Original Article

Assessment of national sanitation foundation water quality index and other quality characterization of Mamloo dam and supporting streams

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ABSTRACT

Aims: This study was aimed to determine national sanitation foundation water quality index (NSFWQI), sodium adsorption ratio (SAR) and some other parameters such as electricity conductivity (EC) and sodium percent (%Na) to investigate the quality of the Jajrood and the Damavand rivers, the mix of them and Mamloo dam.

Materials and Methods: The tested parameters were pH, dissolved oxygen, biochemical oxygen demand, total solids, nitrate, phosphate, turbidity, temperature, fecal coliform, EC, Na, potassium (K), calcium and magnesium. The used indices were NSFWQI, SAR, %Na and magnesium hazard.

Results: average WQI for the Jajrood river (S_1), Damavand river (S_2), mix of S_1 and S_2 (S_3) and the Mamloo dam (S_4) were 71.7 (good), 64.5 (medium), 70.6 (medium) and 77.3 (good), respectively. According to USA Laboratory Diagram and Wilcox diagram, all the sampling points were in C_3-S_1 (very good to good classes), C_2-S_1 (good to permissible classes) categories.

Conclusion: According to the results, the water of sampling points is unsuitable for direct human consumption. However, for the S_1, S_2 and S_3 as drinking water, advanced treatment may be needed. For S_4 as a drinking water source, conventional treatment may be necessary. All the sampling points are suitable for irrigation purposes under normal conditions.

Key words: Mamloo dam, NFEWQO, SAR, surface water

INTRODUCTION

The development and enlargement of Tehran city structure have caused the environmental problems on the watershed of the Latyan dam, which is one of the drinking water resources of Tehran.[1] The Latyan dam is located on downstream of the Jajrood river in the Northeast of Tehran, the capital of Iran. It is one of the most important water supply reservoirs in Tehran city supplying 30% of the potable water in this city.[2]

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Traditional assessment of water quality in water resources consists of comparing the individual water quality parameters levels with their guideline or standard values based on allocated water use or uses. This type of assessment is simple and detailed, but fails to provide a detailed and interpreted picture of water quality especially for managers and decision-makers who require concise information about water bodies. To resolve this decision-making problem, several water quality indices have been developed to transform water quality parameter levels to an integrated indicator value. A water quality index (WQI) describes the general situation of water bodies by changing water quality parameters levels into a numerical score using mathematical tools.[3] Water quality index is one of the most effective tools to monitor the surface water as well as ground water pollution and can be used efficiently in the water quality upgrading programs.[4] Horton developed the first WQI by selecting and weighting water quality parameters and introducing an aggregation function. The WQI was then revised by the U.S. National Sanitation Foundation (NSF) using the Delphi technique. The NSF revised WQI (NSFWQI) has been used all over the world extensively.[3] NSFWQI is an excellent management and general administrative tool in communicating water quality information.[5] Sodium adsorption ratio (SAR) is a measure for the suitability of water for application in agricultural irrigation, as determined by the concentrations of dissolved solids in the water.[6]

Many of the studies have been performed in this regards. The study of Shokuhi *et al*. on evaluation of the Aydughmush dam reservoir water quality by NSFWQI showed that most water samples are in a good category of NSFWQI. Based on the results of NSFQWI calculations, the dam reservoir water quality is suitable for various purposes.[7] In another study, surface water quality of the Godavari river at Aurangabad was investigated. The results of the NSFWQI of Godavari river indicated that its water quality was as bad-medium over the stretch. Based on the results, the conservation measures at the studied point should be reviewed and in this regard additional measures were suggested.[8]

The purpose of the present study was to determine NSFWQI, SAR and some parameters such as electricity conductivity (EC) and sodium percent (%Na) to investigate the quality of Jajrood and Damavand rivers, mix of them and Mamloo dam and that whether these waters could be used for various purposes or not. In this paper, a 2 years monitoring of these waters has been reported. We assess the waters quality for aquatic life, recreational use by NSFWQI and for irrigation by Wilcox and magnesium hazard (MH) indexes.

