than that of water [14]. By applying this kind of biofilm carriers, a moving hotbed of microorganism can be formed in the wastewater, and because of the low densities of these carriers, MBBR consumes far less energy than other moving-medium biofilm processes, such as RBC and FBR, to drive the medium bed to move all over the reactor [15].

The filtration resistance of mixed liquid is to a certain degree related to the MLSS concentration. That is to say, lower MLSS concentration may lead to smoother membrane filtration. Biofilms grow better in low MLSS concentration and produce less suspended biomass [16], so applying MBBR is expected to be another solution to the problem of poor filterability.

EXPERIMENTAL

Influent quality

As the feed water in the experiment, the low concentration CMC wastewater was acquired from the specialty chemicals factory mentioned in the last chapter. However, for transport convenience, the raw wastewater had been condensed in the factory, and it had to be diluted back before the experiment. The condensed wastewater was close to high concentration CMC wastewater in property. Table 1 shows the quality of the condensed CMC wastewater.

Table 1. The quality of the condensed CMC wastewater

Item	Unit	Value
SCOD	mg/L	70000
Chloride	mg/L	140000
SS	mg/L	3500
Nitrogen	mg/L	0
Phosphor	mg/L	0
pH	-	8
Temperature	°C	50

Pilot devices

Part one - Basic research

In part one, the two trial solutions – adding micronutrients and applying MBBR were compared upon filterability. Note that in the experiment, adding micronutrients was achieved by mixing filtered natural water into CMC wastewater instead of dosing soluble chemical agents into it. This is because: firstly, the proper formula for micronutrients dosing is unknown; secondly, the filtered natural water can be considered

as the solution of soluble micronutrients and pure water; thirdly, the variety and quantity of micronutrients in the natural water is believed to be ideal to the organism.

The experiment was conducted in three parallel aerobic SBRs. The dimension of each reactor was 300 mm×200 mm×300 mm, and the reaction volume was 12 L. Each reactor was aerated by an electromagnetic air pump with the blowing capacity 100 L/min, which can definitely meet the demand for aerobic respiration and complete stirring.

Reactor #1 was the control reactor, where distilled water was utilized to dilute condensed wastewater, and CAS process was applied. In Reactor #2, natural water was utilized, and CAS process was applied. The natural water had been collected from the Mirror Moon Lake, an ecological scenic water in Donghua University, and then was filtrated by 0.45 μm pore size membrane. In Reactor #3, distilled water was utilized, and MBBR process was applied. The biofilm carriers are made of PP, with the specific gravity of 0.92, the total surface area of 500 m^2/m^3. The filling fraction of biofilm carriers was 40% [17].

In order to ensure the control experiment precise, all the other experimental settings were adjusted to being as uniform as possible among the three reactors. The bacteria had been inoculated from the wastewater treatment plant of the specialty chemicals factory mentioned in the last chapter, and the starting MLSS was 1000 mg/L in each reactor. The sludge/ /biofilm culture period lasted for one month, and then the operation period lasted for two months. During both periods, the SCOD concentrations were almost uniform among all reactors at the start of a treatment batch, and a treatment batch ended when the SCOD concentration was below 500 mg/L in all reactors. Carbamide and potassium dihydrogen phosphate were dosed to adjust the C-N-P mass ratio to 100:5:1 at the beginning of a treatment batch. During the whole course of part one, the reactors were running in a non-shock status.

Part two - Applied research

If filtered natural water showed ideal performance in part one, theoretically this would prove that the soluble micronutrients in the natrual water help to improve the filterability of the mixed liquid in CMC aerobic treatment. However, the utilization of natural water in wastewater treatment is practically illegal, so in part two, it would be quite significant to investigate the performance of municipal sewage, which is also believed to contain abundant micronutrients.

The experiment would be conducted in the three parallel aerobic SBRs same as in part one. Reactor #1 was the control reactor, where distilled water was utilized to dilute condensed wastewater; in Reactor #2, natural water was utilized for dilution; in Reactor #3, municipal sewage was utilized for dilution. All the other experimental settings would remain consistent with in part one. Table 2 shows the experimental settings of the two experiment parts.

