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APPLICATION OF MICROFILTRATION AND ULTRAFILTRATION FOR REUSING TREATED WASTEWATER; AS A SOLUTION TO EASE IRAN'S WATER SHORTAGE PROBLEMS

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ABSTRACT

Water shortage is a big problem in the Middle East. This paper investigates the possibility of reusing municipal wastewater by membrane filtration for non-potable consumption. The wastewater used for tests in this study was secondary effluent discharged from the secondary sedimentation pond of Ekbatan wastewater treatment plant in Tehran. These tests on reusing wastewater involved four main processes. Results showed that the best process was that ozone injection before MF and UF with COD removal efficiency of approximately 78 percent. In this case, removal efficiency of turbidity and TSS were 100 percent; additionally, traces of total and fecal Coliforms were completely removed. In the membrane processes, removal efficiency of TKN was about 40 percent. The removal efficiency of TP in all processes was about 7 percent, while it increased to 14 percent in the hybrid treatment. It can be concluded that all of further purification processes failed to achieve total phosphorus (TP) standards and thus in order to eliminate TP and reach allowable level, further researches are needed.

Keywords: wastewater reuse; microfiltration and ultrafiltration; membrane; COD; total and fecal coliforms.

Academic Discipline And Sub-Disciplines

Environmental Engineering, Chemical engineering.

SUBJECT CLASSIFICATION

Water and wastewater treatment, Membrane technology, Microfiltration , Ultrafiltration.

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1. INTRODUCTION

Water shortage is a problem in the Middle East. Furthermore, Iran also suffers from a lack of water resources. In the southern regions, potable water is consumed with a TDS of between 4000 and 5000 ppm. Even this low quality water is not enough to supply the population's daily consumptions. In addition, a high volume of water is consumed by various industries [1].

Reusing treated municipal effluent for non-potable purposes is therefore considered essential to supply existing demands and to limit the use of Water Resources and protect the remaining water sources from becoming contaminated [2]. Reusing water should be considered as part of a more integrated water resource management plan; also, thorough possibility studies should be conducted. Moreover, many different aspects have to be detailed (such as geological, technical, economic, environmental and sociological). For this purpose, it must be added that water quality, as well as risk issues should be counted [3]. Most existing wastewater treatment plants can be improved to meet new wastewater discharge requirements. It is often technically and economically practicable to re-purify and/or desalinate effluent in order to provide alternative or new water sources. Tertiary effluent is usually of adequate quality to use for irrigation and industrial cooling applications [4].

In recent decades, membrane filtration (MF) has developed as a novel technology in wastewater treatment. It is probably that application of membrane filtration to reuse municipal wastewater effluent will constantly increase in according to tightening discharge regulations and other restrictions [5]. Membrane filtration, in comparison with traditional treatment processes has benefits such as increasing water quality, saving space, reducing chemical dosages, reducing sludge production and less maintenance requirements [6-7].

MF and UF are observed as liquid phase, pressure-driven or vacuum-driven membrane processes that use microporous and high-flux membranes to physically remove all colloidal and suspended solids. MF membranes (with pore size between 0.1 to 0.2 microns) and UF membranes (with pore size between 0.02 to 0.1 microns) serve as effective barriers against passing much smaller particles and they can steadily produce filtrate with a turbidity of less than 0.5 NTU. The flow pattern through the membrane and backwash process is also important, For both MF and UF. MF and UF also provide an effectual barrier to most human pathogens present in secondary effluent, including bacteria, protozoan cysts and in a lower degree, viruses [8].

The effluent water from activated sludge processing still includes dissolved species and particulate substances. It's not possible to remove dissolved components by filtration, even if the membrane is coupled with coagulation–flocculation process. The residual dissolved organic matter of treated wastewater can be effectively removed by utilization of adsorption, ozone injection or high-pressure membranes. Therefore, combinations of MF membranes with any other physical and chemical processes as a pre treatment can lead to improve the quality of wastewater treatment and reduce fouling of the membrane [9].

The safety of operation in water reuse systems therefore depends on wastewater disinfection, which is the most widely used treatment for public health protection. Requirements for wastewater reuse are determined by regionally specific standards and recommendations, and there is some controversy with consider to the quality targets for effluent. However, all standards and guidelines are based principally on biological quality considerations. These standards are becoming increasingly strict in order to avoid hazards to public health and the environment [4].

