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Research on Biological Contact Oxidation — Ultrafiltration Membrane System for Community Intermediate Water Reuse

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Abstract:

This issue is mainly on biological contact oxidation - ultrafiltration membrane water reuse project application. By the tracking test of the operation period, the system optimum operating parameters were investigated and determined. Furthermore, the organic matter and ammonia nitrogen removal of the system were analyzed emphatically, and the economic and environmental benefits of the water reuse project were evaluated. It was found out that, the system for the removal of CODcr and ammonia nitrogen was stable and efficient, with an average removal rate of 92.37% and 89.40%, respectively, and the effluent has reached domestic miscellaneous water quality standard. In addition, the unit cost of this water treatment was 2.05 yuan/m3, which was lower, comparing with conventional activated sludge and three stage biochemical process for water reuse. To sum up, the biological contact oxidation - ultrafiltration membrane process combined the advantages of traditional methods of wastewater treatment and membrane bioreactor (MBR), and was at the high level for CODcr and ammonia nitrogen removcal, besides economic and environmental benefits. The biological contact oxidation - ultrafiltration membrane process can be popularized as one of the water reuse technologies.

Keywords*: Membrane bioreactor, Biological contact oxidation, Ultrafiltration membrane, Intermediate water reuse.*

I. INTRODUCTION

Membrane bioreactor is a new water treatment technology, which is the integration of high performance membrane separation unit and biological treatment unit with efficient degradation. Efficient MBR technology to replace the conventional activated sludge process, applied to large-scale municipal sewage treatment, is an important direction for the development of reuse water [1-2].However, existing experimental research and engineering practice shows that, the MBR quality water is based on high energy consumption and the membrane fouling, which limiting its large-scale promotion [3-6]. In this study, the bio-contact oxidation was combined with ultrafiltration membrane technology, to remove part of the organic matter in biological contact oxidation unit and reduce the organic load of the follow-up ultrafiltration membrane unit. The main purpose of this paper is to investigate contribution rate of

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contaminant removal of biological contact oxidation unit and ultrafiltration membrane, respectively, and the strengths, weaknesses, and engineering adaptation of the long-running in wastewater reuse for this technology.

II. PROJECT OVERVIEW

2.1 Raw Water Quality

The object of this research was a residential area, with the total floor area of approximately 50,000 square meters, green area of 35%, a total of more than 1,000 households and 3,800 people. The district established a reclaimed water station, using the shower drain, toilet drain, and laundry drain water as the source. The capacity of the station was 370 m3 / d, and the effluent was used for residential green, water features, pouring road, washing public toilets, and so on. The raw water quality was shown in TABLE I.

TABLE I. Quality of raw water

Item	Variation range (mg/L)	Average value (mg/L)
CODcr	250.67~427.50	332.10
BOD5	125.16~265.52	176.87
NH4+-N	20.33~30.18	26.12
TN	24.79~33.26	27.25
SS	186~320	221
pH	6.62~7.30	7.04

2.2 Technological Process

According to the quality of raw water and effluent standards, the following process was used (see Fig 1).

The raw water flowed into the regulation pool firstly, where the grille and hair collector were set at the entrance to remove larger floaters and hair. Since the adjust action on water quality and quantity of regulation ponds, the sewage peak flow or concentration change effects were avoided, so as to ensure the stability of the subsequent reaction. And then, sewage flowed into the bio-contact oxidation-ultrafiltration membrane reaction cell. Biological contact oxidation reaction zone was assumed most of the organic matter and ammonia removal, and the rejection of the ultrafiltration membrane of the membrane separation zone, further removed the small particles of suspended solids, bacteria, viruses and organic macromolecules, etc.. After that, the treated effluent entered the pool storage, cleansed with chlorine dioxide disinfection. Wastewater finally qualified for the green, flushing, etc.

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2.3 Major Structures and Equipment

Structures and its parameters were shown in TABLE II.

