Scientific Review – Engineering and Environmental Sciences (2020), 29 (3), 332–342
Sci. Rev. Eng. Env. Sci. (2020), 29 (3)
Przegląd Naukowy – Inżynieria i Kształtowanie Środowiska (2020), 29 (3), 332–342
Prz. Nauk. Inż. Kszt. Środ. (2020), 29 (3)
http://iks.pn.sggw.pl
DOI 10.22630/PNIKS.2020.29.3.28

Mohammed Fakhraldeen AHMED
Mosul University, College of Environmental Sciences and Technology

The performance assessment of reverse osmosis stations at Al-Mahalabea area

Key words: brackishwater, desalination, membrane technology, reverse osmosis, SAW, TOPSIS

Introduction

Reverse osmosis (RO) is a wide spread technique used to supply potable water from seawater and brackishwater. There are different types of membranes used in RO structure such as; micro porous, symmetric, non-porous symmetric, asymmetric and thin film composite (TFC). Most companies synthesis TFC membranes that have a lot of advantages including durability with long lifetime in spite of sensitivity to chlorine (Bouchareb et al., 2019). Membrane life is an important factor to determine the economic efficiency of RO systems (Metcalf & Eddy et al., 2007). Process of RO has simple design, easy operation, and able to remove organic and inorganic pollutants. Therefore, RO is more environmentally friendly option (Garud, Kore, Kore & Kulkarni, 2011; Al-Hotmani, Al-Obaidi, John, Patel & Mujtaba, 2020). The most disadvantages of RO include the requirement for high pressure and adding of chemicals against scaling and fouling.

A number of researchers have evaluated the performance of RO process based brackishwater desalination as follows.

Makki (2009) studied the performance of RO in Dura – Iraq power station. The study examined RO with TFC membrane constructed as spiral wound module, and concluded that TFC membrane has higher productivity and durability to chemicals with TDS removing percentage reached 96%.

El-Harrak et al. (2013) evaluated the performance of RO process for irrigation purpose in Dokkala – Morocco. The results showed that the performance of RO system decreases after few months. The study included illumination of chlorine and sodium bisulfate for the feed water.

Al-Bayati (2015) outlined the efficiency of five brackish water desalination plants for drinking purpose at Salahaldin province – Iraq. The research included examination of 17 samples of well water and more than 17 parameters for each sample were analysed. The research concluded that the permeate water were within the permissible standards and the TDS removal percentage reached 98.18%.

Abdel-Fatah, El-Gendi and Ashour (2016) studied a RO system which has flush cycle for the treatment of saline water in Cairo University – Egypt. The study showed that the resulted water has low concentration in TDS which equals to 100 ppm while the feed water concentration exceeds 10,000 ppm.

Al-Jlil (2017) studied the reduction of TDS concentrations from wastewater using Nano Filtration NF and RO in Saudi Arabia. The study found that RO removes mono valent ions such as Cl^- reaching rejection efficiency 94.4 %.

Haider (2017) evaluated the brackishwater at each component of RO system in Buraydah, Qussim – Saudi Arabia during the year 2016. The research used fuzzy AHP to extract the weights of five main variables and fuzzy weighted sum method to evaluate the average monthly performance. The results showed high performance of the system and meets drinking water limits.

Bouchareb et al. (2019) outlined the RO performance which have TFC membrane type (TW30-2540) for desalination brackish water at Alpine region in the north of Algeria. The results showed that this type of membrane has less cost and high rejection efficiency reaches 97% of salts.

The study aims to assess the performance of four RO stations at different sites within Al-Mahalabea area in Nineveh governorate – Iraq. Besides, a ranking of RO stations performance is conducted according to their rejection efficiency (at zero time of operation and after ten weeks of operation) by using the SAW and the TOPSIS techniques, and identifying the higher removal percentage parameters. The collected data of the feed water can be used as a feedback for groundwater quality database for Nineveh governorate.

