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Multiple Decisions Making for the Best Desalination Plant in 1996-2020

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ABSTRACT

The study area, Ghaemshahr-Jouibar plain in Talar basin is a part of Caspian Sea watershed. According to quantity results in Talar basin, in this research to solve the quality and quantity problems desalination plants and the possibility of using them were investigated. Criterion considered for selecting the best desalination plant included Agricultural Sustainability Index (ASI), Environmental Sustainability Index (ESI), Water Exploitation Rate (WER), Yield Reliability (YR), Irrigation Water Deficit (IWD), Domestic Supply Reliability (DSR). The considered alternatives in this research are RO، MD, IE، MSF، MED, ED، TVC، SD، FR، GH, MVC. Decision making in this study was done in terms of calcium, years 1996-2011 and the kind of usage (drinking, agriculture and industry). Weighting methods used in this study were CRITIC and ENTROPY. Among all the decision making methods the combination of three VIKOR, DEMATEL and ELECTRE IFS was applied for the last step of making a decision in Talar basin. Results showed that in drinking part there are two different selections MVC and ED with ENTROPY and CRITIC methods respectively. In agriculture part MD is the best choice.

1. Introduction

Salt water intrusion is possible at the result of unnatural reasons like digging wells, canals and establishing swage systems. This process can make great problems for citizens in the area. Salting the fresh water leads to reduction of the available water for the people. In the Talar basin there are two rivers Talar and Siahroud which using their water follows high costing and facility, except in the close parts to the rivers. In addition the water of these two rivers have high amount of sediments so this subject reduces the quality of water. Irrigating the farm lands with low quality of water in these two rivers changes the texture of soil and also disturbs the agricultural tools in long period. Thus according to these problems and also considering the simplicity of practice and low costing of digging well because of high level of groundwater in Talar basin, the amount of groundwater is being reduced. This leads to salting the fresh water in Talar basin. Wallenius et al. (2000) introduced four factors in salting the groundwater, in which the level of groundwater was one of the factors. Azizi (2003) introduced drought as the main reason of groundwater level reduction. Nairizi and Janparvar (2004) based on the researches done in Mashhad aquifer said that increasing the population can be the main reason for polluting the fresh water. Shamsipoor and Habibi (2008) said that drought and climatical factors are the main reasons for groundwater reduction. In this research the possibility of using desalination plants was analyzed. So it is necessary to review former researches in this field. Zhu et al. (2009a,b and c) studied the performance of RS and showed that this plant has some heat wasting during the desalination process. They also showed