(1) Grille and hair collector

Shower drain, toilet drain, and laundry drain water had less larger suspended solids or floating debris, but more hair. In order to prevent clogging the membrane bioreactor, a mechanical grille with trash rack spacing of 8 mm was selected (mounting inclination of 60°), and a hair collector was used, whose filter aperture was 3 mm to prevent the hair getting into the water pump or the membrane bioreactor.

(2) Regulation tank

Regulation tank had the effective volume of 60 m3, and the hydraulic retention time (HRT) of 4 h.

(3) Biological contact oxidation-ultrafiltration membrane reaction tank

Biological contact oxidation - ultrafiltration membrane tank consisted of two reaction zone: the first was the bio-contact oxidation zone, with interior combination filler of 150mm diameters, and the other was membrane separation zone, which placed hollow fiber ultrafiltration membrane module (see Fig 2). The average pore size of ultrafiltration membrane was 0.2 μm, whose membrane flux was 150 L/(m2 • h) at 25℃. The effective volume of the entire cell body was about 93m3, and the volume ratio of biological contact oxidation zone to membrane separation zone was about 2:3.

(4) Reclaimed water tank

Reclaimed water tank had the effective volume of 60 m3, and the hydraulic retention time (HRT) of 4 h.

(5) Disinfection system

Chlorine dioxide was used as a disinfectant, and its dosage was based on water quality (3 to 6 mg / L), exposure time > 30 min, by metering pump.

TABLE II. Structure and its parameters

Serial number	Name	Specification	Amounts	HRT/h
1	Regulation tank	5m×4m×3m	1	4
2	Biological contact oxidation-ultrafiltration	6.2m×5m×3m	1	6

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	membrane reaction tank			
3	Reclaimed water tank	5m×4m×3m	1	4