Material and methods

The studied area

The studied area is located about 35 km south west of Mosul city. Its area is about 888 km^2. Table 1 illustrates the names of RO stations' sites. Also, the locations of the RO stations can be seen in Figure 1.

The components of used RO stations

The studied RO system is consisted of the following components; working pressure pump (4 bar), flow rate gage,

TABLE 1. Reverse osmosis stations within the studied area

RO station	Site name	Longitude	Latitude	Management
RO1	Ain Alwah,	420°37′08″	360°14′16″	specialized environmental crew
RO2	Misherfa Altaha	420°48′20″	360°05′15″	specialized environmental crew
RO3	Ghiziel	420°40′34″	360°02′39″	untrained labours
RO4	Misherfa	42°52′42″	36°11′57″	untrained labours

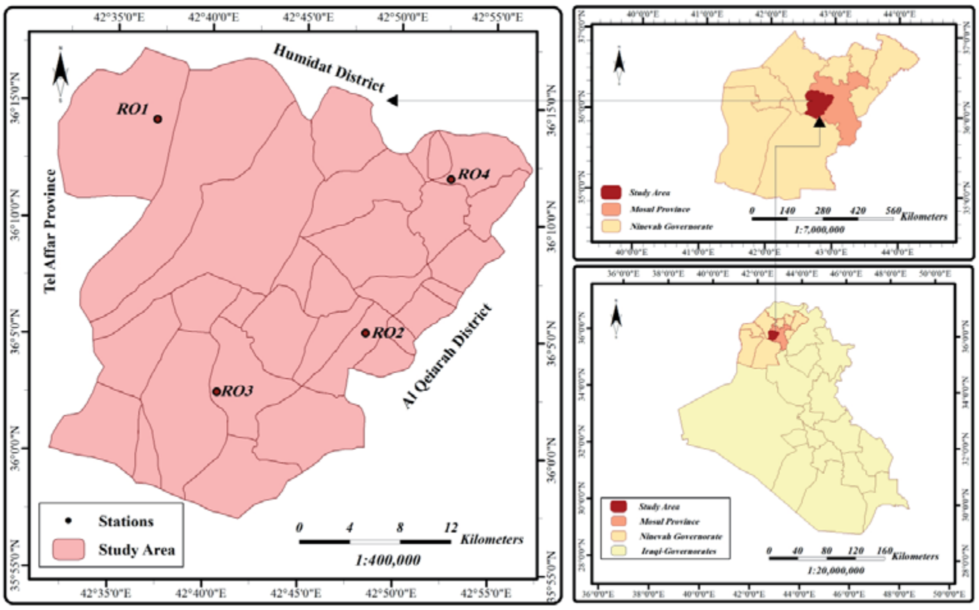

FIGURE 1. The studied area and locations of the operating RO stations

pH gage, TH gage, pH equalization device, in addition to chemical cleaning system. Feed water flow rate capacity is 18 $m^3 \cdot h^{-1}$.

Pretreatment system includes the following components; tanks of reclaimed water, sand filter, activated carbon filter, cartridge 5–10 µm. Permeate capacity is 10 $m^3 \cdot h^{-1}$. Model of RO is Trust CRO-8/12 and the membrane model is AG-8040, noting that all the stations have the same model. The membranes brand name is GE Desal (USA). The diameter and length of the membrane is 8 and 40 inches respectively. The post-treatment system includes the following units: UV unit, in-line storage tanks and ozone unit. Schematic diagram of the studied RO station and the units of the pre and post treatment of groundwater is explained in Figure 2.

Methodology

The studied parameters

Two groups of samples were taken from feed and permeate water and analysed into two periods: the first is at zero time of operation, while the second period occurred after 10 weeks of operation (this period was the recommended period used by the supplied company).

A number of parameters were laboratory analysed for each sample and then compared with local and international standards and examined according to standard methodology (APHA, 2005) in the laboratory of the college of the Environmental Sciences and Technology, Mosul University – Iraq, as in Table 2. The studied parameters are; TH, SO_4, TDS, TA, Mg, Ca, Cl, Na, pH, turbidity and NO_3.