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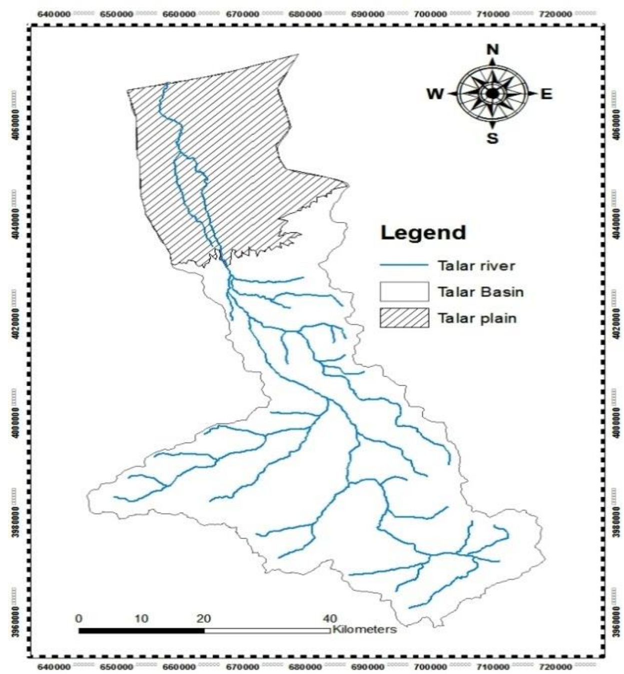
that this problem can be solved simply by substituting the membranes in the plant. On the other hand, Li (2010) created an optimization model for increasing the quality of desalination plant named SEC but they did not present any satisfactory result for their model. Fulaij (2011) in its Ph.D. thesis analyzed the performance of MSF plant. He used FLUENT in order to optimize the performance of MSF and showed that the performance would be increased from 3 to 39 percent by applying FLUENT beside MSF. Skiborowski et al. (2012) combined two desalination plants and they understood that this combination is possible in every condition. Discussion on the water resources was started from the ancient times but nowadays it becomes more important. Thus programming of water resources practices are originating of more complex analyzes. With increasing the demands and challenges on water resources, single criteria analyzes changed to multiple ones (Abrishamchi et al. 2005). Multiple analyzes includes two kinds first is done by one person (MCSDM) and second is done by more than one person (MCMDM). Some of MCDM methods are ELECTRE introduced by Roy (1991), DEMATEL and VIKOR and also TOPSIS (Hwang, 1998), PROMETHEE (Brans and Mareschal 1992) and other methods. Wallenius et al. (2008) showed that among 7000 times that multiple methods are used 267 times is related to water resources management. Atanassove and Gorgiev (1993) introduced A-IFS and told that with this method it is possible to have rational programming. Klir and Bou (1995) in their research showed that fuzzy methods are suitable when we have inputs made in programming language. In fuzzy environments making so many decisions can be possible (Chowdhary and Champagen 2006). Mohsen and El-Jayyousi (1999) classified desalination plants with AHP and showed that RS and IE are the best alternatives among other methods. Their results are consistent with the results of Hajeeh and El-Osman (2005). In 2010 they presented that the amount of energy used in desalination plants, water quality and investigation cost are the most important criterion for selecting the best desalination plant. Li (2005) introduced some new methods based on A-IFS and told that A-IFS is a linear method that analyze alternatives and criterion individually. Based on Rahmani (2010) results and also data gathered from Water Organization of Mazandaran's province (WOMP) and due to increasing in population, and as a result of indiscriminate extraction of groundwater, the slope of water table became reverse allowing salty water of sea entering into the aquifer. So in this research tried to solve the problem of salting water. One of the methods for solving this problem and using the available water in the basin is desalination of salting groundwater. For making a good decision about desalination it is necessary to choose the best desalination plant among all the plants created in the recent years.

2. Materials and methods

2.1 Study Area

Talar basin is part of Caspian Sea basin that is located between Albourz altitudes and Caspian Sea (see figure1). Talar basin covers a surface of 3385 km^2 and its aquifer is about 899 km^2. The Talar basin is fall between 52˚ 35′ 10″ to 53˚ 24′ 7″ longitude and 35˚ 54′ 0″ to 36˚ 47′ 0″ latitude. The main cities located in Talar basin are Sari, Ghaemshahr and Jouibar. The area has experienced intensive human activities including agricultural and industrial and tourism. According to Rahmani (2010) different sources of pollution are identified including main cities, geological formations and mining activities. Mining from rivers and variability of precipitation in time are two factors that limit the water resources. Since water in wells is of good quality and is available, people use it for daily needs. But, due to increasing in population, and as a result of indiscriminate extraction of groundwater, the slope of water table became reverse allowing salty water of sea entering into the aquifer. Location of wells in Talar aquifer demonstrated in Figure 1.