Table 2. The experimental settings of the two experiment parts

Settings	Reactor #1	Reactor #2	Reactor #3
Part one			
Dilution	Distilled water	Natural water	Distilled water
Process	CAS	CAS	MBBR
Sanility	Uniform		
Part two			
Dilution	Distilled water	Natural water	Sewage
Process	CAS	CAS	CAS
Sanility	Uniform		
General			
Aeration	Consistently uniform		
pH	Consistently uniform		
Temperature	Consistently uniform		

Analysis methods

SCOD, MLSS and DO concentrations were determined every day; chloride concentration was determined every batch. Dichromate method has been used to determine COD concentrations [18]; Gravimetric method has been used to determine SS concentrations [19]; silver nitrate titration method has been used to determine chloride concentration [20]. DO concentration was measured with a WTW oxi 330i portable dissolved oxygen meter. SCOD concentrations were obtained through two steps: 1) filtering the mixed liquid with 0.45 μm-pore-size membrane; 2) determining the COD concentrations of the filtrate.

When analyzing the filterability, filtration time was recorded every day. CST has widely been adopted to characterize the filterability of activated sludge [21]. The method is to measure the time of a certain filtrate travelling a fixed distance on a specific filter paper. However, in this study, a dead-end vacuum filtration device was designed to simulate the actual working condition on site, as shown in Figure 1. The time of acquiring 50 mL filtrate from total 500 mL mixed liquid was recorded. Note that the volume was converted from the mass by the density of filtrate.

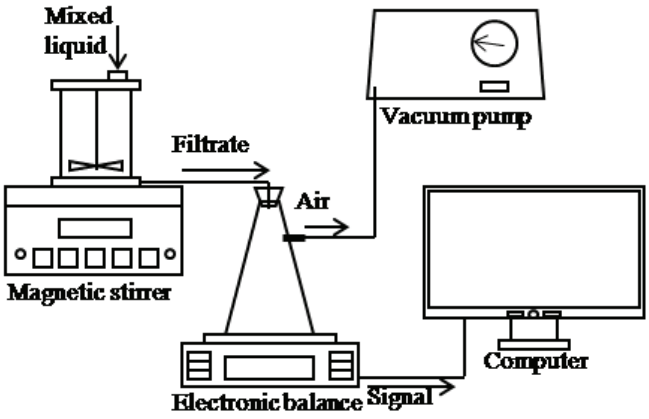

Figure 1. The schematic of the dead-end vacuum filtration device.

RESULTS AND DISCUSSION

Treatment and biomass

During operation period of part one, the treatment efficiency was very close among the three reactors. It took nearly same days for each reactor to degrade SCOD to below 500 mg/L.

For the two CAS reactors (#1 and #2), within a treatment batch, the organic loading kept decreasing along the treatment progress, while the MLSS increased in the early stage and decreased in the late stage. The inflection points of MLSS curve occurred when the organic loading decreased to around 0.4 kgCOD/kgMLSS. That is to say, the biomass increased when the organic loading was above 0.4 kgCOD/kgMLSS, and the biomass decreased when the organic loading was below 0.4 kgCOD/kgMLSS. The fact proves that the minimum F/M that can maintain biomass is approximately 0.4 kgCOD/kgMLSS.

Filtration time record

One treatment batch was picked out from the operation period of part one for analyzing the filterability. Figure 2 shows the daily filtration time record of the three reactors within this treatment batch. Obviously, the mixed liquid with filtered natural water added (Reactor #2) had the best filterability with a great advantage/margin, while the MBBR (Reactor #3) was far worse than the two CAS reactors in filterability.

Normally, a mixed liquid with less suspended solid will have less filtration resistance, but the finding reveals that the filterability of MBBR mixed liquid is much poorer than that of CAS, regardless that the MLSS in MBBR is far less than in the CAS reactor. It is inferable that the difference in structure of suspended solid between suspended sludge (in CAS reactor) and flaking biofilm (in MBBR) caused the widely different performance in filterability.