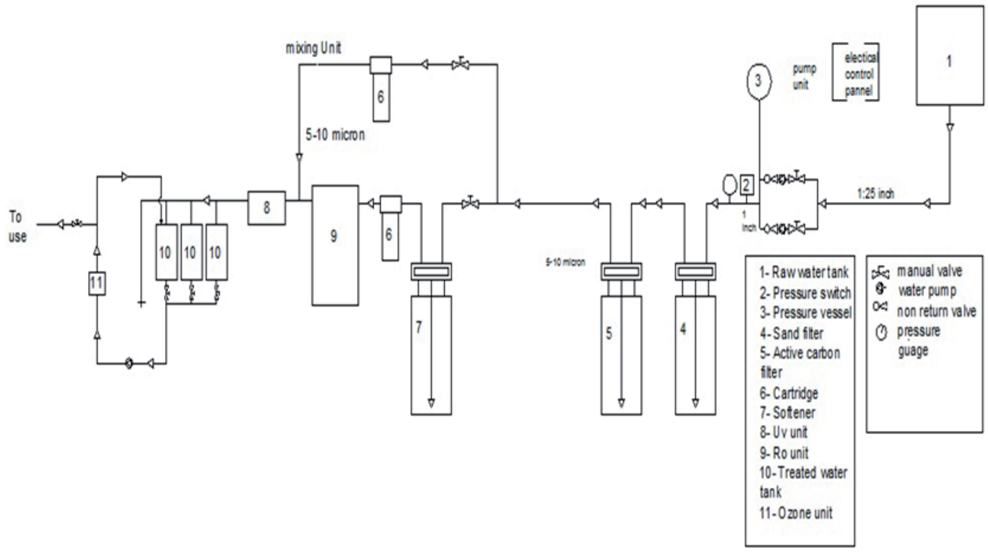

FIGURE 2. Schematic diagram of RO station and its components

TABLE 2. Local and international GWQ standards

No	Parameter	Unit	Environmental Protection Agency (2004)	World Health Organization (2003)	National standards (IHM, 2001)
1	TH	$mg \cdot l^{-1}$ as $CaCO_3$	500	100–500	100–500
2	SO_4	$mg \cdot l^{-1}$	400	–	–
3	TDS	$mg \cdot l^{-1}$	1 000	500–1 500	500–1 500
4	TA	$mg \cdot l^{-1}$ as $CaCO_3$	200	–	125–200
5	Mg	$mg \cdot l^{-1}$	150	30	50–150
6	Ca	$mg \cdot l^{-1}$	200	75	75–200
7	Cl	$mg \cdot l^{-1}$	600	–	200–250
8	Na	$mg \cdot l^{-1}$	200	20	200
9	pH	–	6.5–8.5	6.5-8.5	6.5–8.5
10	turbidity	NTU	5	5	5
11	NO_3	$mg \cdot l^{-1}$	10	10	50

Methods used to determine RO stations performance

Two methods are used to determine RO stations performance: the Simple Additive Weight (SAW) and the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS). As follows a summary of each method.

The SAW method is firstly used by (McDuffie & Haney, 1973). This method recaps the studied parameters values in one index. A relative weight (w_i) is given to each parameter depending on its importance. Sum of these relative weights must equal 1. The quality rating (q_i) is calculated by equation: $q_i = (C_i / S_i) \cdot 100$, where C_i refers to the concentration of a certain parameter, S_i is the depended values limits. Sub-index (S_{Ii}) of a parameter is calculated by multiplying the w_i by q_i. Index value is gained from summation of sub-indices which has five ranges: excellent 0–25, good 26–50, poor 51–75, very poor 76–100, and unsuitable > 101 (Afshari, Mojahed & Yusuff, 2010; Al-Ozeer & Ahmed, 2019).

