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Improvement of tap water quality for domestic use by membrane process

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ABSTRACT

Nowadays, clean water supply demand is increasing day by day in Ho Chi Minh city due to the rapid increasing in population. In addition, the tap water quality did not comply with the drinking water quality standard. In this study, average values of pH, hardness, residual chlorine, NH_4^+-N, NO_3^--N and total Fe were 7.2±0.5, 75±13 mgCaCO₃/L, 0.33±0.12 mg/L, 0.28±0.15 mg/L, 0.025±0.001 mg/L, and 0.06±0.02 mg/L, respectively. In order to improve the water quality, low pressure reverse osmosis membrane system was proposed to polish quality of tap water. The results showed that the removal efficiency of NO_3^--N, NH_4^+-N, total Fe, hardness, and residue chlorine was 41±17.6%, 18±17%, 47±26%, 39±6%, and 94±7%, respectively. Thus, the low-pressure reverse osmosis membrane could achieve effective improvement of water supply quality for domestic use and satisfy the demand of drinking water in Ho Chi Minh city.

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1 INTRODUCTION

Throughout the world, water scarcity is being threatened matter to human activity in the present or future, and as a consequence, a definite trend to develop alternative water resources such as desalination can be observed (Bartram *et al*., 2014). On the other hand, drinking water is essential to life, yet it can be a source of exposure to pathogens, including bacteria, viruses and protozoa; drinking water is a major contributor to human exposure. The provision of safe drinking water to the majority of the world's population is one of the great public health achievements of recent centuries. People in developing countries have to face substantial health problem due to lack of access to adequately treated water (Yang *et al*., 2013). But while the human is fighting to maintain and improve one of the world's best health care systems, they have ignored new, important preventative action to keep people healthy, instead of focusing on treating illness after it sets in (Jacangelo *et al*., 1997; Gleick, 1998). Membrane processes are widely used as a means of treating the surface water, well water and even wastewater (Bodzek *et al*., 2011).

In the treatment of water for drinking purposes, the choice of the suitable membrane process depends on the size of removed contaminants and admixture from the water. Significant improvements in technology and design of reverse osmosis (RO) membrane as the availability of alternative energy sources, the possibility of pretreatment and applied materials have caused the process to become environmentally-friendly source of fresh water in many regions of the world, particularly in those where their sources are limited (Bick *et al*., 2001). In particular, seawater desalination by RO has been the main source of drinking water supply in many regions in the world. RO membranes used in water desalination are capable of producing good water quality by removing salts and contaminant for sea water with lower cost compared to other desalination process (Sassi *et al*., 2010). Depending on the water supply, the appropriate treatment is applied in order to meet legislation quality criteria.

In this study, water quality parameters, i.e. hardness, chloride, ammonia, nitrate and iron in the feed and treated water were investigated during operation to identify the influence of RO application to improve the quality of tap water.

2 MATERIALS AND METHODS

2.1 Experimental setup

The experimental system of RO membrane was located in the laboratory of Ho Chi Minh University of Technology (HCMUT), Vietnam. Tap water used for this research was distributed by Saigon water supply company. Firstly, tap water entered the system by pressure created by water supply distribution and passed pre-treatment stage including basic filtration systems: microfiltration membrane, granular active carbon filter cartridge and carbon block filter cartridge. The contaminants with big size of 5 µm as suspended solids were removed by microfiltration membrane, and organic compounds were probably absorbed by activated carbon. Then, water was pumped over RO membrane module. Particularly, RO is operated with pressure filtration to remove well multivalent, organic compounds, bacteria, viruses, natural organic matters, etc. (Table 1).

