Original Article

Water Quality Assessment of Dorudzan Reservoir, Shiraz, Iran, for Drinking and Irrigation Uses

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Abstract

Background and Purpose: Today, by increasing different pollutants, the continuous monitoring of surface waters is essential. Dorudzan Dam is one of the main sources of surface water in Fars Province, Iran; hence, the current study investigated the quality of Dorudzan Reservoir for drinking and irrigation consumptions.

Materials and Methods: In this study, various physicochemical parameters [pH, total dissolved salt (TDS), Ca, Mg, electrical conductivity (EC), HCO_3, CO_3, Na, Cl, NO_2, NO_3, F, SO_4, K, PO_4, TH, sodium adsorption ratio, temperature, and turbidity] were measured. Besides, to determine the water quality in the studied water supply, 31 samples (18 samples in the cold seasons and 13 samples in the warm seasons) were taken from the reservoir outlet. For analyzing the gathered data, Canadian Water Quality Index was utilized.

Results: The irrigation water quality in the reservoir was determined between 73 and 78 (good) in cold, warm, and all seasons together, and for drinking consumption, the value was 89-90 (very good). The model showed that TDS (480.03 ± 59.14) and HCO_3 (206.71 ± 23.75) in the irrigation consumption and EC (693.00 ± 94.11) and turbidity (1.10 ± 0.23) in the drinking consumption had the greatest contributions in reducing the quality of the water source.

Conclusion: The results revealed that generally the physicochemical quality of the reservoir's water was more suitable for drinking consumption in compare to irrigation use. Nevertheless, based on the used model, its quality for irrigation is also desirable.

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1. Introduction

The deterioration of water quality reduces its usability and significantly affects the life of humans, animals, and plants (1,2). Among the various sources of water, surface water is the most vulnerable due to the rather easy discharge of industrial, urban, and agricultural waste waters (3-5). Therefore, to use these resources for agriculture or drinking consumptions, continues monitoring of their quality seems necessary (6,7). For this reason, developing countries have shown a growing interest in water quality monitoring programs over the past decade (4). Hence, many studies have been carried out around the world regarding surface water quality. For example, in separate studies, different researchers measured various physical and chemical parameters to evaluate the quality of surface water resources (3-5,7). Due to its ease of withdrawal, surface water is one of the most widely used water sources. 44% of total water consumption in Iran is from surface water sources (8), and it is estimated to increase in future due to regulations which inhibited the use of groundwater resources in many plains.

Fars Province (South Iran), where drought is one of the most important climatic features (9), water resources management is very important both in quantitative and qualitative terms. Hence, the purpose of this study is water quality assessment of Dorudzan Reservoir, Shiraz, Iran, a major surface water resource in this area, for drinking and agricultural consumptions. Interpretation and decision-making in relation to water quality have always been a great challenge. To resolve this problem, various indices have been developed to measure and define the quality of water resources. These indices need high volumes of data and change them into a set of small and useful information. Examples include the Horton quality index, USA National Sanitation Foundation index, Prati index, McDuffie index, Dinius index, Dojlido index, Walski and Parker index, Nemerow and Sumitomo index, Oregon index, and Harkins index (10,11). Among the various measures which proposed, it seems that the Canadian Water Quality Index (CWQI) is better and more flexible than others are. Thus, in this study, CWQI was used to interpret and analyze the data about the water quality of Dorudzan Reservoir.
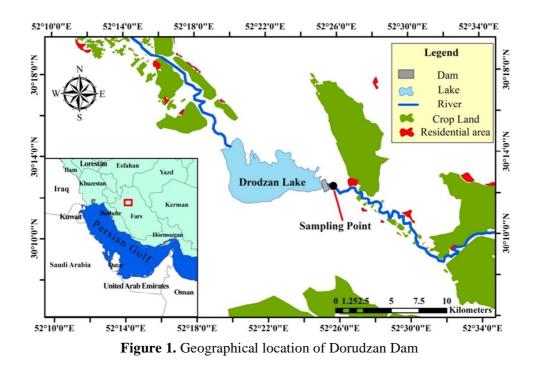
2. Materials and Methods

2.1. Characteristics of the study area

Dorudzan Dam is located in Fars Province (Figure 1), 100 km away from Shiraz, Iran. The lake covers an area of more than 5000 ha (22 km × 2.5 km). The deepest point of the lake occurs during monsoon season, and it is about 60 m at the crown. Dorudzan Dam was constructed, in 1971, to provide water for irrigation of the farms in the area and to supply drinking water for Shiraz. It is an earth dam, and its average depth is 30 m. Average annual rainfall in the area is 412 mm, and the average annual temperature is 15° C.