The TOPSIS method is a mathematical method used in ranking the alternatives. It is a goal-based decision making technique for finding the alternative that is closest to the ideal solution (Behzadian, Otaghsara, Yazdani & Ignatius, 2012; Tahyudin, Rosyidi, Ahmar & Haviluddin, 2018). In this study, this method is used to rank the performance of four stations.

The main steps of the TOPSIS method can be summarized as follows (Tsaur, 2011):

Step 1: Input decision matrix as in Table 3, where $X_{i,j}$ represents the feature value, where: $i = 1, ..., M$ and $j = 1, …, 7$.

Step 2: Normalized a decision matrix, as in $R_{i,j} = \frac{x_{i,j}}{\sqrt{\sum_{i=1}^{n}\left[(x)_{1,1}\right]^{2}}}$.

Step 3: W_j (the weights), noting that, the values of the weights which are inserted in the two methods are the same, and these weights are determined according to the importance of each parameter.

Step 4: Construct the weighted normalized matrix ($V_{i,j}$) by multiplying each column by W_j.

Step 5: The highest value in the column V_j^+.

Step 6: The lowest value in the column V_j^-.

Step 7: Determined the S^+;

$$S^+ = \sqrt{\sum_{j=1}^{m}(V_{i,j} - v_j^+)^2}$$

Step 8: Determined the S;

$$S^- = \sqrt{\sum_{j=1}^{m}(V_{i,j} - v_j^-)^2}$$

Step 9: Calculate closeness to ideal solution (C_i); $C_i = S_i^- / (S_i^+ + S_i^-)$.

Step 10: Rank all sites according to the results of Step 9.

Results

Data of feed and permeate water in two periods and the calculated rejection R efficiency are tabulated in Tables 4, 5, 6 and 7. The rejection R is calculated by the formula $\%R = (1 - P / F) \cdot 100\%$, here F and P represent feed and permeate water concentrations.

TABLE 3. Matrix of parameters and alternatives used in the TOPSIS

W_j	0.15	0.12	0.12	0.1	0.1	0.1	0.1	0.06	0.05	0.05	0.05
Parameter	TDS	Mg	Ca	Cl	NO_3	SO_4	TH	turbidity	pH	Na	TA
Site 1	*X*11	*X*12	*X*13	*X*14	*X*15	*X*16	*X*18	*X*19	*X*110	*X*111	*X*112
Site 2	*X*21	*X*22	*X*23	*X*24	*X*25	*X*26	*X*28	*X*29	*X*210	*X*211	*X*212
Site 3	*X*31	*X*32	*X*33	*X*34	*X*35	*X*36	*X*38	*X*39	*X*310	*X*311	*X*312
Site 4	*X*41	*X*42	*X*43	*X*44	*X*45	*X*46	*X*48	*X*49	*X*410	*X*411	*X*412

TABLE 4. Rejection values of RO1 parameters

After 10 weeks)			At zero time			Unit	Parameter
%R	*P*	*F*	*%R*	*P*	*F*		
92.3	154	2 019	94.7	105	2 010	$mg \cdot l^{-1}$ as $CaCO_3$	TH
95.7	78	1 812	96.2	67	1 800	$mg \cdot l^{-1}$	SO_4
90.5	226	2 400	91.8	228	2 800	$mg \cdot l^{-1}$	TDS
51.4	68	140	70.1	40	134	$mg \cdot l^{-1}$ as $CaCO_3$	TA
92.3	26	340	92.0	26	326	$mg \cdot l^{-1}$	Mg
90.4	24	250	92.2	21	269	$mg \cdot l^{-1}$	Ca
55.5	16	36	60.0	12	30	$mg \cdot l^{-1}$	Cl
58.6	12.4	30	61.8	10.3	27	$mg \cdot l^{-1}$	Na
–	7.1	7.3	–	7	7.2	–	pH
90.0	0.28	2.8	95.7	0.2	4.75	NTU	turbidity
89.2	0.97	9.0	92.6	0.63	8.5	$mg \cdot l^{-1}$	NO_3

