RESEARCH ARTICLE

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A Comprehensive Evaluation Optimal Ground Water Desalination Process with Membranes and Integrated Process Using AHP Method in Qom Province, Iran

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Background & Aims of the Study: Recently membranes have been widely used in Mena region especially Iran, due to purify the brackish water and solved the water scarcity. Qom province is located in desert like area of Iran and faced to water shortage. The aim of this study is evaluation of the best method of membrane process in the ground water wells of Qom province, Iran, in 2016.

Materials and Methods: This descriptive cross sectional survey carried out at the central laboratory of water and Wastewater Company of Qom. The experimental tests were done in order to evaluate the treatment process of 12 physical-chemical water parameters such as: salinity, pH, TDS, EC, TH and Mg, Ca, SO_4, Na, K, Cl and temperature, which performed by NF.RO Hybrid NF/RO desalination membranes installed on water desalination plant with pretreatment devices. All laboratory tested carried out undertaken of standard method of water and waste water 2012 with $P_{value}<0.05$ .Then, the result of experimental tests weighted and ranked by AHP method and expert choice software11.

Results: The evaluation of experimental tests showed the brackish water purified by NF membrane in ranges of 21.5%-95.5%, RO membrane 43%-97.2% and Hybrid NF/RO 63.95%-98.4%. Afterward the analyses of membrane performance carried out by weighting and scoring with AHP method and expert choice .The outcomes of the AHP revealed that Hybrid process obtained the best preference of membrane desalination by weight 0.449 .Then, RO by weight of 0.308, got second turn and NF, by weight of 0.243, followed by RO. It is considerable that the quality of brackish ground water treatment by Hybrid process has the highest function as the highest weight.

Conclusion: The experimental tests were done by performed housing desalination plant with three membranes NF, RO, Hybrid NF/RO. The results showed the Hybrid membrane has the highest function as treatment and removal of 12 water parameters. Also, the result of hierarchy process with an expert choice and AHP method confirmed the best desalination process belongs to Hybrid membrane.

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Background

Water is one of natural resources necessary for survival of all creatures. In addition, around 97.5 percent of total water in the earth are consist of salty and brackish water only about

2.5 percent of aquatic resources are considered fresh water and potable water for human being (1,2).

Nowadays, water resources including surface and ground water are to be polluted and contaminated by physical - chemical changes and ions. For these reasons the quality of these valuable resources are very important to provide healthy water supply and preserve the environment (3). In the whole global, water supplies encounter lack reliable access to clean water because of drought, low precipitation and population growth. One of the region in the earth that located in arid and hyper arid zone of the world is challenged with water stress called MENA Region (4,5). For these reasons, countries in this area which located in water scarce region, is using renewable water resources with installing desalination plants (6). Iran is located in arid and state of physicality water scarcity of Mena region so, applies desalination methods and nanotechnology for solving limitation fresh water supply (4).

Moreover, Qom province has arid and semi-arid climate and desert like weather is facing water shortage, unsuitable water reused management and low quality of water supplies (7). Furthermore, membranes purification are strongly candidate for removal dissolved contaminations and separation physical and chemical parameters of feed water (8,9). in addition, in Iran and Qom previous researches suggested that the performance of RO membrane is the most appropriate desalination membranes for rejecting dissolving parameters of brackish water (10,11). In Iran and other countries, researchers indicated that beside reverse osmosis, nanofiltration used for soften of feed water (12,13).

Although, there are many options for water treatment and desalination processes, to select the best option need to take a proper decision making. Since, the function of each membrane filtration is complicated, multi-criteria decision making model has been used (14,15).

The AHP method which is based on multi-criteria decision-making technique method has been developed by Thomas el saati and has been applied by experts in water refinery (16-18).

AHP provides pairwise comparison techniques for selecting the best option from several options. The best option obtained base on preference one criteria over the other criterion. Following weighting criteria the option which computed highest score get the best rank and selected alternative (19,20).

Aims of the study:

The aims in this survey were to illustrate the successful application of membranes desalination to remove water parameters of Qom groundwater wells and select the performing membrane by using AHP and expert choice. The novelty of this paper is analysis function of RO and NF and Hybrid NF/RO by 12 physical-chemical water parameters with expert choice and AHP.