As a result of increasing public acceptance, health protection, and comprehensive regulatory guidance; non-potable water reuse applications have been widely practiced. However, the non-potable reuse programs still face institutional and legal issues inherent in reclaimed water services. Furthermore, due to these legal and financial constraints, it is important to increase the economic benefits and financial performance of non-potable reuse projects [10].

2. METHODS

2.1. Source water

The pilot plant used in this research is located in the Ekbatan wastewater treatment plant in tehran. This facility treats municipal wastewater using an A2O process for removing phosphorus and nitrogen. An A2O process removes biological phosphorus along with simultaneous nitrification denitrification. In the process, ammonia is transformed into nitrite and then nitrate (nitrification) in the aerobic tank, and the return supernatant in the aerobic tank is returned to the anoxic tank to proceed with denitrification. Then phosphate is released in the anaerobic tank, and then the excess is taken up in the following aerobic tank. Thus, phosphorus and nitrogen removal can be achieved simultaneously in the A2O process [11]. Source water for the current research was obtained immediately after secondary sedimentation pond(before chlorination). Table 1 presents source water characteristics measured during the operation of the pilot plant.

Table 1. Ekbatan treated wastewater characteristics

Parameter	Feed water concentration
Hp	6-8
DOC (mg/l)	23-43
SST (mg/l)	8-10
ytidibruT (FTU)	12-14
PT (mg/l)	2.35-2.54
NKT (mg/l)	1.08-1.14
atoTl Coliforms (MPN/100ml)	110-170
Fecal Coliforms (MPN/100ml)	15-43

The effluent exiting from the wastewater treatment plant has been used to irrigate the green space of Ekbatan Complex, a planned town built in western part of Tehran, Iran. Although the quality of effluent as indicated in Table 1 fulfils the existing criteria in Iran to reuse in agriculture, it has been not succeeded enough in following EPA guidelines for irrigating urban green areas. The present study attempted to reach the effluent quality to the EPA guidelines level using membrane processes so that the recycled water can be used in irrigating green spaces or other similar applications with higher level of certainty. Furthermore, the microbial quality standards tried to be attained without the need for chlorine injection so that the costs and risks of chlorine application particularly producing harmful byproducts can be avoided.

2.2. Membrane system operation

The pilot plant worked 6 hours/day and was feed with the secondary sedimentation effluent. A scheme of the microfiltration and ultrafiltration membranes pilot plant configuration is shown in Figure 1.

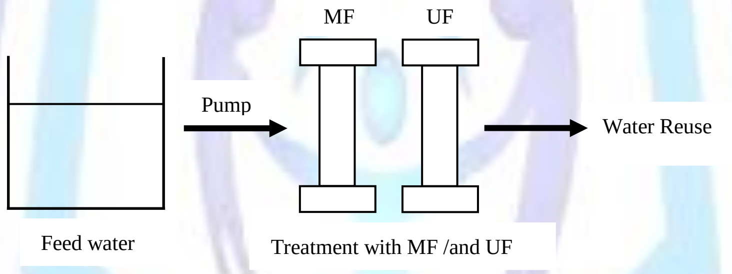

Fig 1: A scheme of the microfiltration and ultrafiltration membranes pilot plant

From the feed tank, a pump was used to distribute the feed into the membrane system. MF and UF that are used in this study are spiral and hollow fiber respectively. MF and UF are of the 10-inch module with polypropylene fibers. MF with pore sizes of 1 µm were placed before the UF membrane with a porosity of 0.02 µm in order to prevent fouling.The feed water passed through the lumen of the fibers and then permeated through the pores to the outside of the fibers. The production period was 40 minutes. Then, a backwash period took the next 2 minutes. For the backwash period, the permeate was mixed with sodium hypochlorite in order to membrane disinfection and reduction fouling.

2.3. Pretreatments

Coagulation–flocculation experiments were performed in a conventional jar-test apparatus, equipped with six beakers of 1 L volume at room temperature. The experimental procedures consisted of the following steps: rapid mixing (30s), low mixing (10 min) and settling (20 min). The best dose of coagulant was 10 mg/lit aluminum sulfate and 1 mg/lit polyelectrolyte as coagulant aid. In other pretreatment methods, ozonation is conducted to improve the removal of soluble matters which cannot be easily removed using MF membranes. Ozone gas was generated using an ozone generator (Model 07EGS48800-A, china) whit 1 mg/l dosage. The ozone injection were examined in order to reduce the fouling potential of MF membranes and to enhance the water quality.