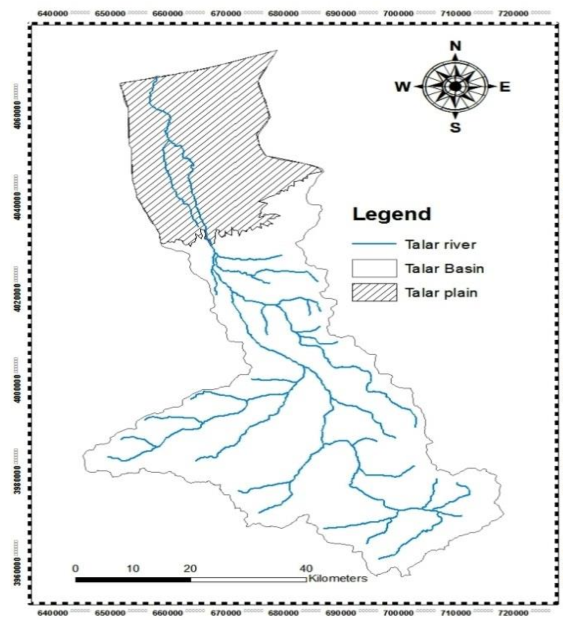


Figure 1: Geographical location of Talar basin

2.2 Data Collection

Quantity data of 42 piezometric wells

1) Quality data such as Anions and Cations

Water quality data collected from the Water Organization of Mazandaran's province (WOMP). Usually, uncertainties are embedded in the observed data as well as development processes that is propagated through synthesizing, developing thresholds based on unimpaired flow and assessing resources gaps (Liang et al. 2012). According to table 1 and 2 there are 27991 wells in Talar aquifer in which the usage of wells for different usage has provided.

Table 1: Cumulative and individual numbers of wells during 1951-2011 in Talar basin

Year	1951	1961	1971	1981	1991	2001	2006	2011
Numbers of wells	64	187	795	3984	14168	8045	718	30
Cumulative	64	251	1046	5030	19198	27243	27961	27991

Table 2: Wells characteristics based on different usages in Talar basin

Parameters	Category				
	Drinking	Industrial	Agriculture	Fishing	Total
Numbers	4090	53	23785	63	27991
Average depth (meter)	11.8	15.3	3.2	26.9	-
Minimum depth (meter)	5	4	4	6	-
Maximum depth (meter)	150	130	170	130	-
Mean discharge	4.2	5.4	8.2	5.7	-

(lit/s)

3. Methodology

In this research the combination of three decisions making methods DEMATEL, VIKOR and ELECTRE-IFS was used to select the best desalination plant. DEMATEL just show the relationship among criterion. Second with CRITIC and ENTROPY the weight of each criterion was determined. Next the alternatives were classified using VIKOR method and at last the classification resulted by VIKOR method was optimized with ELECTERE under IFS environment.

3.1 Entropy method (EM)

Entropy is generally understood as a measure of uncertainty in the information, as defined by Shannon and Weaver (1947). It indicates that a broad distribution represents more uncertainty than does a sharply peaked one (Deng et al.., 2000).

3.2 CRITIC method

In addition to the entropy method, any other method of measuring the divergence in performance ratings can be used to determine the objective weights. Diakoulaki et al.. (1995) has proposed the CRITIC Network. Then the performance matrix was created for predicted data except for one criterion IWD. IWD was computed and predicted for 1996-2011 and 2011-2020 by WEAP. Finally all the needed items are ready to run the decision making process.

4. Results

In order to select the best alternative among all the desalination plants a combination of three decision making methods DEMATEL, VIKOR and

(The Criteria Importance through Inter-criteria Correlation) method that uses correlation analysis to detect contrasts between criteria.

Yilmaz and Harmancioglu (2010) introduced some factors ASI, ESI, DSR, IWD, B/C, YR, IWUE, TPV and WER as suitable criterion but applying Mode method in this research distinguishes the most important ones (ASI, ESI, DSR, IWD and WER) among all the factors introduced by Yilmaz and Harmancioglu (2010). Then after computing the amount of each criterion next to each alternative the performance matrix will be created. Next with creating the performance matrix it is possible to compute the ability of each alternative to reduce the quality factor (Ca) in input water in years 1996 to 2020 and in different parts such as drinking, industry and agriculture. Finally the most suitable desalination plant for the Talar basin would be introduced. One of the important items considered in this paper is that data recorded in the study area is for 1996 to 2011 but the results present some information about year 2020. For solving this gap for years 2011 to 2020, at first the amount of Ca was predicted using Neural

ELECTRE-IFS was used. To combine these three methods together in the environment of Excel first DEMATEL then VIKOR and finally ELECTRE-IFS methods were entered in to the excel environment and the output of combination of three methods determines the final decision making. It must be mentioned that before running the model the weights of each one of the criterion was calculated by two methods ENTROPY and CRITIC. Tables 3, 4 and 5 show the results of this part.