Materials & Methods

Study area:

Qom Province is located in dry and semi-arid region of Iran, and also near Salt Lake. The precipitation in Qom province is reported to be 100 mm per year. Most of the water resources in Qom province are supplied from wells around the city of Qom and Aliabad. Generally, the underground waters in Iran contain Total Dissolved Solids (TDS) and high electrical conductivity (EC) that make the water undrinkable and desalinating processes necessary (21,22).

Methods:

This descriptive cross-sectional study was performed in2016 in central laboratory of water and wastewater company of Qom province in Iran. In present study AHP modeling method was used select the best membrane desalination of brackish groundwater water in Qom.

In general AHP method which is a multi-criteria decision-making technique develops by Thomas el saati provide an optimistic hierarchy

of criteria and alternative to solve the complexity of decision making and reach the aim of decision (goal) .The AHP evaluated based on a chemical processes as criteria and valued numerically between options which considering the best option (23,24).

Therefore, in present study 12 physical-chemical parameters considered as criteria for using AHP method. The water parameters that examined for experimental study was carried out by standard method for examination water and waste water 2012. After wards, all 12 physical-chemical water parameters were measured both feed water and rejection by deferent and specifics devices. The evaluation of salinity, pH, TDS, EC, temperature were done by HACH portable multi- parameter meter (HQ40D 530000). TH, Ca, Mg and were estimated by titrimetry, Na and K by flame photometry. Also the measuring SO_4 was conducted by photometer. Moreover, After all parameters passing through membranes in turn NF90-2540 Nano-filtration membrane, TW30-1821-100 reverse osmosis membrane and hybrid NF/RO (integrated NF membrane an RO membrane) as rejection were estimated with membranes processes which installed on Luna water100GPD desalination plant. The performing three desalination processes to purified feed water considered as the alternatives in AHP method. In brief, the hierarchical technique structure was constructed in the form of a hierarchical tree under the supervision of Saati (23) as shown in Fig. 1. In the hierarchical model of AHP, the title is placed on the first line, the parameters are in the second line and the decision alternatives are on the bottom line.

