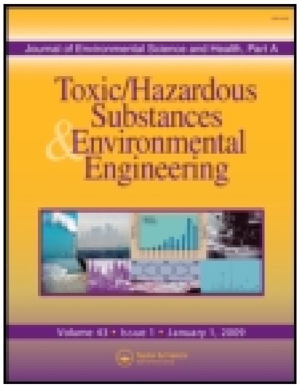

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WASTEWATER RECLAMATION AND REUSE

Recycling and Reuse of Wastewater from a New-Developed Community Using Sand Filtration, Ultrafiltration, and Ozonation

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ABSTRACT

In this study, the pilot apparatus combined with sand filtration, ozonation and ultrafiltration was established. Wastewater from the secondary treatment effluent in the new-developed community was taken as the sample for looking into the feasibility of domestic wastewater reuse and recycling. The test results by sand filtration, sand filtration/ultrafiltration, sand filtration/ozonation, and sand filtration/ultrafiltration/ozonation were compared for looking for appropriate treatment processes applied in the domestic wastewater reuse and recycling. Finally, cost analysis was carried out and sand filtration/ozonation process was suggested to be one of the best processes. The total cost is about 0.1–0.32 $USD per cubic meter of produced water by considering the capital and operation cost for five years in the small domestic wastewater treatment plant (50–750 CMD).

Key Words: Domestic wastewater; Ozonation; Recycling and reuse; Ultrafiltration.

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INTRODUCTION

As urbanization progresses, residential communities have been developed more rapidly. People demand much water than before to suit their needs. However, the shortage of water in Taiwan becomes severe especially in spring and summer since the change of climate. In order to meet the water requirements in the future, the government has formulated pragmatic water policies and water-saving programs for full implementation. At present the government has launched the mid-channel system, which is a water supply system focusing on the recovery of wastewater and recycling of water resources after appropriate treatment in newly developed communities, commercial buildings, resorts and schools, in order to meet the objectives of water resources recycling and saving.

Odor, color, and bacteria are very important issues for recycling the secondary effluent. Ozone with strong oxidative capability is excellent on the removal of odor, color, and bacteria. Paraskeva et al. (1997) used a 5 L capacity and 3 m high bubble column reactor, with G/L ratio of 0.05–0.2 (using counter current), operation dosage of 2.5–25 mg/L, in treating secondary wastewater discharge. He demonstrated 15–50% removal rate for BOD and 40–80% removal rate for color.[1] Sasai et al. (1997) used a 4 m high and 31.4 L capacity bubble column reactor to treat the secondary wastewater discharge of Kisshoin wastewater treatment plant, employing operation dosage 15 mg/L. About 13% of TOC and 33% of COD were degraded and color was reduced from 1.4 to 0.2°.[2] Tatsuki and Hirata (1997) also used a 4 m high bubble column reactor, applying a G/L ratio of 0.36, ozone dosage of 3–25 mg/L, exposure time of 5–25 min, for processing the water discharged from wastewater treatment plant (previously filtered and processed with active carbon). In the ozonation process with control of the dosage at 12–15 mg/L and exposure time at 10 min, the coliform bacillus content was well controlled under 50 CFU/100 mL.[3]

Membrane separation technologies are also becoming important in wastewater treatment, water reuse, and recycling. Ultrafiltration membrane allows to control separated materials such as particle, bacteria, and high molecular weight of organic with the selective small pore size. In this study, the pilot apparatus combined with sand filtration, ozonation, and ultrafiltration was established. Wastewater from the secondary treatment effluent in the new-developed community was taken as the sample for looking into the feasibility of domestic wastewater reuse and recycling. The test results by sand filtration, sand filtration/ultrafiltration, sand filtration/ozonation, and sand filtration/ultrafiltration/ozonation were compared for looking for appropriate treatment technologies applied in the domestic wastewater reuse and recycling.