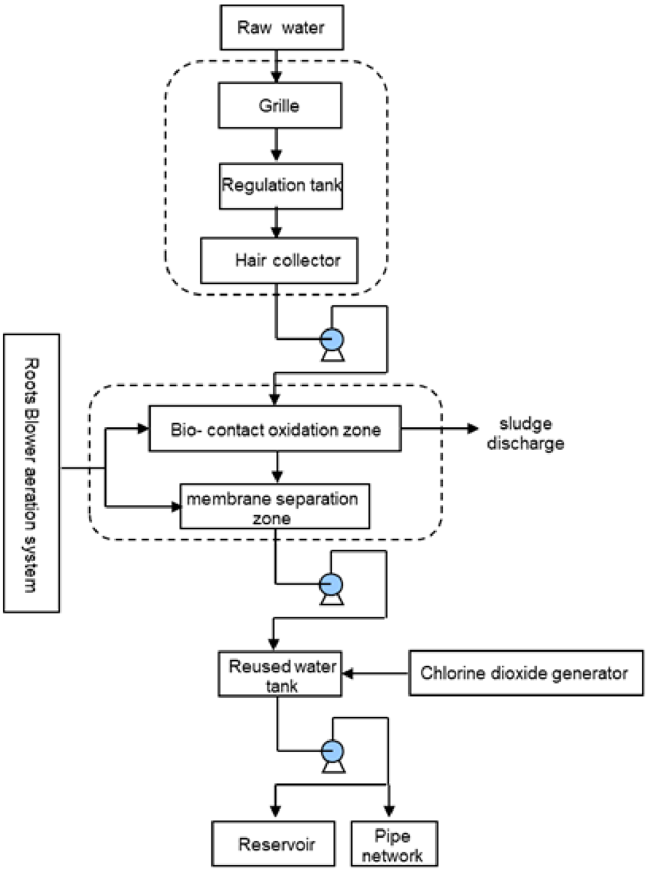

Fig 1: Schematic diagram of technological process

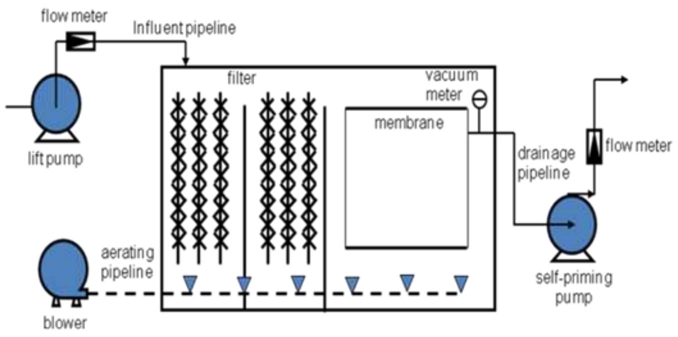

Fig 2: Schematic diagram of biological contact oxidation–ultrafiltration tank

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III. SYSTEM ADJUSTMENTS

3.1 Biological Contact Oxidation Zone Adjustment

The method of packing biofilm in biological contact oxidation reaction zone was natural start-up, which making the wastewater flow through the packing only, without inoculation sludge or C, N and P nutrients to promote microbial growth, after 46 days, biofilm culturing was succeeded, and behaved that CODcr removal of the biological contact oxidation zone had stabilized at 70% above. Besides, large number of active protozoa (such as the bell insect) and more metazoan (eg, nematodes) were observed in the biofilm.

3.2 Ultrafiltration Membrane Zone Adjustment

In addition, to ensure the good performance on filtration of the membrane, and taking into account the maximum possible reduction in energy consumption, the suction pressure of pump was controlled at 0.1MPa, aeration volume maintained from 400m3/h to 600m3/h, and using operation mode of the membrane as suction for 13 min, then stopping for 2 min.

IV. ANALYSIS OF RUN EFFECT

4.1 Organic Removal Efficiency

The organic removal capacity of biological wastewater treatment process is one of the main indicators for the technology performance, and CODcr is used to reflect the organic content in the sewage. During stable operation period, the organic matter removal efficiency of the biological contact oxidation-ultrafiltration membrane system was shown in Fig 3.

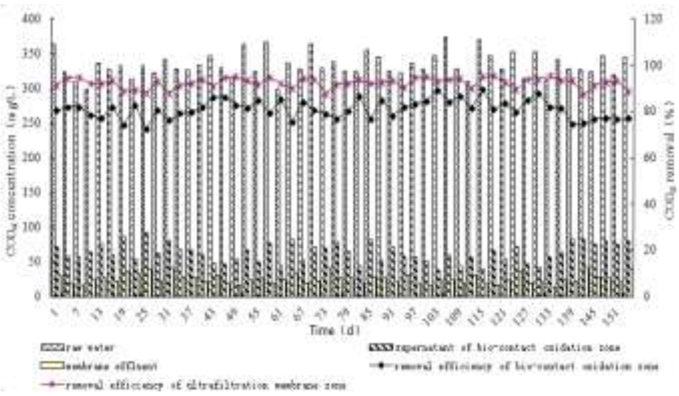

Fig 3: CODcr removal of biological contact oxidation–ultrafiltration system

From Fig 3, it was found that CODcr of membrane effluent was at range of 14mg/L to 41mg/L, with an average of 25.42mg/L, which has reached domestic miscellaneous water quality standard (≤50mg/L),

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when the CODcr of raw water was at the range of 298~373mg/L. And CODcr removal was from 87.42% to 95.51%, with an average of 92.37%. Biological contact oxidation - ultrafiltration membrane system for the removal of CODcr was stable and efficient.

As Fig 3 shows, the CODcr concentration of supernatant of bio-contact oxidation zone changed from 38mg/L to 92mg/L, with an average of 63.10mg/L. The difference between supernatant of bio-contact oxidation zone and membrane effluent average CODcr concentration was 37.67mg/L, which was 11.30% in the form of average CODcr removal efficiency. CODcr removal efficiency difference between the supernatant and membrane effluent, demonstrated that ultrafiltration membrane had the ability to further remove the remaining refractory organics. This is attributed to two aspects [7]: on one hand, rejection of microbial by ultrafiltration membrane, making the degradation of organic matter in bioreactor enhanced; on the other hand, the rejection of organic macromolecules by ultrafiltration membranes, made the macromolecules retained within the bioreactor, to gain more reaction time with microbial than the conventional activated sludge, which was also contribute to cultivation of some specifically microorganisms and the organic removal efficiency. Thus, ultrafiltration membrane had an important role in the organic removal process, as it guaranteed the stability of the effluent quality.