It is also noted that the daily filtration time experienced a nearly synchronous rise and fall for all the three reactors within this treatment batch. Figure 3 shows the relation between MLSS and filtration time. For the two CAS reactors, the filtration time went up with the increase of MLSS and went down with the decrease of MLSS, while for the MBBR, the rise and

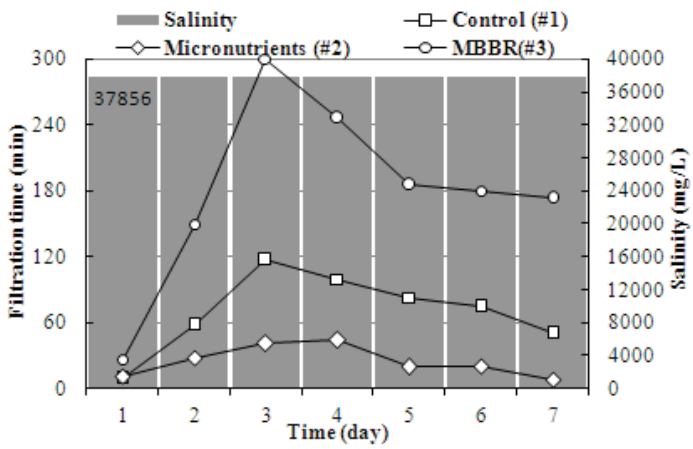

Figure 2. The daily filtration time record in part one.

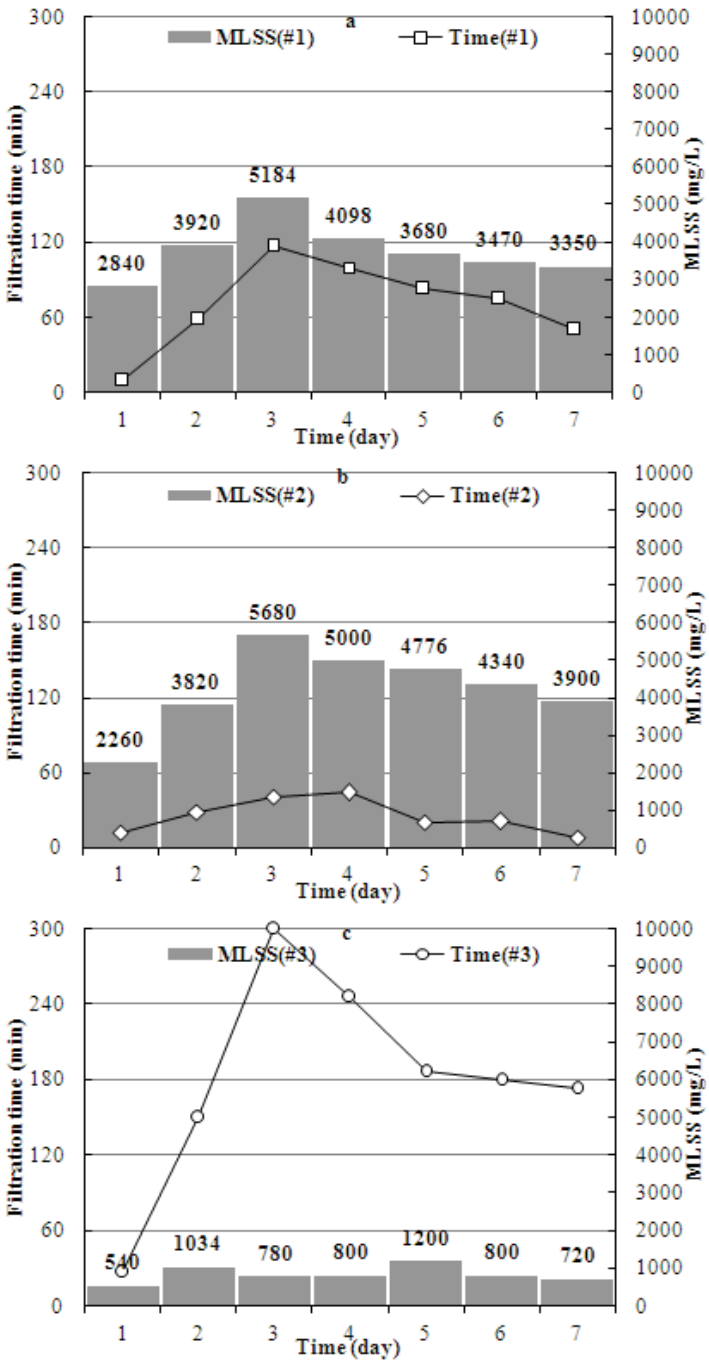

Figure 3. The relationship between MLSS and filtration time: a) Reactor #1, b) Reactor #2 and c) Reactor #3.

fall of filtration time had no relationship with MLSS. It is inferable that the microbial activity has a more decisive impact on the filterability than the biomass. That is to say, the mixed liquid has a large filtering resistance in the exponential and stationary phases because the bacteria are much active and are growing at a high speed, while the mixed liquid has a small filtering resistance in the death and lag phases because the bacteria are decaying in activity and are deceasing more than growing.