METHODS

Experimental Setup

Wastewater samples were taken from the secondary effluent of wastewater treatment plant in the newly developed-residential communities. The pilot plant combined with one sand filter, ozonation reactor (shown in Figs. 1 and 2) and ultrafiltration unit. The sandfilter column is 1.2 m high and diameter 0.1 m with an operating filtration rate at 150 m/day. Two bubble columns, 1.5 m high and diameter 0.1 m, were used as the ozonation reactors. On the bottom of each reactor is a porous diffuser for releasing gas with aperture of 100 μm (0.1 cm). Raw water passed through the sand filter and then proceeded with the ozonation process. The in-off ozone gas flow and concentration were measured by an electro-magnetic controller and SEKI analyzer. Ozone residual was detected using the Indigo method (Bader and Hoigne, 1981).[4] Thus the consumed ozone was obtained by calculating the items above. The UF system shown in Fig. 3 included a spiral ultrafiltration membrane with automatic flush control. The influent flow rate was 10 L/min.

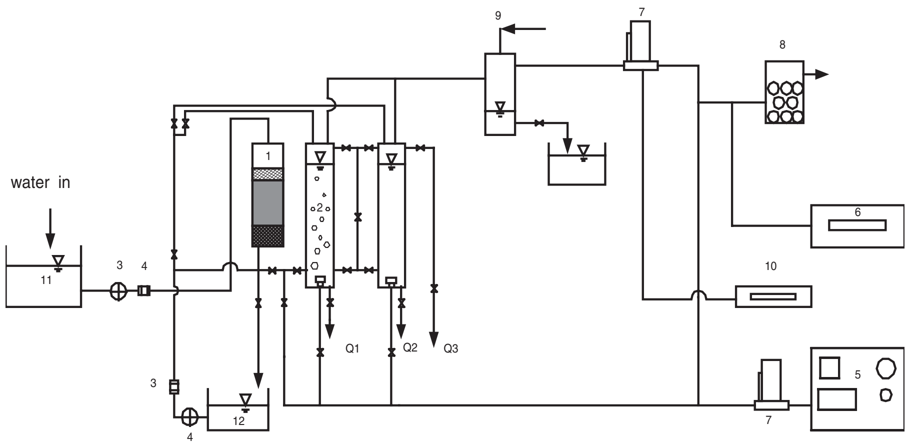

Figure 1. The schematic of sand filter and ozonation setup.

1. sand filter
2. ozone contactor
3. pumps
4..flow meter
5.ozone generator
6.ozone detector
7..flow controller
8.ozone destructor
9. foam destructor
10.flow indicator
11.storage tank
12.filter water tank

Q：sampling port

Figure 2. The apparatus of sand filter and ozonation setup.

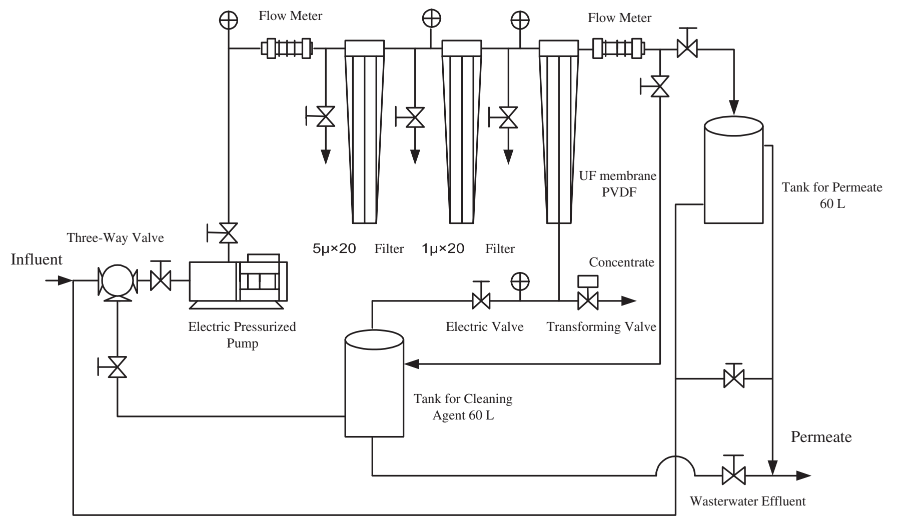

Figure 3. The apparatus of the ultrafiltration unit.

The MWCO was 50,000 dalton and recovery was 80% for the UF membrane operation.