The Fig 4 presented the CODcr removal proportions of different reactor stage. For the removal of CODcr, regulation pool accounted for about 11%, and biological contact oxidation zone occupied 73%, while the membrane accounted for 16%. The above distribution of CODcr removal rate was quite meaningful for system running effect. Firstly, with the dilution and stabilizing effect of regulation tank, the CODcr concentration was reduced, which was conducive to nitrification in follow-up contact oxidation reaction zone. Since the nitrifying bacteria are autotrophic, the activity of heterotrophic bacteria will be limited, while the nitrifying bacteria will be more dynamic, with less CODcr concentration. Secondly, most of the CODcr was degraded in biological contact oxidation zone, which significantly reduced the load of the membrane separation zone, and thus slowed down the membrane fouling, and ensured the system operating well uptime. Finally, by the ultrafiltration membrane interception of the refractory organics, the effluent quality met the requirement of miscellaneous water standards.

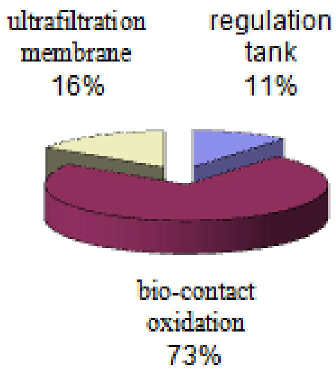

Fig 4: CODcr removal proportions of different reactor stage

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4.2 Ammonia Nitrogen Removal Efficiency

From Fig 5, it was found that ammonia nitrogen of membrane effluent was at range of 1.60mg/L to 4.10mg/L, with an average of 2.74mg/L, which has reached domestic miscellaneous water quality standard (≤10mg/L), when the ammonia nitrogen of raw water was at the range of 20.00~30.19mg/L. And ammonia nitrogen removal efficiency was from 80.44% to 94.32%, with an average of 89.40%. Biological contact oxidation - ultrafiltration membrane system had good nitrification.

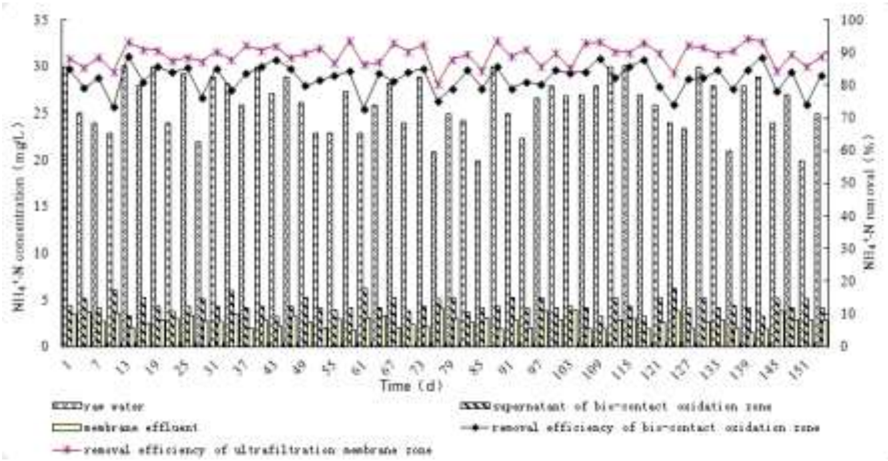

Fig 5: Ammonia nitrogen removal of biological contact oxidation–ultrafiltration system