MATERIALS AND METHODS

Location of sampling

In this research, the study states were divided into four sampling stations for integrated analysis. Jajrood river (S_1), Damavand (S_2), mixed of S_1 and S_2 (S_3) and Mamloo dam (S_4) have been monitored. The locations of these points have been shown in Figure 1.

Analytical procedures

Water quality indexes of the sampling points were the main factors for determination of the water quality. The samples were collected monthly from the S_1 to S_4 from 2008 to 2010. The samples were analyzed according to the standard methods (APHA 2005). The temperature, dissolved oxygen (DO) and pH of samples were measured in the sampling point using a thermometer, DO meter and a portable pH meter, respectively. The biochemical oxygen demand (BOD) was estimated by the modified Winkler method. The turbidity was determined by turbidimeter. The phosphate (PO_4) was measured with digestion and molybdophosphoric reagent. The nitrate (NO_3) value was measured with a spectrophotometer (9200 UV). For the total solid (TS) measuring, a well-mixed sample was evaporated in a weighed dish and dried to constant weight in an oven at 103-105°C. The increase in weight over that of the empty dish represents the TSs. Fecal coliform test was done using the standard method as colony per 100 ml.[9] The entire reagents have analytical grade from Merck Company. The EC was determined with EC meter (Combo meter, Model HI 98129). The Ca^{2+}, Mg^{2+}, Na^+ and K^+ were measured by Ion chromatography.

Water quality indices

The used indices in this study are as following:

Mathematical expression for NSFWQI is given by:

$$NSFWQI = \sum_{i=1}^{p} Wi\ Ii \quad (1)$$

Where Ii is the sub-index for i^{th} water quality parameters, and W_i is the weight (in terms of importance) associated with i^{th} water quality parameter [Table 1].[5] i^{th} parameter can be each of 9 parameters used for NSFWQI calculating.

The formula for calculating SAR is:

$$SAR = [Na^+]/\{([Ca^{2+}] + [Mg^{2+}])/2\}^{1/2} \quad (2)$$

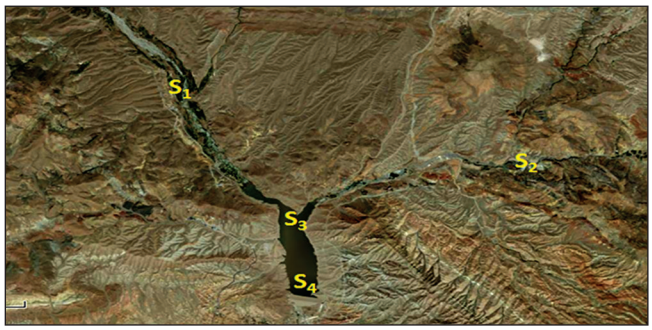

Figure 1: Satellite image of the sampling stations

Where, Na, Ca, and magnesium are in milliequivalents per liter.

For describing the relative activity of Na ions in the exchange reactions with the soil, the SAR index was used. This ration measures the relative concentration of Na to Ca and magnesium.[6]

The formula for calculating %Na is:

$$\%Na = ([Na^+] + [K^+] \times 100/([Na^+] + [K^+] + [Ca^{2+}] + [Mg^{2+}]) \quad (3)$$

Where, all ionic concentrations are expressed in milliequivalents per liter.

The formula for calculating MH is:

$$MH = [Mg^+]/([Mg^+] + [Ca^+]) \quad (4)$$

Where, Ca and magnesium are in milliequivalents per liter.[10]

Some parameters such as pH, DO, BOD and fecal coliforms have been considered four important water quality parameters for classifications of surface water [Table 1].[4] Table 2 shows classification criteria based on NSFWQI.[11] The NSFWQI has been computed for Jajrood river, Damavand river, mix of Jajrood river and Damavand river and Mamloo dam reservoir from April 2008 to February 2009 and from April 2009 to February 2010. The EC, Na, Ca and magnesium were determined for the computing of SAR, %Na and MH indices and Wilcox diagram. Using SAR and EC, the water can be classified for irrigation [Tables 3 and 4].[12]