Table 3: Final weights for Calcium in years (1996-2011)-1

Final weights degrading	1	2	3	4	5	6	7	8	9	10	11
Drinking-ENTROPY	ED	TVC	RO	MD	MED	MSF	MVC	SD	IE	GH	FR
Each unit weight	0.78	0.64	0.52	0.51	0.48	0.421	0.418	0.386	0.381	0.379	0.32
Drinking-CRITIC	ED	MSF	MED	SD	TVC	RO	MVC	FR	GH	MD	IE
Each unit weight	0.629	0.66	0.623	0.599	0.586	0.579	0.577	0.455	0.43	0.41	0.33
Agriculture-ENTROPY	RO	IE	ED	MED	MD	SD	TVC	MSF	MVC	GH	FR
Each unit weight	0.667	0.532	0.513	0.51	0.504	0.477	0.472	0.419	0.411	0.354	0.323
Agriculture-CRITIC	IE	ED	MD	RO	FR	GH	MED	SD	TVC	MSF	MVC
Each unit weight	0.789	0.744	0.612	0.611	0.6	0.592	0.499	0.419	0.411	0.403	0.329
Industry1-ENTROPY	FR	MD	IE	MED	MSF	MVC	SD	TVC	ED	RO	GH
Each unit weight	0.716	0.683	0.65	0.616	0.583	0.55	0.55	0.483	0.45	0.416	0.4

Industry1-CRITIC	MED	FR	MSF	SD	MVC	TVC	IE	ED	RO	GH	MD
Each unit weight	0.77	0.64	0.62	0.55	0.54	0.512	0.491	0.488	0.487	0.476	0.419

Table 4: Final weights for Calcium in years (1996-2011)-2

Final weights degrading	11	10	9	8	7	6	5	4	3	2	1
Industry2-ENTROPY	RO	MD	IE	ED	MVC	TVC	SD	MSF	MED	FR	GH
Each unit weight	0.416	0.428	0.45	0.483	0.516	0.55	0.583	0.616	0.65	0.683	0.716
Industry2-CRITIC	IE	ED	MVC	TVC	SD	MED	MSF	RO	GH	FR	MD
Each unit weight	0.383	0.416	0.45	0.5	0.516	0.55	0.566	0.65	0.651	0.683	0.716
Industry3-ENTROPY	IE	ED	MVC	TVC	SD	MED	MSF	GH	RO	FR	MD
Each unit weight	0.383	0.4	0.45	0.466	0.5	0.533	0.566	0.6	0.633	0.666	0.7
Industry3-CRITIC	MVC	RO	ED	IE	MED	SD	GH	MSF	TVC	MD	FR
Each unit weight	0.5	0.571	0.619	0.630	0.642	0.642	0.642	0.714	0.715	0.716	0.785
Industry4-ENTROPY	MD	ED	IE	RO	GH	MVC	TVC	SD	FR	MED	MSF
Each unit weight	0	0.142	0.190	0.214	0.285	0.286	0.357	0.428	0.5	0.547	0.619
Industry4-CRITIC	MVC	ED	MD	MSF	MED	TVC	SD	IE	RO	GH	FR
Each unit weight	0	0	0.071	0.190	0.191	0.192	0.193	0.2	0.214	0.215	0.428

Table 5: Final weights for Calcium in years (2012-2020)