The expriments contained four main processes as follows, each process is repeated 10 times:

(1) Passing wastewater through MF and using ultra violet radiation for disinfection,

(2) Adding coagulation and coagulation aid then and then passing through MF and UV radiation,

(3) Sequential use of MF and UF without any pretreatment,

(4) Ozone injection into the wastewater before it was passed through MF and UF.

2.4. method analysis

For each wastewater sample allocated for the present study and each effluent of filtration system , a part analysis such indices as total suspended solids (TSS), pH, turbidity, chemical oxygen demand (COD), total kjeldahl nitrogen (TKN), total phosphorus (TP), total and fecal Coliforms were measured. Turbidity was measured by Hach turbidimeter model 2100N and total Coliforms analysis followed the method of APHA 9222 B. All of these analytical concentrations such as COD, TSS, TKN and TP were measured according to Standard Methods for Examination of Water and Wastewater (19Ed).

3. Results and Discussions

Supplementary purification processes, have no significant impact on output pH, and pH values in all processes have remained within the allowed range of 5.8 to 8.5 in order to be reused in all EPA standard listed applications.

Test results indicate that all processes are capable to completely eliminate turbidity and input TSS, except the coagulant addition that causes increased particulate material and thus reduced turbidity and TSS removal efficiency. Turbidity and TSS removal efficiency of 100% was obtained in all processes and only in the process of adding coagulant turbidity and TSS removal efficiencies of 69% and 75% were obtained, respectively.

The results of the use of membrane filters for the removal of turbidity in this research are consistent with that of Durham [10] and Kim [12], with 100% efficiency of turbidity removal by membrane filters. Moreover, the results of TSS removal obtained in this research are consistent with that of Durham with 100% effluent TSS removal efficiency by membrane filters.

MF and UF membrane filters are more effective for nitrogen removal than phosphorus removal. TKN removal efficiency was about 40% in all membrane processes and the final TKN concentration was in the range of 0.4 to 0.6. While TP removal efficiency of processes was about 7% that is increased to 14 percent in the hybrid treatment (Adding coagulation and coagulation aid) because of trapping a part of it into the flocs formed. TP final concentration was ranging from 2.0 to 2.3.

TKN removal efficiency in the study is higher than that of 8% TN removal efficiency of Kim, who had used only the MF that can be due to probable differences in microfilter pore size and the use of MF after UF.

TP removal efficiency of this research work is consistent with that of Kim, with the 7% TP removal efficiency.

COD removal efficiency can be used as a criterion to select the most efficient process. Generally MF and UF are expected to be able to remove particulate COD. Tables 2 show evaluations for removal efficiency of COD. In the process (1), 40% of COD is removed by getting caught in the pores of the membrane filter that is higher than 23% COD removal efficiency in the study by Kim. In the process (2) the addition of coagulant increased COD removal efficiency by 9% than that of the process (1). In the study conducted by Phetrak [13], COD removal efficiency in the microfiltration process remained unchanged without and with coagulants and remained 70%, the higher the efficiency of Phetrak research with respect to this research was due to the smaller pore size of Phetrak microfilter and higher COD input. In the process (3) COD removal efficiency reached to 52 percent, compared with the amount by Tylla [14], that obtained 87.5 percent COD removal efficiency using ultra filtration, it can be due to the difference between the two studies MF and UF filters pore size.

Wang [15], in their research stated that ozonation as a pretreatment before membrane filtration reduces clogging of the membranes and higher COD removal. In this study, the COD removal efficiency in the process (4), namely, ozonation and then the passage from MF and UF was 78 percent that has increased compared to the consecutive use of MF and UF.