Table 1: Water quality parameters used in WQI calculating

Parameters	Standard value	Weight
pH	7-8.5	0.11
BOD (mg/L)	1-6	0.11
DO (mg/L)	>6	0.17
TS (mg/L)	500-1500	0.07
Nitrate (mg/L)		0.1
Phosphate (mg/L)		0.1
Turbidity (NTU)		0.08
Fecal coliform (CFU/100 ml)		0.16
Temperature (°C)		0.1

WQI: Water quality index, BOD: Biochemical oxygen demand, NTU: Nephelometric turbidity unit, DO: Dissolved oxygen, TS: Total solids, CFU: Colony forming unit

Table 2: Classification criteria based on NSFWQI

NSFWQI	Water quality	Aquatic life	Recreational use	Category
91-100	Excellent	High diversity	Fully usable	A
71-90	Good	High diversity	Very few limits	B
51-70	Medium	Some stress	Use with caution	C
26-50	Bad	Low diversity	Limited contact only	D
0-25	Very bad	Very limited	No body contact	E

NSFWQI: National Sanitation Foundation Water Quality Index

Table 3: Classification of water for irrigation based on EC

Levels of water salinity	Class	EC (mhos/cm)
Low	C1	100-250
Moderate	C2	250-750
High	C3	750-2250
Very high	C4	<2250

EC: Electricity conductivity

Table 4: Classification of water for irrigation based on SAR

Quality	Class	SAR
Very high	S_1	SAR <10
High	S_2	SAR=10-18
Moderate	S_3	SAR=18-26
Low	S_4	SAR >26

SAR: Sodium adsorption ratio

RESULTS

Jajrood river (S_1)

pH, turbidity, BOD, fecal coliform and TS varied between 8.06 and 8.74, 1.2-45.7 nephelometric turbidity unit (NTU), 1-3.4 mg/L, 24-1600 colony forming unit (CFU)/100 ml and 432-801 mg/L during sampling periods, respectively. Concentrations of NO_3 varied from 3 to 17 mg/L and PO_4 from 0.01 to 0.4 mg/L in 2008-2010. DO varied between 6.3 and 11.2 mg/L in temperatures ranging from 9°C to 22°C in 2008-2010 [Figures 2 and 3].

Damavand river (S_2)

Range of pH, turbidity, BOD, fecal coliform and TS values were between 8.05 and 8.55, 5-640 NTU, 1.1-4.3 mg/L, 2-1600 CFU/100 ml and 467-1245 mg/L during sampling periods, respectively. DO varied between 6.6 and 12.6 mg/L in temperatures between 10°C and 24°C in 2008-2010. NO_3 and PO_4 values ranged between 8.3-15 mg/L and 0-0.09 mg/L in 2008 and 2010, respectively [Figures 2 and 3].

Mix of Jajrood and Damavand river (S_3)

pH, turbidity, BOD, fecal coliform and TS varied between 8.23 and 8.65, 3.9-51 NTU, 1-3.4 mg/L, 13-82 CFU/100 ml and 396-772 mg/L during sampling periods, respectively. Concentrations of NO_3 and PO_4 were between 3 and 17 mg/L and 0.01-0.4 mg/L in 2008-2010, respectively. The range of DO was variable between 7.5 and 11.2 mg/L in temperatures interval between 12°C and 22°C in 2008-2010 [Figures 2 and 3].