2.2. Sampling and analysis

All materials used in this study were provided from Sigma-Aldrich and Merck companies. Electrical conductivity (EC) and pH of the sample were measured by EC meter (Metrohm, model 856) and pH Meter (Metrohm, model 827), respectively.

Figure 1. Geographical location of Dorudzan Dam

Concentrations of Ca, Mg, and Na were determined by Jenway flame photometer (Model PFP7). To measure the amounts of SO_4, HACH spectrophotometer (model DR. 2500) was used. Spectrophotometer PG Instruments Ltd. (model T80) was used to measure NO_3 and NO_2. The turbidity was measured by the AQUALYTIC turbid meter (model AL450T). Parameters of HCO_3, CO_3, and total dissolved salt (TDS) were measured based on the proposed method in the Standard Methods for the Examination of Water and Wastewater, 20th Edition.

To test the quality of water supply of Dorudzan Reservoir for drinking and agricultural purposes, 17 water quality parameters including pH, TDS, Ca^{2+}, Mg^{2+}, EC, HCO_3, CO_3, Na^+, Cl^-, NO_2, NO_3, F^-, SO_4, K^+, PO_4, temperature, and turbidity were measured over a year in the warm (spring and summer) and cold (winter and autumn) seasons. Total hardness and sodium adsorption ratio (SAR) parameters were calculated using the measured parameters. 31 samples (18 samples in the cold seasons and 13 samples in the warm seasons) were taken via simple random sampling from the outlet channel of the reservoir and transported to the laboratory for analysis.

2.3. Equations and CWQI model

After sampling and analysis the mentioned parameters, the mean, minimum and maximum variations of each parameter in the warm and cold seasons and all the seasons together were determined and compared with standards for drinking and irrigation purposes (Table 1). SAR was calculated based on equation 1 (7).

$$SAR = \frac{Na^+}{\sqrt{\frac{Ca^{2+}+Mg^{2+}}{2}}} \qquad (1)$$

Table 1. Grouping of values obtained for CWQI (12-14)

Description	WQI value	Rank
There is no threat to the water quality, and these index values can only be obtained when all parameters are within objectives virtually all the time	95-100	Excellent
There is a slight presence of threat or impairment for the water quality	89-94	Very good
There is minor degree of threat for the water quality; conditions rarely depart from desirable levels	80-88	Good
Water quality is usually protected but occasionally threatened; sometimes, conditions depart from desirable conditions	65-79	Fair
Water quality is frequently threatened; conditions often depart from natural or desirable levels	45-64	Marginal
Water quality is almost always threatened and conditions usually depart from desirable levels	0-44	Poor

CWQI: Canadian Water Quality Index

The CWQI was used to determine the quality of the water source for drinking and irrigation purposes. This index is composed of three factors. The first factor (F_1) represents the percentage of variables that do not comply with the guideline during sampling (Equation 2). The second factor (F_2) represents the percentage of failed individual tests (Equation 3).

$$F_2 = \left(\frac{\text{Number of failed variables}}{\text{Total number of variables}}\right) \times 100 \quad (2)$$

$$F_2 = \left(\frac{\text{Number of failed tests}}{\text{Total number of teste}}\right) \times 100 \quad (3)$$

The third factor (F_3) shows the extent of deviation which the failed tests do not meet their objectives. It is calculated in three stages (Equations 4-8). In cases where the test value must not exceed the objective, the index is obtained from equation 4. However, in cases where the test value must not fall below the objective, the index is obtained from equation 5.

$$\text{Excursion}_i = \left(\frac{\text{Failed test value}_i}{\text{Objective}_j}\right) - 1 \quad (4)$$

$$\text{Excursion}_i = \left(\frac{\text{Objective}_j}{\text{Failed test value}_i}\right) - 1 \quad (5)$$

The normalized sum of excursions (NSE) is calculated by equation 6. It normalizes the excursions from the desired standards.

$$\text{NSE} = \frac{\sum_{i=1}^{n} \text{excursion}_i}{\text{Number of teste}} \quad (6)$$

Factor F_3 (Equation 7) is calculated using a formula that scales the nest range between 1 and 100. Finally, CWQI is calculated from equation 8. The CWQI value is compared with table 1, and thus the quality of the water source is determined.

$$F_3 = \frac{\text{NSE}}{0.01\text{NSE}+0.01} \quad (7)$$

$$\text{CWQI} = 100 - \left(\frac{\sqrt{F_1^2+F_2^2+F_3^2}}{1.732}\right) \quad (8)$$

In this study, several standards (Iran and EU) were used to calculate CWQI for drinking water use. FAO guidelines for irrigation water quality were used to calculate the index for irrigation water. To perform calculations and draw graphs, Microsoft Excel 2010 and MedCalc software version 13.0.6.0 (MedCalc Software bvba, Ostend, Belgium) were used.