Table 1: Specification of RO membrane

Items	Characterizations
Membrane	DOW, FILMTEC™ TW30-1812-50
Material	Polyamide composite
Pore size	0.001 µm
Membrane size	D x L = 4.5 cm x 25.4 cm
Operational pressure	<21 bar

2.2 System set-up and operating conditions

RO membrane was purchased from DOW Filmtec (FILMTEC™ TW 30-1812-50). This membrane was made from polyamide composite material with a pore size of 0.001 µm. Operating pressure has the maximum value of 21 bar as low-pressure RO. The system was operated in batch for 3-6 hours per day and 3-4 days per week. The total operating time for all experiments was 800 hours with the total amount of used tap water of 14,000 L. Trans-membrane pressure was 5.28±0.48 bar and 5.09±0.52 bar recorded before and after sampling, respectively. The temperature was ranging from 28 to 30°C during operation. Water sampling was conducted at different points including influent, RO-concentrate and RO-permeate (Figure 1) after 30-60 minutes of starting operation.

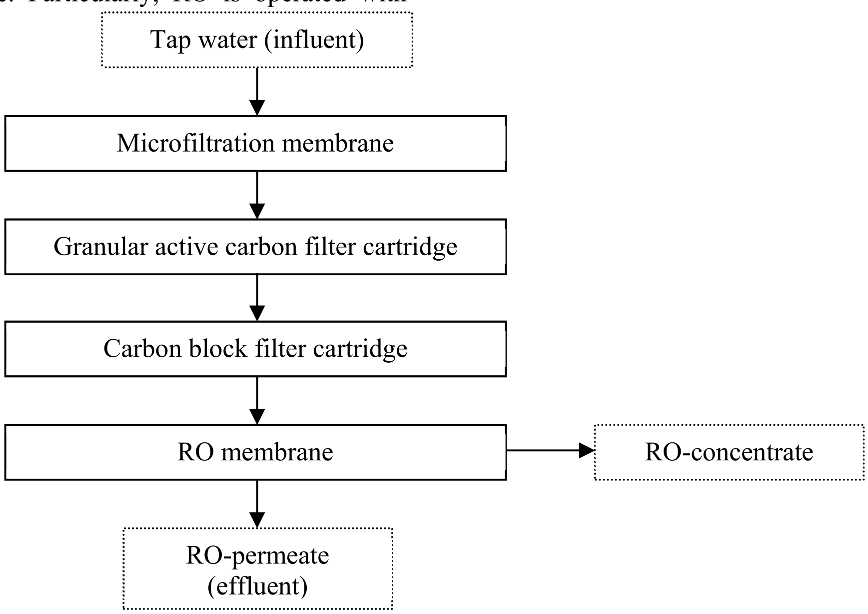

Fig. 1: Diagram of RO membrane system for improving drinking water quality

2.3 Analytical methods

Parameters were determined under standard methods (APHA, 1998). Parameters of pH, hardness, residual chlorine, NH_4^+-N, NO_3^--N, and total Fe were 7.2±0.5, 75±13 mgCaCO$_3$/L, 0.33±0.12 mg/L, 0.28±0.15 mg/L, 0.025±0.001 mg/L, and 0.06±0.02 mg/L, respectively. In order to evaluate the efficiency of the treatment system, samples were collected at 3 points for specific kind of water on a system such as influent (tap water), effluent (RO-permeate) and RO-concentrate. The results were compared and evaluated based on Vietnam National standard QCVN 01:2009/BYT (Ministry of Health, 2009) and EU's drinking water standards 1998.

3 RESULTS AND DISCUSSIONS

3.1 pH variation

There is no significant difference in terms of pH values before and after treatment. In details, pH of influent, RO-concentrate, and RO-permeate were 7.2 ± 0.5, 7.3 ± 0.5, and 7.2 ± 0.6, respectively. Since pH of RO permeate was 7.2 ± 0.6, RO process did not function to change pH values of water supply and already satisfied the standards. However, pH of permeate flow was higher than that of influent in some days due to the change of hardness relating to bicarbonate. If pH is lower than 7, human health will not be affected especially on dental health, digestive enzymes. However, in the case of pH increases up to 8.5, the presence of natural organic matters with Chlorine disinfection forms trihalomethane causing cancer.