TABLE 5. Rejection values of RO2 parameters

After 10 weeks			At zero time			Unit	Parameter
%R	*P*	*F*	*%R*	*P*	*F*		
96.50	70	1 995	96.8	66	2 086	$mg \cdot l^{-1}$ as $CaCO_3$	TH
97.83	39	1 800	98.05	35	1 800	$mg \cdot l^{-1}$	SO_4
95.42	96	2 100	97.5	70	2 812	$mg \cdot l^{-1}$	TDS
72.66	41	150	93.3	12	180	$mg \cdot l^{-1}$ as $CaCO_3$	TA
95.1	16.3	335	97.9	7.6	365	$mg \cdot l^{-1}$	Mg
90.45	21	220	91.06	21	235	$mg \cdot l^{-1}$	Ca
62.14	21.2	56	75.86	7	29	$mg \cdot l^{-1}$	Cl
78.46	8.4	39	83.46	4.3	26	$mg \cdot l^{-1}$	Na
–	7	7.3	–	6.9	7.7	–	pH
90.00	0.2	2	96.55	0.2	5.8	NTU	turbidity
90.1	0.8	8.9	94.4	0.53	9.5	$mg \cdot l^{-1}$	NO_3

TABLE 6. Rejection values of RO3 parameters

After 10 weeks			At zero time			Unit	Parameter
%R	*P*	*F*	*%R*	*P*	*F*		
91.3	130	1 500	95.7	65	1 535	$mg \cdot l^{-1}$ as $CaCO_3$	TH
94.7	106	2 010	97.8	42	1 910	$mg \cdot l^{-1}$	SO_4
87.7	144	1 170	91.8	90	1 100	$mg \cdot l^{-1}$	TDS
67.7	40	124	77.0	30.8	134	$mg \cdot l^{-1}$ as $CaCO_3$	TA
89.8	28	275	97.7	6	265	$mg \cdot l^{-1}$	Mg
90.3	49	507	96.8	16	507	$mg \cdot l^{-1}$	Ca
61.1	11.7	30	80	6	30	$mg \cdot l^{-1}$	Cl
58.6	8.7	21	78.2	4.5	20.7	$mg \cdot l^{-1}$	Na
–	–	7.6	–	6.6	7.6	–	pH
90.0	0.4	4	93.0	0.27	3.9	NTU	turbidity
94.3	0.73	12.8	97.6	0.32	13.6	$mg \cdot l^{-1}$	NO_3

TABLE 7. Rejection values of RO4 parameters

After 10 weeks			At zero time			Unit	Parameter
%R	*P*	*F*	*%R*	*P*	*F*		
94.9	627	1 230	97.2	30	1 100	$mg \cdot l^{-1}$ as $CaCO_3$	TH
97.0	207	690	98.4	12	770	$mg \cdot l^{-1}$	SO_4
94.3	91.7	1 610	96.9	46	1 518	$mg \cdot l^{-1}$	TDS
77.3	60.3	266	95.9	10	245	$mg \cdot l^{-1}$ as $CaCO_3$	TA
94.7	7.6	144	97.8	2.4	112	$mg \cdot l^{-1}$	Mg
95.7	25.8	600	98.7	8	624	$mg \cdot l^{-1}$	Ca
65.8	45.5	133	78.3	8.2	38	$mg \cdot l^{-1}$	Cl
78.6	16.6	77.7	88.3	6.4	55	$mg \cdot l^{-1}$	Na
–	7.1	7.4	–	7	7.1	–	pH
85.4	0.55	3.8	91.2	0.35	4	NTU	turbidity
91.2	1.1	12.6	96.0	0.47	11.8	$mg \cdot l^{-1}$	NO_3

A number of calculations were done to determine the RO stations performance as in Table 8 according to the SAW method. The results show that performance at Ain Alwah RO1, Misherfa Altaha RO2, Ghiziel RO3, and Misherfa RO4 were 98.3, 97.9, 95.3 and 86.3%, respectively.