Mamloo dam reservoir (S4)

Range of pH, turbidity, BOD, fecal coliform and TS values were variable between 8.1 and 8.37, 2.6-7.8 NTU, 1.2-2.8 mg/L, 2-79 CFU/100 ml and 468-743 mg/L during sampling periods, respectively. PO_4 values ranged between

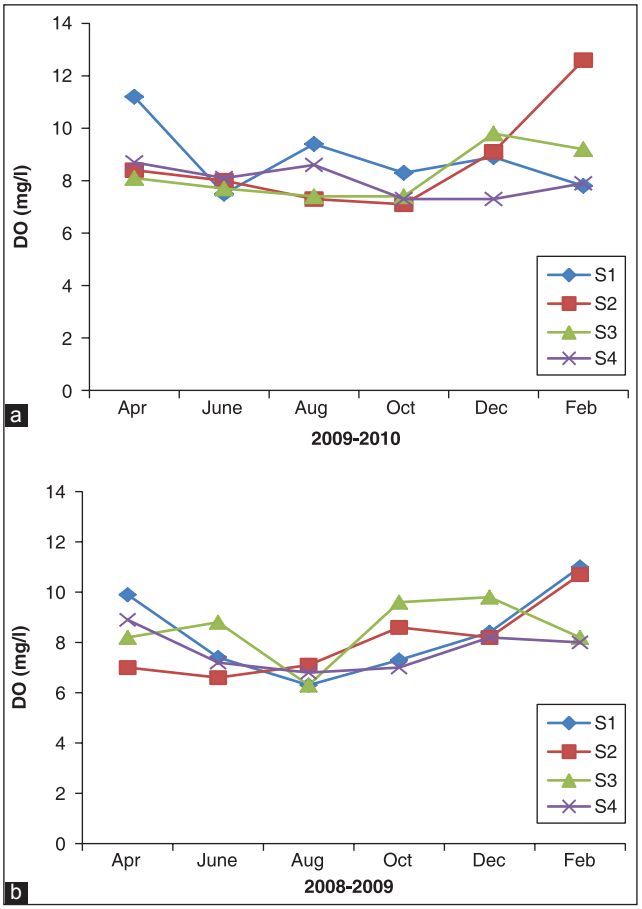

Figure 2: (a) Graph of variation trend of dissolved oxygen (DO) in four stations during April 2008 to February 2009, (b) Graph of variation trend of DO in four stations during April 2009 to February 2010

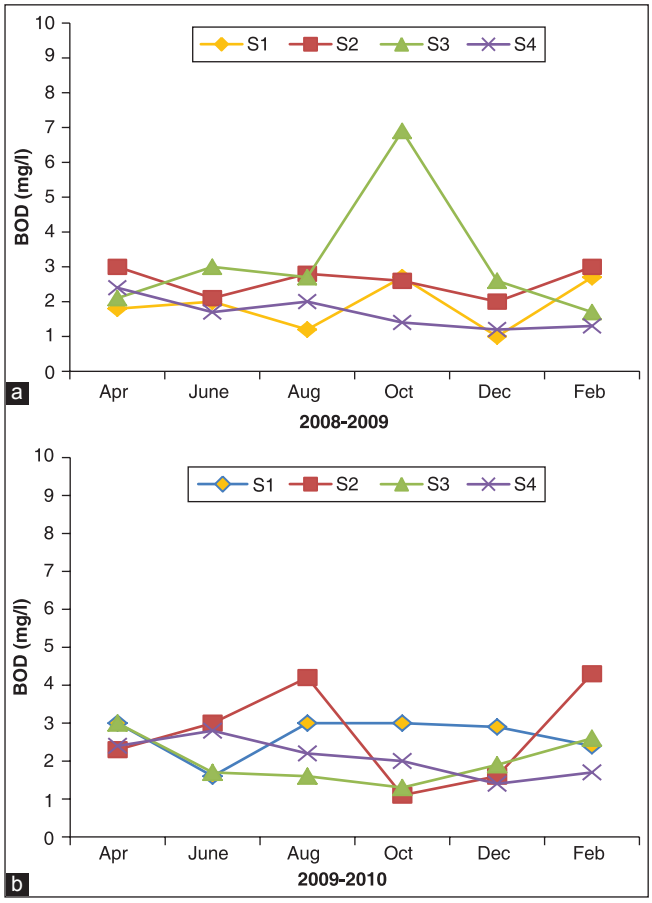

Figure 3: (a) Graph of variation trend of biochemical oxygen demand (BOD) in four stations during April 2008 to February 2009, (b) Graph of variation trend of BOD in four stations during April 2009 to February 2010

0.01 and 0.18 mg/L and concentration of NO_3 was 3-17 mg/L in 2008-2010. DO varied between 6.8 and 8.9 mg/L in temperatures ranging from 10°C to 25°C in 2008-2010 [Figures 2 and 3].