3.2 Hardness removal

Average hardness values in influent, RO-permeate and RO-concentrate were 75±13 $mgCaCO_3/L$; 47±11 $mgCaCO_3/L$ and 97±14 $mgCaCO_3/L$, respectively (Figure 2). All values above met QCVN 01:2009/BYT (Ministry of Health, 2009) which is 300 $mgCaCO_3/L$. The removal efficiency of the hardness of pre-treatment system was very low of 0-10% compared to the overall performance of RO system of 29-54%. These results are considered lower than those obtained by Pervovet *et al*. (2000) as 75-85% at the stage of 12 m^3 to 14 m^3.

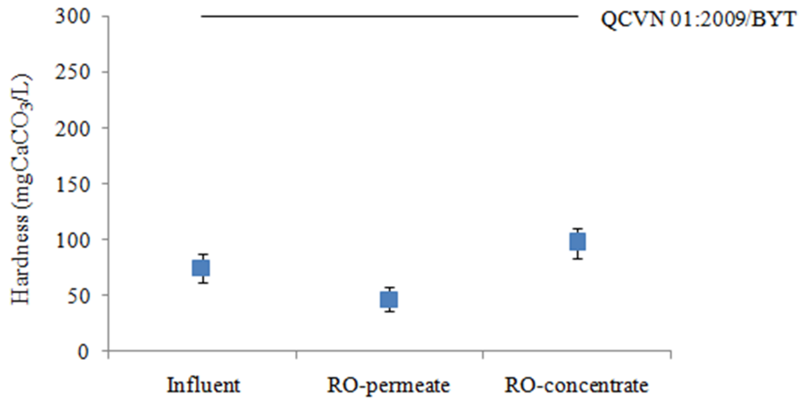

Fig. 2: Concentration of hardness of tap water (influent), RO-permeate and RO-concentrate

3.3 Residue chlorine removal

The chlorine concentration in influent was varying of 0.33±0.12 mg/L. However, in some cases, chlorine concentration exceeded the standard of QCVN 01:2009/BYT of Ministry of Health (residue chlorine of 0.3-0.5 mg/L) so that a water treatment system was required to improve the quality. The chlorine of permeate and RO-concentrate were 0.02±0.02 mg/L and 0.04±0.036 mg/L, respectively. The chlorine rejection was as high as 80-100%.

3.4 Ammonia and nitrate nitrogen removal

Ammonia in tap water creates the high demands of oxygen consumption and reduces the efficiency of disinfection stage in water treatment process and storage due to the conversion of ammonia to nitrate and nitrite which seriously effect human health. Ammonia nitrogen concentration in influent, RO-concentrate and RO-permeate was 0.28±0.15 mg/L, 0.27±0.12 mg/L and 0.24±0.08 mg/L, respectively. This shows that the ammonia is not able to be removed through the RO membrane. Figure 3 indicates that there was a large variation of ammonia nitrogen in the influent which exceeded both standards of EU and the nation. For instance, with EU standard for drinking water, ammonia nitrogen is given at 0.5 mg/L thus treated water or raw water could comply with the standard limit of ammonia nitrogen.

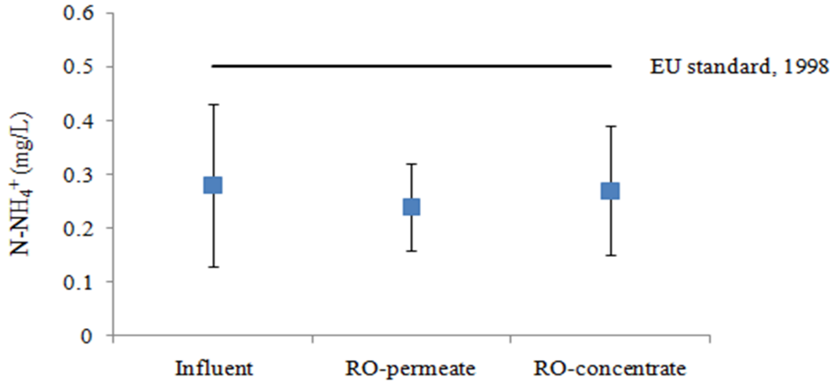

Fig. 3: Concentration of ammonia nitrogen in tap water (influent), RO-permeate and RO-concentrate

Average values of nitrate nitrogen for all samples during the operation were lower than Ministry of Health's QCVN 01:2009/BYT and EU's drinking water standards 1998. The concentrations of nitrate nitrogen of both permeate and influent were always lower than national standard limits (QCVN 01:2009/BYT) and EU's drinking water standards (50 mg/L).