TABLE 8. Ranking of RO stations using the SAW method

Site	Indices at zero time of operation		Rejection efficiency [%]	Indices after 10 weeks of operation		Rejection efficiency [%]	Difference between rejection efficiency [%]	Inverse difference [%]	Rank
	F	*P*		*F*	*P*				
Ain Alwah	228.8	20.7	90.9	215.5	23.2	89.2	1.7	98.3	1
Misherfa Altaha	234.6	11.7	95	204	14.9	92.7	2.3	97.9	2
Ghiziel	180.6	12.4	93.1	185	21.4	88.4	4.7	95.3	3
Misherfa	154.1	8.8	94.2	163.5	31.9	80.5	13.7	86.3	4

The ranking performance resulted from TOPSIS are 99.95, 99.92, 40.2 and 17.99%, respectively as in Table 9.

TABLE 9. Ranking of RO stations using the TOPSIS method

Rank	P_i	Results after 10 weeks of operation			Results at zero time of operation			Site	No
	%	P_i	S_i^-	S_i^+	P_i	S_i^-	S_i^+		
1	99.95	0.9995	0.039	84.44	0.9999	0.004	143.83	Ain Alwah	RO1
2	99.92	0.9992	0.065	84.46	0.9998	0.015	143.82	Misherfa Altaha	RO2
3	40.2	0.4020	57.76	38.83	0.1802	127.5	28.04	Ghiziel	RO3
4	17.99	0.1799	80.11	17.58	0.0036	143.6	0.529	Misherfa	RO4

After comparing the performance results of the SAW and the TOPSIS methods, it was seen that the stations' performance can be ranked from high to low as follows: RO1: Ain Alwah, RO2: Misherfa Altaha, RO3: Ghiziel, and RO4: Misherfa.

Discussion

Figure 3 shows a comparison between the SAW and the TOPSIS results. There is a difference in values between them. And this is due to the principles applied by the two methods themselves, where the SAW occupies weighted average, whereas the TOPSIS focuses on maximizing distance from the negative ideal solution, and minimizing the distance from the positive ideal solution. The SAW gives more convenient values than the TOPSIS method. The result of this study is a good agreement with the findings of the studies of Thor, Ding and Kamaruddin (2013) and Tahyudin et al. (2018).

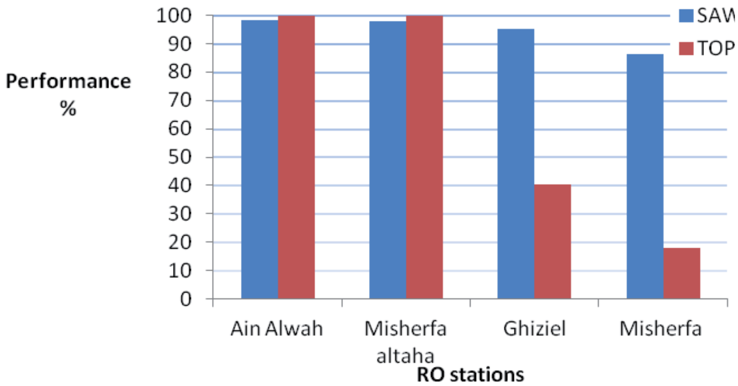

FIGURE 3. A comparison between the SAW and the TOPSIS methods

It was seen that the overall performance shows an excellent rejection efficiency reaching 90% in the following set of parameters; SO_4, TDS, Ca, Mg, NO_3, Ca, turbidity and TH, however, the other set of parameters CL, and Na show a less rejection efficiency between 60 and 85%, as in Figure 4. It was shown that the divalent cations have higher percentage removal than monovalent anions.

Assessing the performance of RO stations is carried out where RO1 was the best station while RO4 was the worse one. Although the RO system model and the membrane model were the same, the operating conditions of these stations were different. Mismanagement of RO stations (untrained labours) with low maintenance and the lack of frequent washing of the membrane can be considered as the main reason in decreasing (RO3 and RO4) station's performance.