Table 2. Removal efficiency of COD

Repeat times	COD (mg/l)				
	Feed Water	(1)	(2)	(3)	(4)
1	27	16	16	14	6
2	41	24	22	17	9
3	34	20	16	16	8
4	23	14	13	10	6
5	25	15	13	13	5
6	43	26	23	20	8
7	32	19	15	15	9
8	37	22	18	18	7
9	29	17	14	14	5
10	35	20	19	16	8
Average Removal efficiency	-	40	48	53	78

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Total coliformss and fecal coliformss values are among important measure of reuse of wastewater for various purposes. Tables (3) and (4) show total coliformss and fecal coliformss input and output values and removal efficiencies for different processes. As observed, the presence of UF is a guarantee for total coliforms and fecal coliforms complete removal. In the process (2) compared with the process of (1) the addition of coagulant and coagulant aid increased total coliforms removal efficiency from 38 percent to 85 percent.

Phetrak, in a similar work could completely remove total coliforms and fecal coliforms using a 1.0 micron microfilter.

Table 3. Removal efficiency of Total Coliforms

Repeat times	Total Coliforms (MPN/100)				
	Feed Water	(1)	(2)	(3)	(4)
1	150	93	23	ND	ND
2	120	75	17	ND	ND
3	140	93	22	ND	ND
4	170	95	25	ND	ND
5	140	93	21	ND	ND
6	150	90	23	ND	ND
7	170	95	26	ND	ND
8	110	75	17	ND	ND
9	150	90	22	ND	ND
10	170	95	26	ND	ND
Average Removal efficiency	-	38	85	100	100

Table 4. Removal efficiency of Fecal Coliforms

Repeat times	Fecal Coliforms (MPN/100)				
	Feed Water	(1)	(2)	(3)	(4)
1	23	23	23	ND	ND
2	43	43	43	ND	ND
3	31	31	31	ND	ND
4	33	33	33	ND	ND
5	40	40	40	ND	ND
6	43	43	43	ND	ND
7	23	23	23	ND	ND
8	27	27	27	ND	ND
9	40	40	40	ND	ND
10	26	26	26	ND	ND
Average Removal efficiency	-	-	-	100	100

Residual chlorine was not detected in the samples since the samples were collected before chlorination unit. The important point is the complete removal of total coliforms and fecal coliforms using Ultrafiltration without any need to add chlorine disinfectant and concern for the formation of harmful compounds such as trihalomethanes.

Table 5 Comparison USEPA guidelines [16] for water reuse and quality parameters for feed water and result four processes to elaborate possibility reuse treated wastewater.

Table 5. Comparison USEPA guidelines for water reuse

	COD (mg/lit)	Turbidity (FTU)	Fecal coli/100 MPN	Residual chlorine (mg/lit)	T-N (mg/lit)	T-P (mg/lit)	pH
Guidelines (USEPA)	20	2	ND	1	10	1	5.8-8.5
feed water	41	22	17	ND	1.12	2.38	6-8
(1)	19	ND	ND	ND	0.50	2.32	6-7.5
(2)	17	16	16	ND	0.43	2.04	5.5-7
(3)	15	ND	ND	ND	0.51	2.32	6-7.5
(4)	7	ND	ND	ND	0.48	2.28	6-7.5

As it can be seen in Table 5, it can be concluded that none of treatment processes could meet the TP output standard and more research and test is needed to remove the TP and reach the allowed amount that can be considered in future studies. For other parameters, both processes (3) and (4) are consistent with EPA Guidelines for water reuse except for the TP value, and can be used with some considerations.

4. Conclusions

As the results of experiments performed in this study shows, the process of " Sequential use of MF and UF" and "ozone injection before MF and UF” are consistent with EPA Guidelines for water reuse except for the TP value, and can be used in a wide range of wastewater reuse applications, such as of agriculture, recreational impoundment and groundwater recharge supply with some considerations. To make selections for optimum application of water reuse attention should be given to the quality of water and the condition of wastewater plant location. Location of the plant determines that the best option would be to convey water reuse to the artificial lake at Cheetgar Park.

Reuse of wastewater to meet the problems of water shortage is inevitable given the scarcity of water resources in many parts of the country and increased the volume of municipal waste in the wake of increasing population. There has been limited research on the reuse of treated wastewater in Iran despite the importance of this issue in the management of water resources. This research can be a start point to work on improving the quality of effluent from the wastewater treatment to the effluent can be based on the standards of the world for applications that require lower quality water, while the operations become more economical. Continued research into the use of membranes in wastewater treatment to reduce membrane fouling and determine the optimal dose of ozone to obtain efficiency and optimal treatment is recommended in future studies.

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