National Sanitation Foundation Water Quality Index

The NSFWQI of Jajrood, Damavand, mix of them and Mamloo dam reservoir has been depicted in Table 5. The classification criteria based on NSFWQI are given in Table 2. According to Table 5, NSFWQI for sampling points 1, 2, 3 and 4 is 64-77, 70-73, 65-75 and 70-81, and the average NSFWQI for these points is 71.7 (good), 64.5 (medium), 70.6 (medium) and 77.3 (good), respectively. Finally, S_1, S_2 and S_3 are in B and C categories from April 2008 to February 2010. At S_4 (Mamloo dam), except in April 2009 (C category), in all the sampling periods of time, NSFWQI was in B category. Figure 4 also shows that water quality index of S_2 (Damavand river) is less than other sampling points in most of the time.

Sodium adsorption ratio and Wilcox diagram

The SAR varied between 0.39 and 4.19 and 0.75-3.5 from April 2008 to February 2009 and from April 2009 to February 2010. Moreover, EC ranged between 441 and 1384 mhos/cm and 480-1337 mhos/cm on these two periods of time, respectively. The %Na varied between 15.9 and 53.4. Furthermore, MH was between 20.8 and 42.3. Mean of EC, SAR and %Na was calculated in 2 years for four sampling points and is represented in Figure 5 and Table 6.

DISCUSSION

At these four sampling points, pH variation was between 8.05 and 8.74 during 2 years being correspondent to standard value (7-8.5) in most of the time. pH was the most stable parameter which, showing no drastic changes during sampling months and sampling points. The result of the study by Jindal and Sharma showed that relatively low values of pH were observed during summer.[13] An inverse relation between pH and carbon dioxide has also been reported by Jindal and Rumana.[14]

Turbidity caused by impurities may include:

i. Clay and silt (runoff),
ii. organic and inorganic matter (by discharged waste),

iii. microorganisms and other organic lives,
iv. colored compounds.

In most of the time, maximum and minimum turbidity was observed in Damavand (S_2) and Mamloo dam (S_4), respectively. Decrease in turbidity in Mamloo dam could be caused by sedimentation in the reservoir. Among sampling months, no significant difference was observed. Results of two studies showed that high values of turbidity have been reported during a rainy season in the Vamura River and the Ganga River.[15,16] In Yamuna river, higher turbidity values during summer have been reported by Narayan and Chauhan.[17] In the aquatic environment, phosphor and nitrogen are essential nutrients for the growth of organisms and complication of their life cycles. Excessive amount of phosphor and nitrogen increases micro-organic aquatic plant and algae activities that cause eutrophication. In this study, the results showed that there is no significant difference between the sampling months and sampling points. Furthermore, concerning the study of Shuhaimi-Othman on the Chini lake, no important change was observed in NO_3 and PO_4 concentrations at different months and sampling points.[18]

Dissolved oxygen is an important factor in water quality and its reduction is due to the discharge of wastewater and other pollutants. DO in fresh water is about 7-9 mg/L, and this