Conclusions

Total dissolved solids plays a vital role in determining the suitability of the drinking water, where the feed wa-

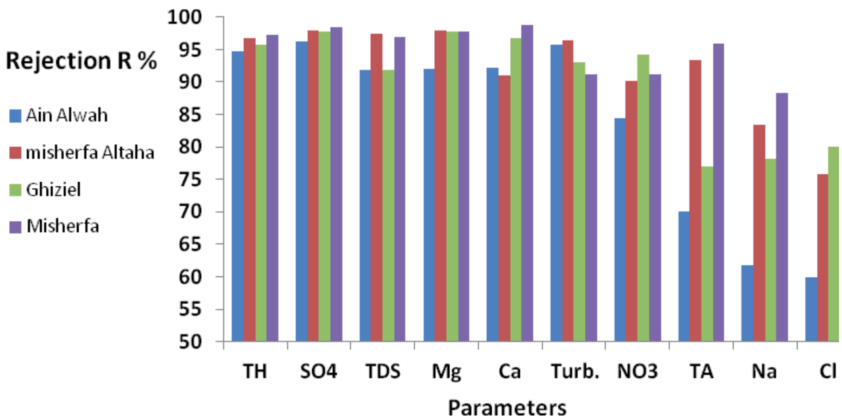

FIGURE 4. Rejection *R* efficiency of the studied parameters at four stations

ter TDS concentrations ranged between 1,100 and 2,800 mg·l^{-1}, while the permeate water ranged between 46 and 228 mg·l^{-1} and it was within the permeable standards of drinking water for all stations. The removal efficiency of TDS ranged between 92 and 97%.

It can be observed that the SAW occupies weighted average and its mathematically easier while, the TOPSIS presents a priority of ranks with an optimal station. Therefore, both methods provide an integrated viewpoint of RO stations performance.

Acknowledgements

The authors are very grateful to the University of Mosul, College of Environmental Sciences and Technology for their provided facilities, which helped to improve the quality of this work.

References

Abdel-Fatah, M.A., El-Gendi, A. & Ashour, F. (2016). Performance evaluation and design of RO desalination plant: case study. *Journal of Geosciences and Environment Protection*, *4*, 53-63. doi 10.4236/gep.2016.42007

Afshari, A., Mojahed, M. & Yusuff, R. (2010). Simple additive weighting approach to personnel selection problem. *International Journal Environmental Management Technology*, *1*, 511-515.

Al-Bayati, M.A., Salehi, S.A. & Al-Abdraba, W.M. (2015). Evaluation of efficiency of groundwater desalination plants in different hydrogeological conditions in Salahaddin Governorate-Iraq. *Tikrit Journal of Science*, *5*(20), 125-136.

Al-Hotmani, O.M.A., Al-Obaidi, M.A.A., John, Y.M., Patel, R. & Mujtaba, I.M. (2020). An innovative design of an integrated MED-TVC and reverse osmosis system for seawater desalination: process explanation and performance evaluation. *Processes*, *8*(5), 607. doi 10.3390/pr8050607

Al-Jlil, S. (2017). Performance of nano-filtration and reverse osmosis for wastewater treatment. *Journal of Materials and Technology*, *51*(3), 541-548.

Al-Ozeer, A.Z. & Ahmed, M.F. (2019). Groundwater assessment at east side of Mosul City during 2014–2017. *Scientific Review – Engineering and Environmental Sciences*, *28*(1), 35-48. doi 10.22630/PNIKS.2019.28.1.4

American Public Health Association [APHA] (2005). *Standard methods for the examination of water and wastewaters*. 21st ed. Washington DC: American Public Health Association.

Behzadian, M., Otaghsara, S.K., Yazdani, M. & Ignatius, J. (2012). A state-of the-art survey of TOPSIS applications. *Expert Systems with Applications*, *39*(17), 13051-13069.