Filtration resistance

As a parameter which characterizes the filterability of mixed liquid, filtration time is intuitive, but not scientific. Hence, filtration resistance is introduced and Darcy's law, which describes the flow of a fluid through a porous medium is quoted and modified:

$$\frac{Q}{t}\frac{1}{A}=\frac{\Delta P}{\mu R} \tag{4}$$

where Q is the cumulative flux (m^3), t is the filtration time (s), A is the membrane surface area (m^2), ΔP is the TMP (Pa), μ is the permeate viscosity (Pa·s) and R is the filtration resistance (1/m). Then, through derivation, the instantaneous flux can be calculated:

$$q = \frac{\mathrm{d}Q}{\mathrm{d}t} = \mathrm{d}\left(\frac{A\Delta P}{\mu R}\right) = \frac{A\Delta P}{\mu r} \tag{5}$$

where q is the instantaneous flux rate (m^3/s), r is the instantaneous filtration resistance (1/m). Finally, just by simple operations, the instantaneous filtration resistance is obtained:

$$r = \frac{A\Delta P}{\mu q} \tag{6}$$

Still within this treatment batch, on the last day, the curves of filtration time – cumulative flux within an hour were recorded, as shown in Figure 4a. After further calculation, the curves of filtration time – instantaneous filtration resistance within an hour were obtained, as shown in Figure 4b.

The lasting rise of filtration resistance was due to the lasting exacerbation of membrane fouling, which is caused by the deposition of soluble and particulate materials into and onto the membrane during filtration [22]. The membrane fouling is composed of reversible, irreversible and permanent membrane fouling. Reversible membrane fouling is considered as a loose adherence of fouling substances to the membrane, which can be removed by physical means; irreversible membrane fouling is considered as a strong adherence, which can only be removed by chemical means [23]; permanent membrane fouling cannot be removed even after physical and chemical wash. So, the total filtration resistance can be divided into four parts:

$$R = R_m + R_r + R_{ir} + R_p \tag{7}$$

where R_m is the filtration resistance of membrane, R_r is the filtration resistance of reversible membrane fouling, R_{ir} is the filtration resistance of irreversible membrane fouling, and R_p is the filtration resistance of permanent membrane fouling.

On the last day of this treatment batch, the four parts of filtration resistance were determined. In the determination, the filtered liquid was deionized water, which wouldn't affect the fouling layer and could uniformly permeate the fouling layer and the membrane. The filtration flux of deionized water was recorded at four successive time points: first, when the membrane was new; second, after the membrane had filtered mixed liquid; third, after the membrane had been physically washed (water rinse); fourth, after the membrane had been chemically washed (10% NaClO bath). The four parts of filtration resistance could be calculated with filtration flux and Eq. (6), as shown in Table 3.