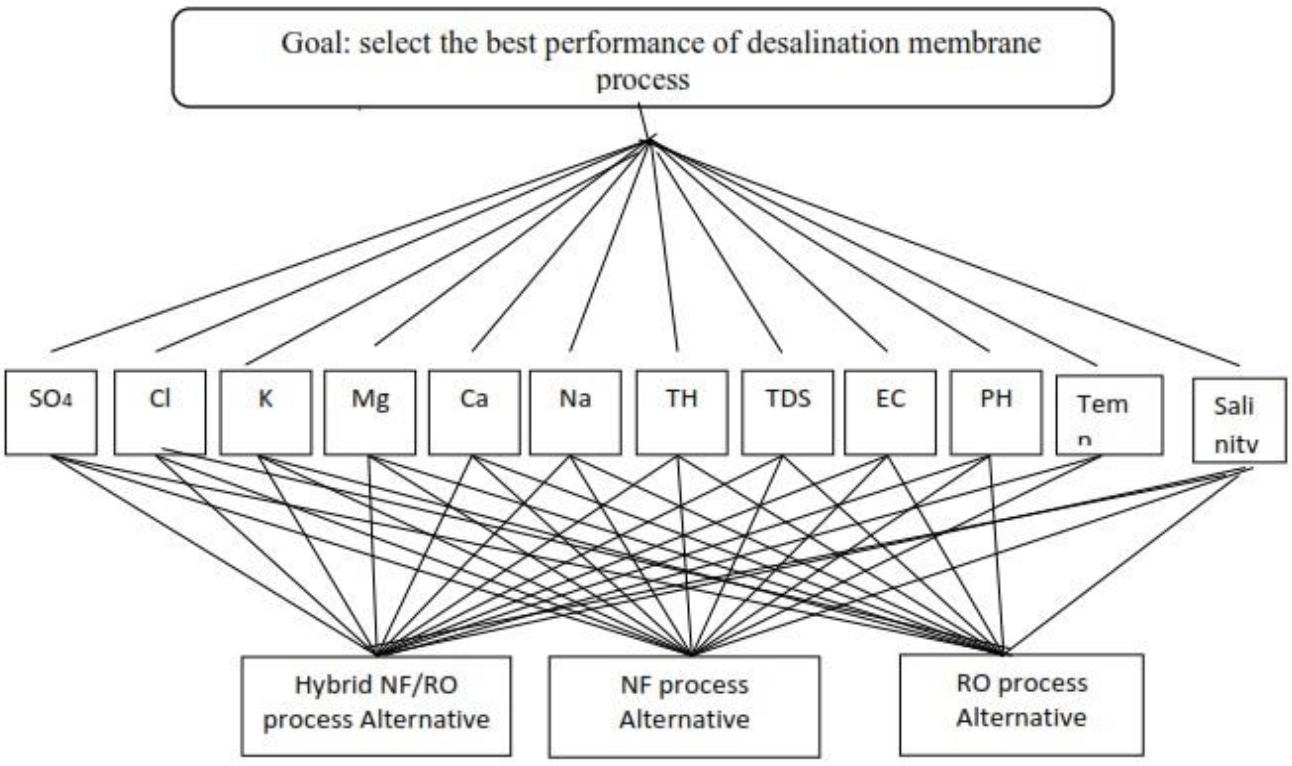

Figure 1) Hierarchical structure of the criteria and Alternatives

In AHP hierarchy to reach the main decision making precisely the involve prioritization of

alternative through the evaluation and weighting of the criteria should be determined. For weighting relative role of criteria and alternatives associated with each other's the pairwise of criteria and alternative should be scaled the degree intensity as Saati proposed scale from1-9.also all criteria weightings are analysed and calculated as pairwise comparisons to show the preferable criteria followed in table 1 (25).

Table1) The comparison scale in AHP (Satya's method)

Option	Numerical Values
Equal	1
Marginally Strong	3
Strong	5
Very Strong	7
Extremely Strong	9

Then, pairwise comparison applied to calculate the comparing each criteria with the performance of each alternative and indicated weight and rank of them .Finally, after determining weight of each alternative the rank of value prioritization of alternative the most among alternatives is illustrated. In addition, expert choice Inc introduce professional commercial software to simplify the impalement AHP steps computation (26,27).

Consider a main propose hierarchy best function of desalination membrane process with 12 criteria (physical-chemical water parameters) on which the three alternatives NF ,RO membranes and Hybrid NF/RO are to be judged. To determine the weighting of the 12 criteria pairwise comparison the first criteria compared against the remaining 11, then this way of pairwise criteria was carried out to others parameters. Then, the prioritized numbers were compared in order to calculate the weight of the parameters in terms of membrane desalination methods of Nano-filtration, Reverse Osmosis and Hybrid. To evaluate statistic data and standard deviation and demonstrate assessment accuracy, assurance distance of 95% is used for experimental examination. In addition, paired t-test is applied to indicate the Purification effect in each membrane process, and to compare between three groups during a year and to compare between three groups during a year, hybrid or LMM model, generalized from Repeated Measure ANOVA, is used. All statistical analysis is obtained P_{value} with statistical calculation and using SPSS23.

Results

In this work the removal and decreased content of 12 water parameters by three membranes processes (NF, RO, and Hybrid NF/RO) was studied. The results are presented in the table 2 .These 12 parameters were tested according to the findings of the studies conducted by, Ardani et al in 2015, the concentration of the total dissolved soluble parameters, electrical conductivity, pH, total hardness and calcium hardness, chloride, sodium and potassium ions and sulfate in Qom province groundwater, were reported to be above the standard (28).

Therefore, in this research, the physical-chemical, salinity, pH, Total Dissolved Solids (TDS), electrical conductivity, total hardness and magnesium, calcium, sulfate, Sodium, potassium and chloride ions and Temperature, were investigated and tested to evaluate the performance of three methods of Nano-filtration, reverse osmosis and Hybrid for purification and desalination of brackish waters wells in Qom province. The experimental results of characteristic and content of ground water before and after passing through membranes processes are presented in Table 2.