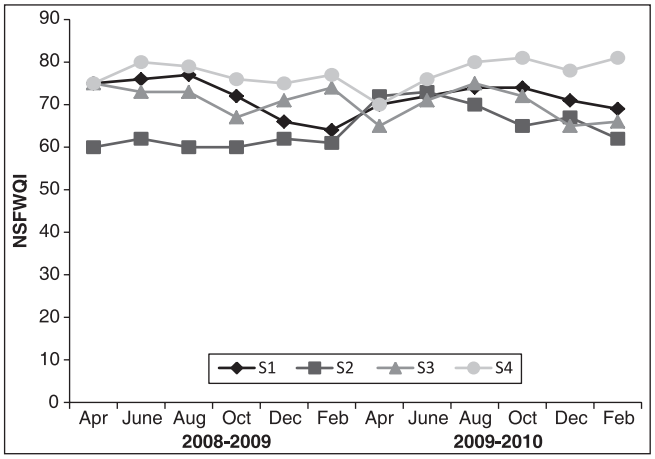

Figure 4: The levels of National Sanitation Foundation Water Quality Index at four sampling sites on 2008-2010 years

Table 5: NSFWQI at four the sampling sites from 2008 to 2010

Years	Months	S_1	S_2	S_3	S_4
2008	April	75	60	75	75
2008	June	76	62	73	80
2008	August	77	60	73	79
2008	October	72	60	67	76
2008	December	66	62	71	75
2009	February	64	61	74	77
2009	April	70	72	65	70
2009	June	72	73	71	76
2009	August	74	70	75	80
2009	October	74	65	72	81
2009	December	71	67	65	78
2010	February	69	62	66	81
	Average	71.7	64.5	70.6	77.3
	Maximum	77	73	75	81
	Minimum	64	70	65	70

NSFWQI: National Sanitation Foundation Water Quality Index

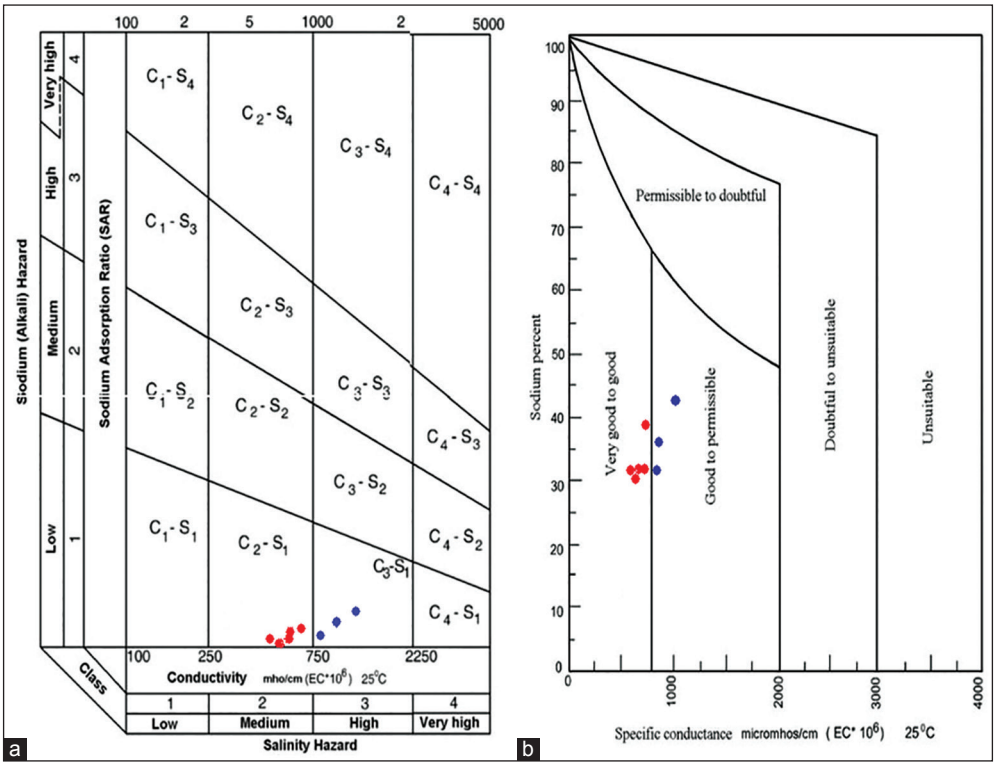

Figure 5: (a) Us salinity diagram and (b) Wilcox diagram

Table 6: Mean of EC, SAR, %Na and MH in 2008-2009 and 2009-2010

Station	EC		SAR		%Na		MH	
	2008-2009	2009-2010	2008-2009	2009-2010	2008-2009	2009-2010	2008-2009	2009-2010
1	771.5	594	1.5	1.2	32.5	29.5	25.3	30.7
2	1050	828	2.7	1.9	42	35	32.2	33.7
3	655	652	1.3	1.4	32	32	31.5	30.6
4	721.5	587.5	1.9	1.3	39	32.5	34.3	35