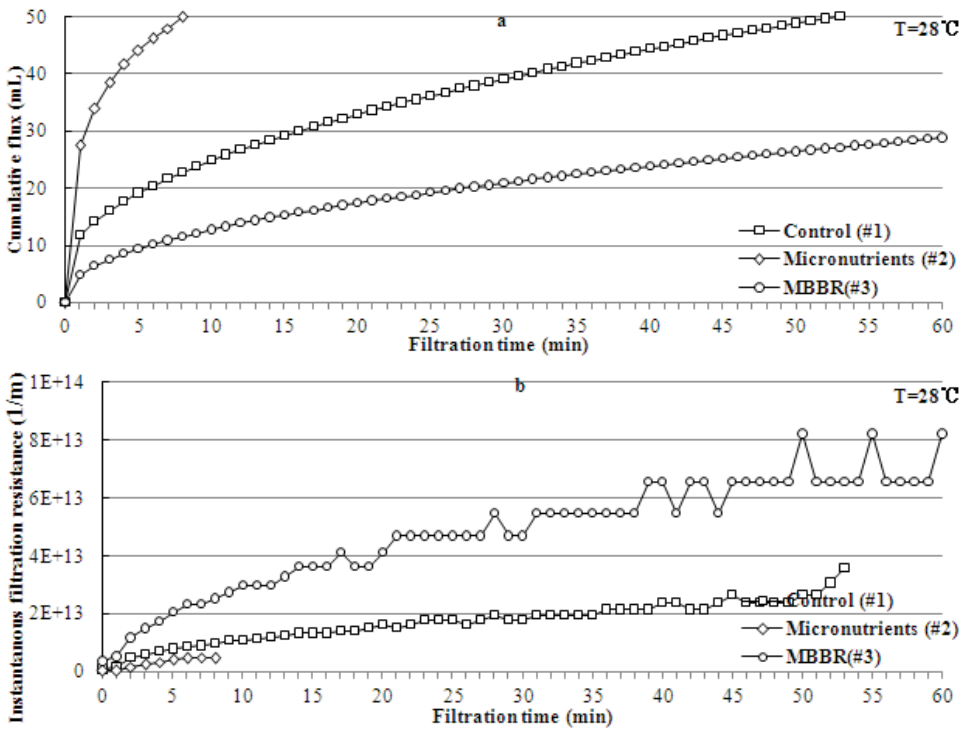

Figure 4. Curves of filtration time: a) cumulative flux within an hour; b) instantaneous filtration resistance within an hour.

Table 3. The four parts of filtration resistance; ΔP = 87 kPa; A = 41.854 m²; μ_{28} = 0.8937 mPa s

Mixed liquid	q / m^3 s^{-1}		R / m^{-1}	
Reactor #1	New	3.546×10^{-6}	Membrane	1.149×10^{11}
	Filtered	1.144×10^{-8}	Total	3.561×10^{13}
	P-washed	3.817×10^{-7}	Reversible	3.454×10^{13}
	C-washed	1.316×10^{-6}	Irreversible	7.578×10^{11}
			Permanent	1.948×10^{11}
Reactor #2	New	3.125×10^{-6}	Membrane	1.304×10^{11}
	Filtered	5.537×10^{-8}	Total	7.358×10^{12}
	P-washed	7.353×10^{-7}	Reversible	6.804×10^{12}
	C-washed	2.778×10^{-6}	Irreversible	4.074×10^{11}
			Permanent	1.630×10^{10}
Reactor #3	New	3.676×10^{-6}	Membrane	1.108×10^{11}
	Filtered	4.967×10^{-9}	Total	8.203×10^{13}
	P-washed	3.968×10^{-7}	Reversible	8.100×10^{13}
	C-washed	1.351×10^{-6}	Irreversible	7.252×10^{11}
			Permanent	1.907×10^{11}

It is observed by Table 3 that the mixed liquid in Reactor #2 not only had the least filtration resistance, but also caused the slightest membrane fouling. There are parameters not present in Table 3 but should be noticed: the sum of irreversible and permanent membrane fouling, which indicate to what extent the membrane flux can be restored after a physical wash. The parameters are significant because the physical wash is most regular and simple way to restore the membrane flux. It is calculated that the sum of irreversible and permanent membrane fouling was 9.526×10^{11} 1/m for Reactor #1, 4.237×10^{11} 1/m for Reactor #2 and 9.159×10^{11} 1/m for Reactor #3.

Moreover, the mixed liquid in Reactor #2 caused slightest permanent membrane fouling, which can also be revealed by SEM photographs of permanent membrane fouling shown in Figure 5. The surface of membrane #2 (for Reactor #2) is pretty clear and its pores are basically open (Figure 5b), while the surface of membrane #1 (for Reactor #1) and membrane #3 (for Reactor #3) is evidently covered and its pores are largely blocked (Figure 5a and c).

Applied research

Since mixing natural water with CMC wastewater had shown ideal performance in part one, the performance of mixing municipal sewage was investigated in part two. As diluent, distilled water was not contaminated but municipal sewage was, and the COD was approximately 400 mg/L, so the treatment efficiency is not comparable among the three reactors. The focus is still the filterability, which is reflected by the filtration time of the mixed liquid in the three reactors.