As Fig 5 shows, the ammonia nitrogen concentration of supernatant of bio-contact oxidation zone changed from 3.27mg/L to 6.24 mg/L, which has reached domestic miscellaneous water quality standard. The membrane effluent compared to supernatant of biological contact oxidation zone, the ammonia nitrogen concentration varied little, with an average difference of 1.82mg / L. From Fig 5 the ammonia nitrogen removal of membrane effluent has not been significantly improved, as the contribution of ultrafiltration membrane was only about 1.82mg / L. The proportion of ammonia nitrogen removal, the bio-contact oxidation zone accounted for 94%, and the membrane separation zone accounted for only 6% (see Fig 6). Since the form of ammonia nitrogen in water mainly is hydrated ammonium ion, which is small inorganic molecules can freely pass through the microporous of membrane, the retention effect of ammonia nitrogen was not well in ultrafiltration membrane zone, and the microorganisms in the bio-contact oxidation reactor played an important role in ammonia nitrogen removal. The little difference of nitrogen removal between supernatant and membrane effluent was caused by nitrifying bacteria and denitrifying bacteria, which was attached on the surface of membrane [8-9].

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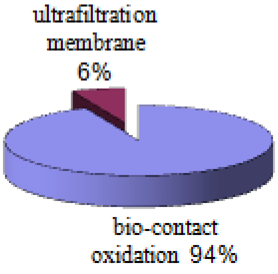

Fig 6: Ammonia nitrogen removal proportions of biological contact oxidation and membrane separation

V. PROJECT-BENEFIT ANALYSES

5.1 Operating Costs

Total annual operating cost was 276,300 yuan, and the unit cost of this water treatment was 2.05 yuan/m3 (see TABLE III), which was lower, compared to conventional activated sludge for water reuse of 2.43/m3, and three stage biochemical process of 2.15 yuan/m3 [10].

TABLE III. Annual operating costs statistics

Serial number	Cost name	Amount (million)
1	Energy consumption costs, E1	9.24
2	Pharmacy fee, E2	0.35
3	Wages of welfare, E3	10.08
4	Basic fixed asset depreciation charges, E4	1.36
5	Equipment overhaul costs, E5	0.71
6	Intangible and deferred amortization charges, E6	2.00
7	Routine repair and maintenance fee, E7	0.30
8	Management fees, sales fees and other charges, E8	3.60
9	Annual operating costs, Ec	24.27
10	Total annual operating costs, Yc	27.63
Unit cost of wastewater treatment: 2.05 yuan/m3		

5.2 Environmental Benefits

The system each year may treat and reuse 135,100 tons of wastewater, representing an increase of the same amount of water. And every year, the CODcr, SS, and NH4+-N were reduced up to 38.10 tons, 25.80 tons, and 2.85 tons, respectively (TABLE IV). For river water quality improvement and raising the level of health of people, this project will play a positive role.

TABLE IV. Annual reduce of pollutant emissions

Item	Influent(mg/L)	Effluent(mg/L)	Annual pollutant reductions(t/a)
CODcr	332.1	≤50	≥38.10
SS	221	≤30	≥25.80
NH4+-N	26.12	≤5	≥2.85

VI. CONCLUSIONS

The biological contact oxidation-ultrafiltration membrane process combines the advantages of traditional wastewater treatment and membrane bioreactor (MBR), with stable and efficient removal of CODcr and ammonia nitrogen, besides, lower unit cost of wastewater treatment, and a significant reduction in CODcr, SS and NH4+-N and other pollutants emissions, reflecting the high economic and environmental benefits of the system.

(1) CODcr removal efficiency of the system was from 87.42% to 95.51%, with an average of 92.37%. For the removal of CODcr, regulation pool accounted for about 11%, and biological contact oxidation zone occupied 73%, while the membrane accounted for 16%.

(2) Ammonia nitrogen removal efficiency was from 80.44% to 94.32%, with an average of 89.40%. The nitrification in the bio-contact oxidation reactor played an important role in ammonia nitrogen removal, while the membrane separation zone accounted for only 6%.

(3) Total annual operating cost was 276,300 yuan, and unit cost of water treatment was 2.05 yuan/m3. The system each year may treat and reuse 135,100 tons of wastewater, representing an increase of the same amount of water. And every year, the CODcr, SS, and NH4+-N were reduced up to 38.10 tons, 25.80 tons, and 2.85 tons, respectively.

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