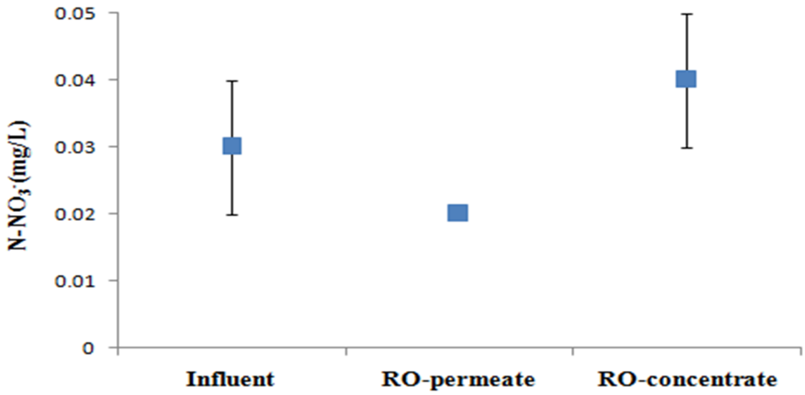

Fig. 4: Concentration of N-NO$_3^-$ in tap water (influent), RO-permeate and RO-concentrate

3.5 Iron removal

The total iron in influent was determined of 0.06±0.02 mg/L. Although these results complied with the standard, total iron concentration has to be removed as much as possible so that RO process was applied. The concentration of total iron in RO-permeate was 0.03±0.02 mg/L which was lower than QCVN 01:2009/BYT (0.3 mg/L) and EU's drinking water standards 1998 (0.2 mg/L) approximately 6 times and 4 times, respectively.

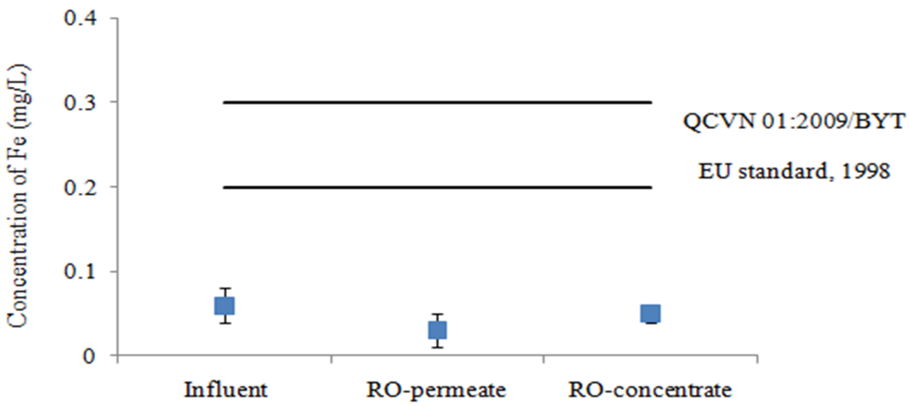

Fig. 5: Concentration of iron in tap water (influent), RO-permeate and RO-concentrate

4 CONCLUSIONS

In this study, RO membrane system was applied as an approach to improve the tap water quality. By analyzing crucial parameters such as pH, hardness, residual chlorine, ammonia nitrogen, nitrate nitrogen and total iron, the overall treatment efficiency was evaluated. It reveals that the simple low-pressure RO membrane system could slightly improve the city tap water quality (in terms of basic water parameters) for the drinkable purposes. However, it is important to conduct further study to evaluate the removal of micro pollutants from tap water by the RO process. The micro pollutants are often appeared as trace to very low concentration; however, they are harmful to human health.

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