Figure 6 shows the daily filtration time record of the three reactors within one treatment batch of part two. It is observed that the mixed liquid with filtered natural water added (#2) cost the shortest filtration time; the mixed liquid with municipal sewage added (#3) cost a bit longer filtration time, but still shorter than the filtration time of the mixed liquid from the control reactor (#1). It was proved that the municipal sewage can also improve the filterability of the mixed liquid in CMC aerobic treatment. Moreover, it is infer-

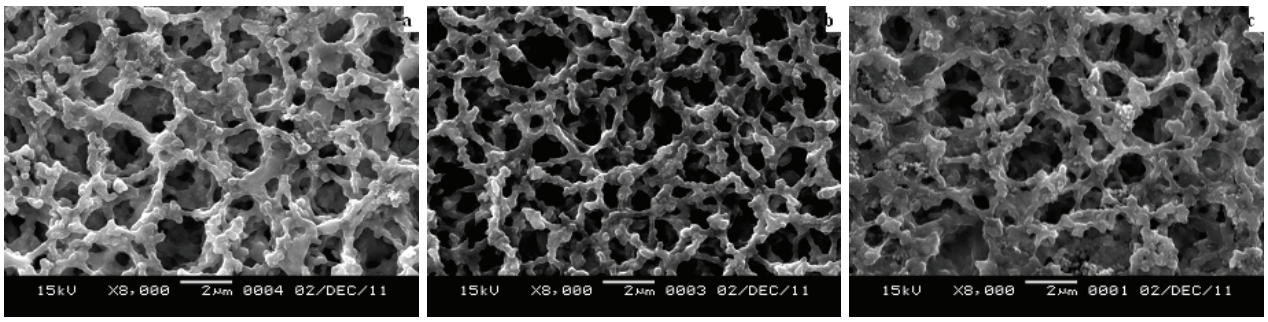

Figure 5. SEM Photographs of permanent membrane fouling: a) the membrane for Reactor #1, b) the membrane for Reactor #2 and c) the membrane for Reactor #3.

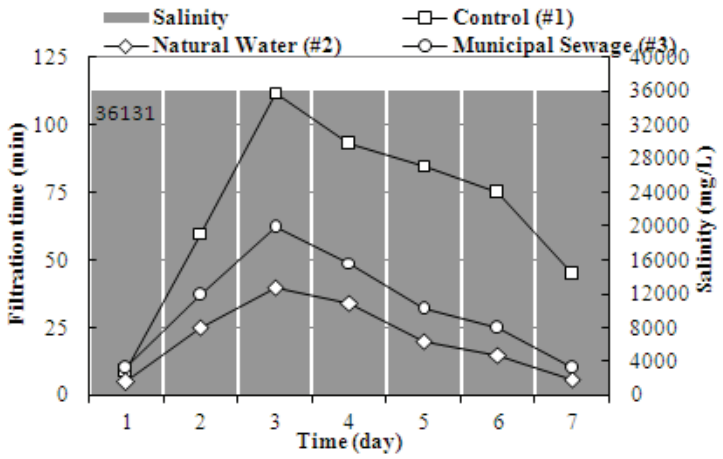

Figure 6. The daily filtration time record in part two.

able that the contaminants (solid and soluble) in the municipal sewage made its performance inferior to filtered natural water.

Micronutrient analysis of natural water

Since the filtered natural water showed an ideal effect on improving the filterability of mixed liquid in CMC wastewater aerobic treatment, it is significant to analyze its micronutrient composition. A PerkinElmer Optima 8300 ICP-OES spectrometer was used for the determination. Table 4 shows the results obtained.