RESULTS AND DISCUSSION

Comparison of Water Quality by Different Treatment Processes

Table 1 shows the results of comparison of water quality by different treatment processes. The values of BOD, color, turbidity, and e-coli in the raw wastewater were around 162 mg/L, 65 Pt-Co, 50NTU and 7.5×10^6 cfu/mL respectively. The secondary effluent water quality was under the discharge limits with 29.7 mg/L of BOD. However odor, color, and bacteria were still very obvious issues for recycling the secondary effluent. After sand filtration and NaOCl disinfection, the filtration rate and chemical dosage were 147 m/day and 5 mg/L, the e-coli was 1.0×10^5 cfu/mL. BOD and color were still 27.1 mg/L and 33.9 which were much higher than the suggested values. The treated water was yellow color with odor smell.

Sand filtration conjoined a spiral ultrafiltration unit with automatic flush control was conducted as a substitute process. The removal rate for coliform bacillus, BOD, turbidity and color reached 99.96, 77.5, 99, and 56.4% respectively. After sand filter plus UF treatment, coliform bacillus content can be controlled under 5 cfu/mL, BOD under 5.4 mg/L, turbidity under 0.24 NTU, and color within 12.5–17. However, the treated water is still light-yellow and a little odor smell. Figures 4 and 5 show the variation of production flow and transmembrane pressure with the automatic flush control, processing filtration for 10 min with one minute flush interval, the transmembrane pressure can be controlled between 30 and 45 psi and fouling can be reduced for a long period of operation.

Table 1. Comparison of water quality between the raw wastewater, secondary effluent and treated water by different processes.

	pH	BOD (mg/L)	Color (Pt-Co)	Turbidity (NTU)	E-coli (cfu/mL)
Raw wastewater	7.3–7.8	130–195 (162)	50–80 (65)	40–60 (50)	6×10^6–9×10^6 (7.5×10^6)
Secondary treated water	7.5–7.8	27–32.3 (29.7)	32.6–41 (36.4)	17–29 (22.2)	2.2×10^3–5×10^6 (1.25×10^6)
Sand filter/NaOCl treated water	7.5–7.9	24–29.1 (27.1)	28.1–38 (33.9)	2.6–4.5 (3.5)	8.9×10^2–3×10^5 (1.0×10^5)
Sand filter/ultrafiltration treated water	7.7–7.8	3.5–7.3 (5.4)	12.5–17 (14.8)	0–0.5 (0.24)	0–10 (5)
Sand filter/ozonation treated water	7–7.3	10.2–11.4 (10.8)	10.3–13.7 (12)	2.0–2.5 (2.2)	0–4 (2)
Sand filter/ultrafiltration/ ozonation treated water	6.5–7.4	2–4.4 (3.2)	1–3.8 (2.4)	0–0.6 (0.3)	n.d.

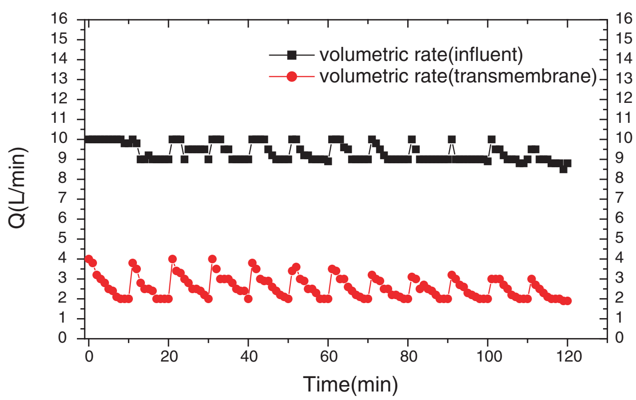

Figure 4. Variation of production flow rate with automatic flush in UF system.

Wastewater from the secondary effluent was conducted to flow into the bubble column reactor for ozone reaction. Figures 6–8 indicate that the removal rates of BOD, color, and coliform bacillus tend to increase as applied ozone dosage steps up. When the operation G/L rate is controlled at 0.4 and applied ozone dosage is over 12 mg/L, BOD removal can reach 9.8 mg/L approx. Color removal also increases as dosage goes up. When the dosage reaches 16 mg/L, processed water is almost colorless, which indicates that high oxidation effect of ozone is very effective for color removal. As for coliform bacillus content, it can be controlled under 10 CFU/mL when the applied ozone dosage is over 8 mg/L, and so is disinfection effect.