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Table 1) Mean and standard deviation of knowledge, practice and attitudes of students and technologists about infection control

Parameters	Internal	Hybrid	NF	RO
		Output	Output	Output
Salinity	2.43 ± 0.17	0.3 ± 0.05	1.21 ± 0.08	0.68 ± 0.07
PH	7.83 ± 0.31	7.81 ± 0.3	7.78 ± 0.31	7.74 ± 0.54
TDS	3000.9 ± 129.1	704.6 ± 68.6	1698.2 ± 87.5	1192.5 ± 63.8
EC	4771.3 ± 202.7	1124.9 ± 80.2	2690 ± 142.2	1892.8 ± 101.5
TH	1325.3 ± 57.2	133.2 ± 12.5	418.4 ± 28	269.8 ± 17.2
Cl	1223.4 ± 54.6	451.5 ± 31.2	965.4 ± 48	696.4 ± 42.6
So_4	900.5 ± 41.1	14.4 ± 2.9	40.5 ± 6.1	25.3 ± 3.6
NA	686.4 ± 35.3	199.7 ± 20.1	438.3 ± 26.6	312.9 ± 20.9
K	13.62 ± 1.18	3.56 ± 1.06	6.33 ± 1.32	4.73 ± 1.06
Ca	270.2 ± 17.3	24.5 ± 3.5	88.7 ± 10.1	53.1 ± 5.6
Mg	156.1 ± 7.6	17.3 ± 1.5	47.1 ± 3.3	32.9 ± 2
Temp.	23.26 ± 2.91	23.31 ± 2.84	23.36 ± 2.81	23.37 ± 2.84

The statistical summary of ground water quality the most water parameters with statistical analysis as determined p-value are less than 0.05. It means that the statistical evaluation is significant meaningful so, the results show that there's difference between performances of desalination membranes.

AHP Result

The weight of performance membranes are computed by expert choice software by applying AHP method. Then pairwise comparing carried out between function of RO and NF in addition to RO and hybrid NF/RO. Furthermore, figure 2 is the result of percentage the pairwise preference between RO and NF alternative which calculated undertaken of 12 parameters as criteria.

In addition, the percentage of prioritization between RO and Hybrid NF/RO is recorded in figure 3.

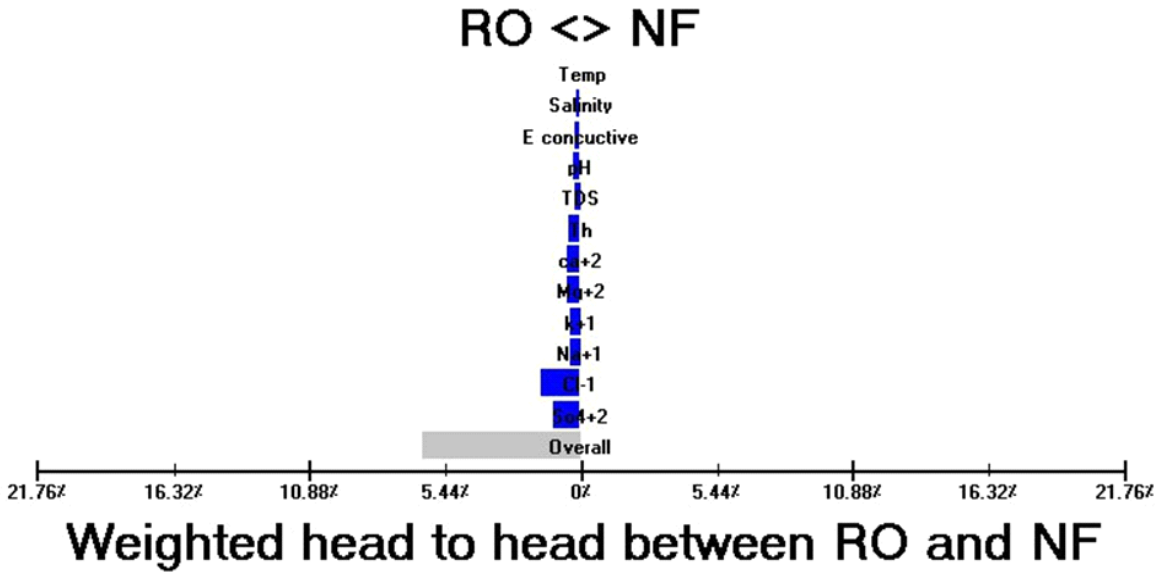

Figure2) Compare the relative importance with respect to Reverse Osmosis performance