Table 4. The soluble micronutrient composition of the natural water utilized in the experiment

Element	Concentration	Unit	Element	Concentration	Unit
Al	12.8	μg/L	Na	110.0	mg/L
Ba	71.7	μg/L	Ni	8.28	μg/L
Ca	52.5	mg/L	Pb	0.132	μg/L
Cd	0.012	μg/L	Rb	9.8	μg/L
Co	0.306	μg/L	Sb	3.65	μg/L
Cr	0.308	μg/L	Se	0.351	μg/L
Cu	2.99	μg/L	Sr	342.3	μg/L
Fe	16.4	μg/L	Tl	0.010	μg/L
Hg	0.011	μg/L	V	0.312	μg/L
K	10.9	mg/L	W	1.11	μg/L
Li	10.8	μg/L	Zn	4.8	μg/L
Mg	16.5	μg/L	As	4.63	μg/L
Mn	75.3	mg/L	Br	110.5	μg/L
Mo	5.75	μg/L	Cl	230.0	mg/L

CONCLUSIONS

1. By mixing adequate natural water with CMC wastewater, the filterability of mixed liquid was largely improved. The improvement was manifested in maintaining the filtration flux and retarding the membrane fouling. However, the treatment efficiency was almost unchanged.

2. Although MBBR produced far less MLSS than CAS did, the filterability of the MBBR mixed liquid was still far poorer than that of CAS in CMC wastewater aerobic treatment. Meanwhile, the treatment efficiency was almost the same.

3. The filtration resistance of mixed liquid was rather great when the aerobic treatment was in-process, and was pretty weak when the aerobic treatment was towards the end. Thus, the membrane filtration posterior to the biodegradation completion is significant for CMC wastewater aerobic treatment.

4. Salinity shock increased the filtration resistance of mixed liquid, especially when the aerobic treatment was in-progress. Mixing natural water with

CMC wastewater was again effective on improving the filterability.

5. For the treatment of CMC wastewater with CAS, the minimum F/M that can maintain biomass is approximately 0.4 kg COD/kg MLSS.

Acknowledgements

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Nomenclature

CAS	Conventional Activated Sludge
CMC	Carboxymethyl Cellulose
COD	Chemical Oxygen Demand
CST	Capillary Suction Time
DO	Dissolved Oxygen
FBR	Fluidized Bed Reactor
F/M	Food to Microorganism ratio
HRT	Hydraulic Retention Time
ICP-OES	Inductive Coupled Plasma - Atomic Optical Spectroscopy
MBR	Membrane Biological Reactor
MBBR	Moving Bed Biofilm Reactor
MLSS	Mixed Liquid Suspended Solid
PP	Polypropylene
PVDF	Polyvinylidene Fluoride
RBC	Biological Rotating Contactor
SBR	Sequence Batch Reactor
SCOD	Soluble Chemical Oxygen Demand
SEM	Scanning Electron Microscopy
SRT	Sludge Retention Time
SS	Suspended Solid
TMP	Trans-membrane Pressure

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NAUČNI RAD

POBOLJŠANJE FILTRIRANJA POSLE AEROBNOG TRETMANA OTPADNE VODE SA KARBOKSIMETILCELULOZOM

Karboksimetilceluloza (CMC) je hemijski modifikovana prirodna celuloza koja se široko primenjuje u različitim industrijama. Otpadna voda sa CMC sastoji se uglavnom od natrijum-glikolata, natrijum-hlorida i vode. Otpadna voda sa izuzetno velikom HPK i salinitetom ne može se biološki tretirati, ali ona sa HPK oko 15000 mg/L i salinitetom oko 30000 mg/L može se aerobno tretirati. Tretman otpadne vode sa malim koncentracijama CMC u aerobnom membranskom bioreaktoru (MBR) je uspešna, ali se suočava sa ozbiljnim problemom otežane filtracije. Očekuje se da se filtrabilnost može poboljšati dodatkom mikronutrijenata i primenom reaktora sa pokretnim slojem sa biofilmom (MBBR). Dodatak mikronutrijenata je postignut mešanjem filtrirane prirodne vode sa otpadnom vodom da bi se izbeglo dodavanje hemikalija u otpadnu vodu. Efikasnost tretamana u oba slučaja je skoro isti, ali dodavanjem mikronutrijenata se znatno poboljšava filtrabilnost koja uključuje veći filtracioni fluks i manje onečišćenje membrana. Dodatkom mikronutrijenata se takođe efektivno poboljšava filtrabilnost pri velikim povećanjima saliniteta.

Ključne reči: karboksimetilceluloza, filtrabilnost, onečišćenje membrane, mikronutrijenti, slane otpadne vode.