Using sand filtration and ozone treatment, the G/L ratio within ozone column reactor can be maintained within 0.2–0.4 and the ozone dosage within 8–12 mg/L. The removal rate for coliform bacillus, BOD, turbidity, and color is 99.96, 62.2, 89.6,

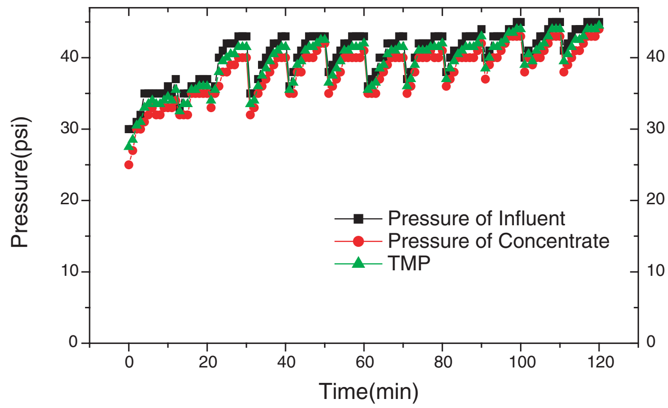

Figure 5. Variation of pressure with automatic flush in the UF system. (1) $Q_g = 0.2$ L/min, $Q_L = 1.0$ L/min (G/L = 0.2); (2) $Q_g = 0.4$ L/min, $Q_L = 1.0$ L/min (G/L = 0.4).

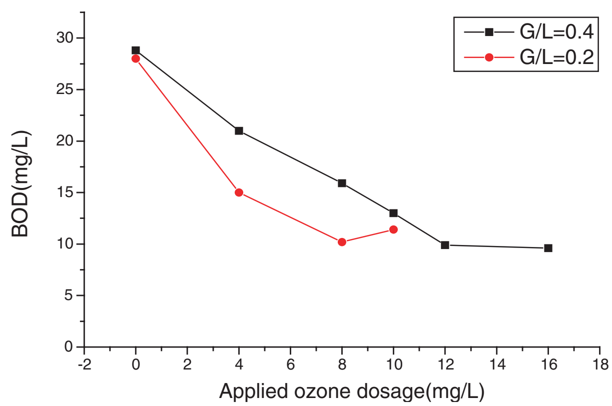

Figure 6. BOD degradation in the sandfilter/ozonation process. $Q_g = 0.2$ L/min, $Q_L = 1.0$ L/min (G/L = 0.2); $Q_g = 0.4$ L/min, $Q_L = 1.0$ L/min (G/L = 0.4).

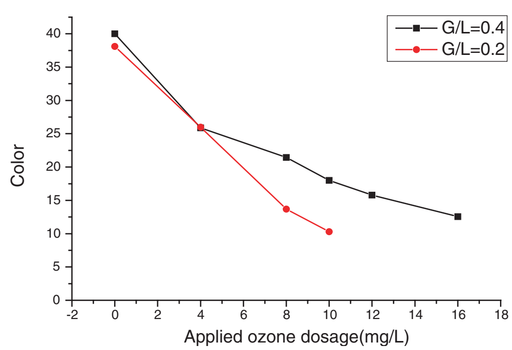

Figure 7. Color degradation in the sandfilter/ozonation process. $Q_g = 0.2$ L/min, $Q_L = 1.0$ L/min (G/L = 0.2); $Q_g = 0.4$ L/min, $Q_L = 1.0$ L/min (G/L = 0.4).

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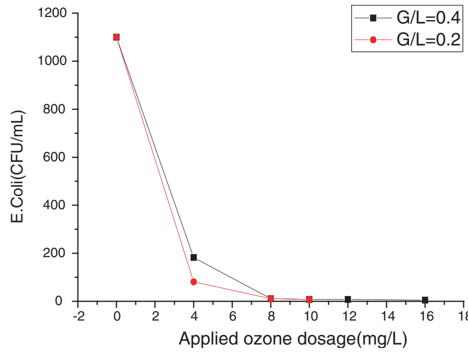

Figure 8. E-coli disinfection in the sandfilter/ozonation process.

and 67% respectively. Ozone with strong oxidative capability is excellent on the removal of odor, color, and bacteria. After ozonation treatment, coliform bacillus content can be controlled under 10 CFU/mL, BOD under 10 mg/L, turbidity within 2.0–2.5 NTU, and color within 10.3–13.7°. The properties of water is almost colorless and odorless, capable of reaching the reference standard for recycled water.