Final weights degrading	11	10	9	8	7	6	5	4	3	2	1
Drinking-ENTROPY	MVC	MED	FR	IE	ED	SD	GH	RO	TVC	MD	MSF
Each unit weight	0.071	0.142	0.2	0.285	0.357	0.485	0.5	0.642	0.642	0.642	0.714
Drinking-CRITIC	IE	ED	MD	MSF	TVC	RO	GH	FR	MVC	SD	MED
Each unit weight	0.142	0.214	0.428	0.5	0.5	0.571	0.571	0.642	0.642	0.7	0.714
Agriculture-ENTROPY	TVC	MVC	MED	FR	GH	MD	ED	IE	MSF	RO	SD
Each unit weight	0.142	0.190	0.285	0.4	0.5	0.547	0.547	0.547	0.642	0.714	0.714
Agriculture-CRITIC	MED	MSF	TVC	MVC	GH	SD	FR	IE	ED	RO	MD
Each unit weight	0.071	0.143	0.143	0.190	0.285	0.357	0.4	0.571	0.642	0.713	0.714
Industry1-ENTROPY	RO	GH	TVC	SD	MVC	IE	MED	ED	FR	MSF	MD
Each unit weight	0	0.214	0.284	0.285	0.405	0.571	0.642	0.643	0.685	0.7	0.715
Industry1-CRITIC	GH	MSF	MED	RO	SD	IE	TVC	MVC	ED	MD	FR
Each unit weight	0.142	0.214	0.285	0.357	0.358	0.428	0.5	0.571	0.572	0.642	0.716
Industry2-ENTROPY	MED	IE	ED	MD	SD	MSF	TVC	GH	MVC	RO	FR
Each unit weight	0.141	0.142	0.190	0.285	0.429	0.570	0.571	0.573	0.642	0.690	0.718
Industry2-CRITIC	RO	SD	MSF	TVC	MED	GH	MVC	FR	MD	ED	IE
Each unit weight	0.190	0.192	0.357	0.359	0.428	0.429	0.430	0.502	0.513	0.644	0.645

Industry3-ENTROPY	MD	FR	ED	IE	GH	MED	RO	SD	TVC	MSF	MVC
Each unit weight	0.142	0.214	0.215	0.218	0.333	0.380	0.390	0.495	0.5	0.561	0.571
Industry3-CRITIC	RO	GH	MED	MSF	SD	TVC	MVC	FR	ED	MD	IE
Each unit weight	0.190	0.191	0.238	0.314	0.316	0.357	0.428	0.571	0.628	0.642	0.644
Industry4-ENTROPY	MED	TVC	ED	IE	RO	MVC	SD	FR	GH	MSF	MD
Each unit weight	0.071	0.142	0.143	0.144	0.214	0.216	0.286	0.342	0.357	0.428	0.571
Industry4-CRITIC	MVC	FR	RO	MED	TVC	SD	GH	MSF	MD	ED	IE
Each unit weight	0.142	0.190	0.214	0.216	0.286	0.357	0.428	0.571	0.576	0.579	0.580

5. Conclusion

Based on the results in the drinking part and also using ENTROPY methods for weighting desalination plants ED, TVC and RO are ranked respectively. On other hand, with CRITIC method this range is different ED, MSF and MED. Also Ghasemi and Danesh (2013), Mohsen and El-Jayyousi (1999), Turk (2003) reached to the same results. This result is opposite to Tomaszewska (2000), Lawson and Liold (1996; 1997) and Li (2005).