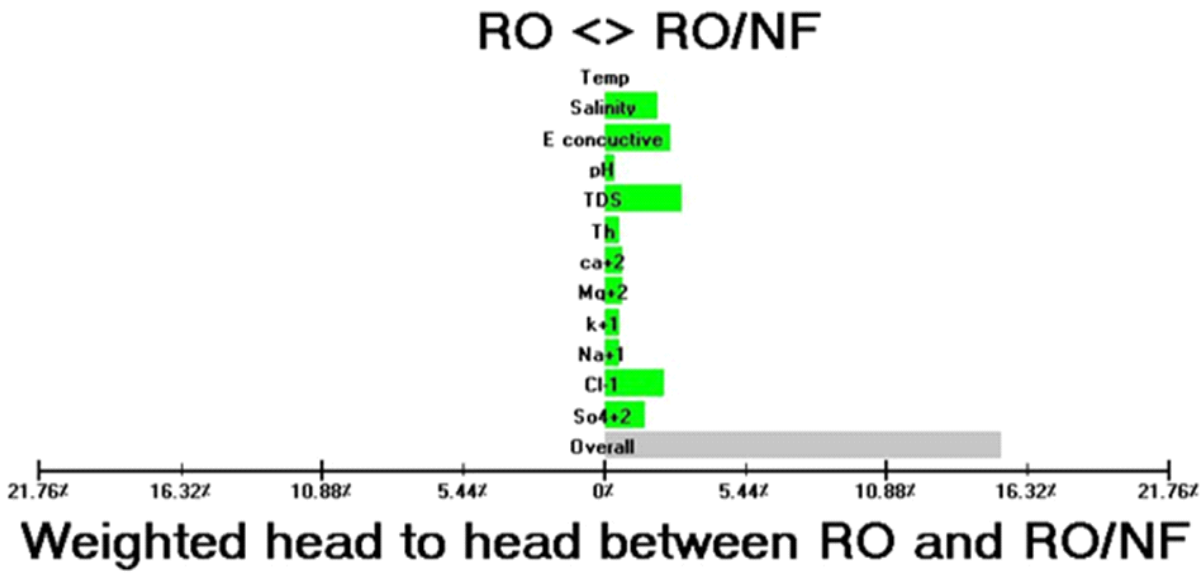

Figure 3) Compare the relative importance with respect to Hybrid NF/RO performance

Totally in fig.4 the outcome of preference pairwise comparison three alternatives (function of membranes processes) based on 12 criteria (12 water parameters) are weighted and recorded rank of them. The results revealed that evaluated the quantities and qualities criteria and alternatives can scale numerical with overall inconsistency rate. The results of prioritization and ranking of options are determined together with the inconsistency rates. The inconsistency rate in this study is scored 0.05.

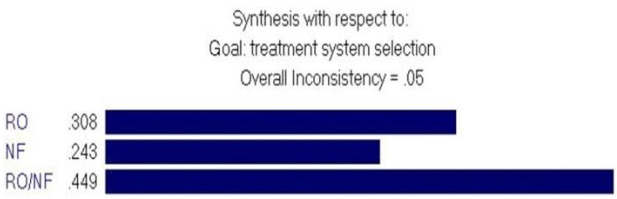

Figure 4) Compare the relative importance with respect selection desalination membranes water treatment

In addition, by controlling the inconsistency rate and ensuring the acceptability of any pair comparison, relative weight of each parameter is calculated for different options. According to Saati, the acceptable rate of inconsistency of a matrix should not exceed 0.1. The amount of 0.1 is expressed as the acceptable minimum (29).

Moreover, Sensitivity is carried out after calculating the ranking of options in order to more accurately assess paired judgments and make decisions by re-calculating and modifying the weight of each parameter and ranking of alternatives and choosing the best sensitivity alternative (26,30).Sensitivity analysis was used in this study and the result of Performance sensitivity graph of desalination membranes processes showed in fig 5.

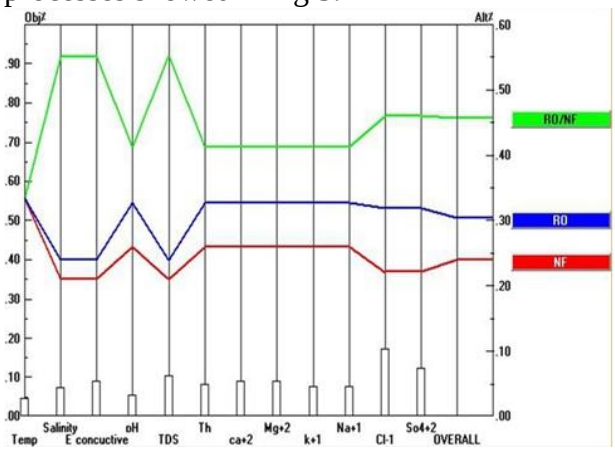

Figure 5) Performance sensitivity graph of desalination membranes processes

Finally Figure 6 is the result of data processing by using Expert Choice according to the

preferences of desalination membranes processes in the Qom brackish ground water in turns and weight. As a result known in fig 6, hybrid NF/RO membrane process 0.449, RO membrane process 0.308 and NF membrane process 0.243.