Furthermore, sand filtration/ultrafiltration/ozonation process was proceeded. Under the same operation condition, coliform bacillus content was not detected, BOD was under 3.5 mg/L, turbidity was under 0.5 NTU, and color within 1–2°. The properties of treated water is excellent and colorless and odorless, capable of reaching the reference standard for recycled water. Table 2 shows the overall comparison between the water quality after treated by different processes and recycled water quality requirements. It indicates that sand filter/ozonation and sand filter/UF/ozonation processes can produce more qualified water on BOD, odor, outlook, and e-coli items for reuse and recycling.

Economic Analysis

Finally, Table 3 indicates the preliminary cost evaluation calculated for the sand filtration/ozonation and sand filter/UF/ozonation processes. The overall cost consists in principal of the capital and operatiing cost. Table 3 shows the costs in terms of $USD per cubic meter of produced water with different treated capacity on the basis of the following:

(1) to assume that the equipment can be used for 5 years
(2) to assume that civil engineering cost is ignored
(3) the operating cost includes the electrical, chemical, and maintenance fee.

Considering the economic effect, sand filter/ozonation is suggested to be one of the appropriate processes for secondary effluent reuse and recycling in the domestic wastewater treatment plant. The total cost is about 0.1–0.32 $USD per cubic meter

Table 2. Comparison of the treated water quality by different processes with the suggestive requirements for recycling and reuse in Taiwan.

Items	For sprinkling	For landscape	For toilet flush	Secondary treated water	Sand filter/ NaOCl treated water	Sand filter/ ultrafiltration treated water	Sand filter/ ozonation treated water	Sand filter/ ultrafiltration/ ozonation treated water
E. coli (CFU/mL)	Not detected	Not detected	10	1.25×10^6	1.0×10^5	5	2	n.d.
BOD (mg/L)	10	10	10	< 33	< 30	< 6	< 10	< 3.2
pH	6.0–8.5	6.0–8.5	6.0–8.5	7.5–7.8	7.5–7.9	7.7–7.8	7–7.3	6.5–7.4
Turbidity (NTU)	10	5	—	< 29	< 4.5	< 0.5	< 2.5	< 0.6
Odor	Not Uncomfortable	Not Uncomfortable	Not Uncomfortable	Odor smell	Odor smell	Light smell	Odorless	Odorless
Outlook	Not Uncomfortable	Not Uncomfortable	Not Uncomfortable	Yellow	Yellow	Light yellow	Colorless	Colorless
Color (Pt-Co)	40	40	40	< 37	< 34	< 15	< 12	< 3

Table 3. The preliminary cost evaluation for the sand filtration/ozonation and sand filter/UF/ozonation processes.

Treated capacity (m3/day)	Sand filter/ozonation ($USD/m3)	Sand filter/UF/ozonation ($USD/m3)
50	0.32	1.05
100	0.25	0.91
200	0.20	0.74
300	0.17	0.69
500	0.13	0.59
750	0.10	0.53

of produced water by considering the capital and operatiing costs for five years in the small domestic wastewater treatment plant (50–750 CMD).

CONCLUSIONS

Sand filter/ozonation is suggested to be one of the best processes for secondary effluent reuse and recycling in the domestic wastewater treatment plant. The removal rate for coliform bacillus, BOD, turbidity, and color is 99.96, 62.2, 89.6, and 67% respectively. After ozonation treatment, coliform bacillus content can be controlled under 10 CFU/mL, BOD under 10 mg/L, turbidity within 2.0–2.5 (NTU), and color within 10.3–13.7°. The quality of recycled water is almost colorless and odorless, capable of reaching the reference standard for recycled water. The total cost is about 0.1–0.32 $USD per cubic meter of produced water by considering the capital and operation cost for five years in the small domestic wastewater treatment plant (50–750 CMD).

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