In years 1996-2011 in agriculture part and with using ENTROPY method, RO, IE and ED are ranked the best and with CRITIC method IE, ED and MD are ranked as the best alternatives. In this part the results of two weighting methods are not the same. This result is the same as Skiborowski (2012), Zhu et al. (2009 a; b; c), Li (2010), Strathmann (1994), Almulla et al. (2005), Weiss (1996), Kim et al. (2009), Brehant (2002). The results of using CRITIC method is opposite to Park et al. (2011). In industry 1 with ENTROPY method FR, MD and IE but with CRITIC ED, FR and MSF can be selected among all the alternatives. The result of ENTROPY method is consistent with the results of Pingli (2005) and Shone (1987) which introduced FR as the most economical desalination plant. On other hand the result of CRITIC method is opposite to them and is consistent with Ghasemi and Danesh (2013), Mohsen and El-Jayyousi (1999), Turek (2003). In the same table for Industry 2 with ENTROPY method RO, MD and IE. This result is the same with Ghoonemi (2012) and with CRITIC method IE, ED and MVC are ranked the best ones which are not the same with the results of Gryta and Tomaszewska (1998), Guijt et al. (2005 a and b), Ding et al. (2003), Phattaranawik et al. (2001; 2003 a; b). For industry 3 with the ENTROPY method IE, ED and MVC and with CRITIC method MVC, Ro and ED are ranked the best alternatives. The first results for this part are opposite to the results of Martinez et al. (1998), Yao (1992), Towler and Sinnott (2007). For the last industry number 4 with ENTROPY method MD, ED and IE and with CRITIC method MVC, ED and MD are preferred because of their high weight in comparison with other desalination plants. The results of the first part are the same with Dow et al. (2010), Macedonio et al. (2007), Banat et al. (2002) and He et al. (2011). On other hand the results of the second part for industry 4 are the same with the results of Khawaji et al. (2007), Nafey et al. (2006). To conclude this part we can prove that the results are the same in agriculture and industry 2 but for other parts such as drinking the classification and the weights of each unit are not the same. So for years 1996-2011 it is not possible to present a same result for all the parts.

Table shows that in years 2012-2020 in drinking part with two methods ENTROPY and CRITIC the classifications are MSF, MD, TVC and MED, SD, MVC. The first results are consistent with Helal (2005), El- Dessouky et al. (1995) and (1998), Ghounemi (2012), Hamed et al. (2000), Kahraman and Mangen (2005), Borsani and Rebagliati (2005), Nafey et al. (2006), Fulaij (2011). The second results are consistent with SkiBorowski et al. (2012), Wade (2001), El-Dessouky et al. (1998), El- Dessouky (2000), Darwish (2000).

In agriculture part and using ENTROPY and CRITIC, these two classifications are determined: SD, RO and MSF and with the second method MD, RO and ED. The ENTROPY result is the same as Bouchekima (2003). In these two researches solar plants are preferred in comparison with other plants. On other hand the result of CRITIC is consistent with Macedonio et al. (2007), Fane (1992), Banat et al. (2002), Drioli et al. (1999), Tomaszewska et al. (1993) and (2001), Nene et al. (2002), Sakai et al. (1986) and (1988).

In industry 1 and using ENTROPY method MD, MSF and FR and at the same part and using CRITIC method, FR, MD and ED ranked the best alternatives. The results of the first part are consistent with Gryta (2007), Perego et al. (2013), Hausmann et al. (2011a,b and 2012), Jansen et al. (2010), Walton et al. (2004), Blanco et al. (2009). On other hand the second results are the same as the results of Pingli et al. (2005).

In industry 2 and using ENTROPY method FR, RO and MVC and at the same part and using CRITIC, IE, ED and MD are ranked respectively. The first result is consistent with Pingli et al. (2005). What determined the second result shows that IE is the best alternative for desalination process in this part but this result has not been proved by others yet.

Industry 3 ENTROPY shows that MVC, MSF and TVC and CRITIC show that IE, MD and ED are the best choices. The first results are consistent with Khawaji et al. (2007) and Nafey et al. (2006). Industry 4 with ENTROPY and CRITIC shows different results. The first method shows that MD, MSF and GH but the second one shows that IE, ED and MD are the best. The first results are the same as Heinzl et al. (2012), Memsys (2011), Cipollina et al. (2012), Martineti et al. (2009), Cath et al. (2005) and (2011), Wang et al. (2011), Turek and Dydo (2003), Ji et al. (2010), Gryta et al. (2002).

In years 2012-2020 there were not any similar results among all the parts so this shows that in this period there is not any possibility to analyze the using of desalination plants or it might show that in these years there are multiple choices suitable for drinking, agriculture and industry. Thus in agriculture and industry 1 and 4 there is only one desalination plant MD that is selected as the best alternative.

To conclude the result, MVC with ENTROPY method and ED with CRITIC for drinking part for the years considered in this research were the best alternatives. This result is opposite to Salahi et al. (2010), Adham et al. (2011), Alley et al. (2011).

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