Bouchareb, A., Metaiche, M., Lounici, H., Khoudja, H.D., Lefkir, A. & Drouiche, N. (2019). Reverse osmosis membrane performance for desalination of Algerian brackish water. *Desalination and Water Treatment Journal*, *151*, 9-19. doi 10.5004/dwt.2019.23912.

El-Harrak, N., Elazhar, F., Zdeg, A., Zouhri, N., Elazhar, M. & Elmidaoui, A. (2013). Performance analysis of the reverse osmosis desalination plant of brackish water used for irrigation: case study. *American Journal of Applied Chemistry*, *1*(3), 43-48. doi 10.11648/j.ajac.20130103.12

Environmental Protection Agency [EPA] (2004). *Guidelines for water reuse. EPA/625/R-04/108*. Washington: Environmental Protection Agency.

Garud, R.M., Kore, S.V., Kore, V.S. & Kulkarni, G.S. (2011). A short review on process and applications of reverse osmosis. *Universal Journal of Environmental Research and Technology*, *1*(3), 233-238.

Haider, H. (2017). Performance assessment framework for groundwater treatment plants in arid environment: a case of Buraydah – Saudi Arabia. *Environmental Monitoring and Assessment*, *189*(11), 189-544. doi 10.1007/s 10661-017-6271-1

Iraqi Health Ministry [IHM] (2001). *Central system for measuring and quality control. Iraqi* *standards. I.S.S., No 417. ICA:13.060.20.* Baghdad: Health Ministry.

McDuffie, B. & Haney, J.T. (1973). *A proposed River Pollution Index*. Washington: Abstracts of Papers of the American Chemical Society.

Makki, H.F. (2009). Performance evaluation of reverse osmosis process in Al-Dura power station. *Basra Journal for Engineering Sciences*, *9*(1), 122-130.

Metcalf & Eddy Inc., Asano, T., Burton, F. & Leverenz, H. Tsuchihashi, R., Tchobanoglous, G. (2007). *Water reuse. Issues, technologies, and applications*. Los Angeles: AECOM Press.

Tahyudin, I., Rosyidi, R., Ahmar, A.S.H. & Haviluddin, H. (2018). Comparison of the Simple Additive Weighting (SAW) with the Technique for Others Reference by Similarity to Ideal Solution (TOPSIS) methods. *International Journal of Engineering & Technology*, *7*(2.2), 87-89.

Thor, J., Ding, S.H. & Kamaruddin, S. (2013). Comparison of multi criteria decision making methods from the maintenance alternative perspective. *The International Journal of Engineering and Science (IJES)*, *2*(6), 27-34.

Tsaur, R.C. (2011). Decision risk analysis for an Interval TOPSIS Method. *Applied Mathematics and Computation*, *218*(8), 4295-4304.

World Health Organization [WHO] (2003). *Guideline for drinking water quality*. Geneva: World Health Organization.

Summary

The performance assessment of reverse osmosis stations at Al-Mahalabea area. The present study assesses RO stations at four sites in Al-Mahalabea area – Nineveh governorate, Iraq during the summer of 2013. The performance of RO stations are ranked by two methods: the Simple Additive Weight (SAW) and the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS). Two groups of samples were collected from feed and permeate water for two periods (at zero time of operation and after ten weeks of operation) with eleven parameters for each sample were analysed. The highest overall rejection *R* efficiency appeared with the first set of parameters more than 90% (SO_4, TDS, NO_3, TH, and turbidity), while the second set was the least (Cl, Na, and total alkalinity – TA) ranged between 65 and 85%. It is observed that both the SAW and the TOPSIS methods are accurate to predict the performance efficiency.

Author's address:
Mohammed Fakhraldeen Ahmed
(https://orcid.org/0000-0003-0414-0409)
Mosul University
College of Environmental Sciences
and Technology
Department of Environmental Technology
Mosul, Iraq
e-mail: milhebi@uomosul.edu.iq