value might decrease in polluted water. This parameter is usually low in wastewater (about <1 mg/L.) The uncontrolled waste discharging to water can eradicate fish, aquatic animals and microorganisms. According to Table 1, DO >6 mg/L indicates the healthy state of the river system. Results in all sampling periods of time showed DO more than 5 mg/L at all the sampling points.

In the rivers, BOD value above 3 mg/L, indicates the domestic sewage pollution throughout the river stream.[5] In this regards, BOD above 3 mg/L was observed just in June 2008 at S_3 (3.4 mg/L), October 2008 at S_3 (6.9 mg/L), February 2009 at S_2 (3.4 mg/L), April 2009 at S_3 (3.8 mg/L) August 2009 at S_2 (4.2 mg/L) and in February 2010 at S_2 (4.3 mg/L). Furthermore, the results showed that there is no important difference between the sampling points and between the months. Furthermore, BOD suggested no significant correlation with DO. The study of Jindal and Sharma showed an inverse correlation among BOD and DO.[13] According to the results of the BOD and DO, it can be said that these sampling points are in the healthy state in the most of the times.

S_4 NSFWQI has higher value than the other sampling points during sampling periods of time, except in April 2009. The trend of NSFWQI did not experienced high variation at the four sampling points during these 2 years. Hence, S_1, S_2, and S_3 are under B (good) and C (medium) categories and S_4 is in B (good) category. However, the average of sampling points NSFWQI showed that S_1 and S_4 are under B (good) category and S_2 and S_3 are under C (medium) category and so, the S_1 and S_4 have aquatic life with high diversity and recreational uses with very few limits. The S_1 and S_4 are suitable for sensitive aquatic species and pisciculture. If the S_1 and S_2 are used as drinking water, conventional treatment will be necessary. On the other hand, if the S_2 and S_3 are used as drinking water, advanced treatment is needed.[7] The results of Hooshmand *et al*. study showed that at the Karoon river, NSFWQI for the total sampling points is between 50 and 65 (medium or C category).[19]

According to SAR results and Table 3, the total of sampling points are in S_1 (very high quality) category during these 2 years. Moreover, as for EC results and Table 2, Damavand river is C_2 Category (moderate salinity), and the other sampling points are in both C_2 (moderate salinity) and C_3 (high salinity) category. Thereupon, according to USA Laboratory Diagram and Wilcox diagram, all the sampling points are in C_3-S_1, C_2-S_1 categories (very good to good and good to permissible classes). Thus, all the four sampling points water can be used for irrigation. Assessment of %Na showed all the samples are <60% during sampling periods and therefore are suitable for irrigation purposes. Although Ca and magnesium ions are essential for plant growth, they may be associated with soil aggregation and friability. Investigation of MH, showed that the MH is <50, and regarding this value, water samples are safe and suitable for irrigation.[10] In this study, MH varied from 20.8 to 42.3 during sampling periods at four of the sampling points.

CONCLUSION

In this research, the NSFWQI of various water bodies has been studied. The sampling points average was calculated, and the sampling points of 2 and 3 proved to be under C category while sampling points 1 and 4 under B categories. Based on the present investigation, the water of sampling points (S_1, S_2, S_3, and S_4) turned out to be unsuitable for direct human consumption. If the S_2 and S_3 are used as drinking water, they should pass advanced treatment. If the S_1 and S_4 are used as drinking water, conventional treatment will be necessary.

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