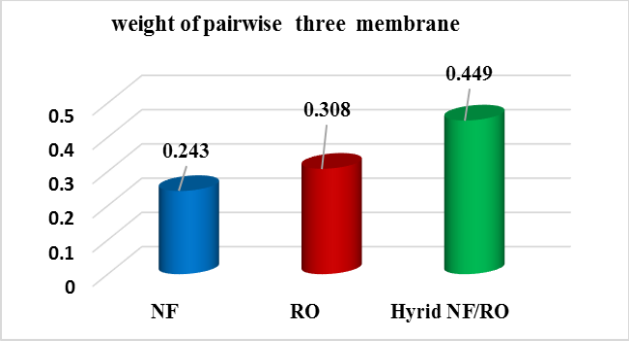

Figure 6) Final priority for the proposed performance of membranes desalination

Discussion

In Qom many studies reuse water treatment processes that use nanotechnology advanced treatment deal with physical and chemical parameters shows the importance of preparedness treatment processes to deal with physical and chemical parameters and they suggested apply proper method to evaluate improvement of the best water purified process (31).

According to Yari study indicated that ground water in Qom has been still microbial and other pollutants after treatment by housing desalination plant. As many studies expressed that Hybrid membrane process has the high level of water desalination purification in ground water (32,33).In this research used nanofiltration kind of nanotechnology filtration and hybrid too.

Also, in experimental results of present study with comparing the content of groundwater output (rejection) after passing through the three membranes NF, RO hybrid NF/RO showed the hybrid has the highest preference as treatment function by 62.95%-98.4%. Then RO revealed more preferable performance43.08%-97.19 % to NFprocess21.5%-95.5%.

In Qom Sadeghiyekta compared conventional and nonconventional water treatment method in Qom by AHP .then the result showed that the highest rank belonged to desalination method (34).

Moreover, Ansari et al. expressed that with AHP could be realized the best method of reused water treatment and pretreatment improved the purified process (18). In addition, although in research of Qhasemi and Danesh did not use hybrid process; reverse osmosis got the second higher rank among other desalination methods too, like respectively in present study (35).

In Dabaghian study the results indicated that membrane processes and preference of RO membrane to NF membrane by judgment of weight in AHP method (36).

Also Eusebio in other countries expressed that in general hybrid membrane process especially with RO membrane has got the most rank and numerical score weight compare with individual membranes like RO and NF processes .In Sadr study used conventional pretreatment before applying to membranes .then weighted the function of hybrid and individual desalination by AHP method (17,37).

Gharibi, Mahvi and Hadipour conducted a study on water quantity assessment based on phasic decision-making model and using the sensitivity analysis method. Then reported the quality of drinking water quality indicators can be determined with greater accuracy by applying sensitivity analysis method.

It is obvious that the applied AHP could assist decision makers approach to the solutions of managing and purification of choice the best method ground water resources (16,38).

Furthermore, in this paper to obtain more precisely of experimental examines and more appropriate decision making to select the best performance of desalination process by three types of membranes used the AHP method. The

final weighting of the alternatives was done by Expert Choice software, which is the hybrid process with a final weight of 0.449 was considered as the most preferred option. The reverse osmosis process with a weight of 0.308 was ranked second and the Nano-filtration process ranked third with a weight of 0.243. According to Figures 2 and 3, the weight of the 12 parameters in the reverse osmosis process has increased about 5.5% compared to the Nano-filtration process and increased 16.30% in the hybrid process compared to the reverse osmosis process.

In this paper used desalination plant with pretreatment to select the best system of desalination processes with AHP method and experimental method. Therefore, the results of this combination of pretreatment plus hybrid system have got the highest score and rank.

In the whole, as the results are illustrated by expert choice and AHP method, water purification in the hybrid process has the highest purification quality after which are the processes of reverse osmosis and Nano-filtration as the second and third quality respectively which is similar to the results by using the laboratory method.

Footnotes

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Conflict of Interest:
The authors declared no conflict of interest.

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