3. Results

After sampling over a year and measuring the desired parameters, the mean, standard deviation, minimum and maximum of each in the warm, cold, and all seasons together were calculated. These results are shown in table 2.
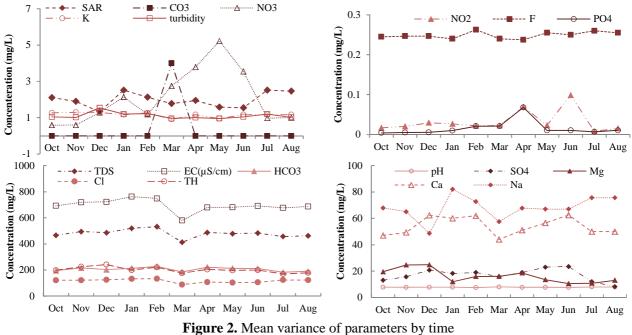
In addition, the variations for each parameter in different months of the warm and cold season are shown in graphs of figure 2.

Table 2. The mean, variations, minimum and maximum of each parameter in the warm and cold seasons and all seasons together

Parameter	Warm season Mean ± SD	Cold season Mean ± SD	All season together Mean ± SD	Min	Max	90% cumulative probability	Guidelines for drinking water	Guidelines for irrigation water
SAR	2.03 ± 0.44	1.92 ± 0.61	1.97 ± 0.54	0.31	2.89	2.52	-	< 3
TDS (mg/l)	475.62 ± 17.48	483.22 ± 77.01	480.03 ± 59.14	199.00	562.00	529.80	< 1500	< 450
EC (µS/cm)	683.77 ± 14.52	699.67 ± 123.97	693.00 ± 94.11	215.00	778.00	752.40	< 700	< 400
pH	7.75 ± 0.26	7.75 ± 0.31	7.75 ± 0.28	7.11	8.40	7.96	6.9-9.0	6.5-8.4
CO_3 (mg/l)	0.67 ± 2.83	0.00 ± 0.00	0.39 ± 2.16	0.00	12.00	0.00	-	< 15
HCO_3 (mg/l)	206.46 ± 18.19	206.89 ± 27.6	206.71 ± 23.75	122.00	244.00	234.24	< 30	< 91
Cl (mg/l)	113.47 ± 9.52	120.31 ± 28.83	117.44 ± 22.78	7.10	140.23	131.00	< 400	< 140
SO_4 (mg/l)	16.47 ± 7.74	16.85 ± 5.57	16.69 ± 6.45	5.76	24.96	23.52	< 400	< 90
Ca (mg/l)	53.23 ± 6.30	53.5 ± 11.67	53.39 ± 9.65	30.00	78.00	65.60	< 300	< 60
Mg (mg/l)	14.26 ± 3.84	19.43 ± 6.51	17.26 ± 6.05	3.60	26.40	24.84	< 50	< 25
Na (mg/l)	70.57 ± 5.6	64.37 ± 19.28	66.97 ± 15.26	8.05	84.87	81.00	< 200	< 69
K (mg/l)	1.13 ± 0.11	1.21 ± 0.26	1.18 ± 0.21	0.39	1.56	1.56	-	< 20
NO_2 (mg/l)	0.05 ± 0.03	0.02 ± 0.01	0.03 ± 0.03	0.01	0.15	0.083	< 3	-
NO_3 (mg/l)	2.9 ± 2.06	1.29 ± 0.98	1.98 ± 1.70	0.19	5.58	5.15	< 50	< 45
PO_4 (mg/l)	0.028 ± 0.06	0.011 ± 0.014	0.018 ± 0.040	0.002	0.230	0.033	-	< 1.21
F (mg/l)	0.25 ± 0.02	0.25 ± 0.02	0.25 ± 0.01	0.22	0.29	0.27	< 1.5	< 1
Turbidity	1.02 ± 0.09	1.16 ± 0.28	1.10 ± 0.23	0.87	1.96	1.35	< 1	-
Total hardness	192.50 ± 14.79	211.94 ± 31.17	203.79 ± 27.07	125.00	275.00	226.00	< 500	-

SD: Standard deviation, SAR: Sodium adsorption ratio, TDS: Total dissolved salt, EC: Electrical conductivity
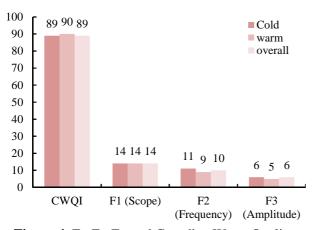

Figure 2. Mean variance of parameters by time
(SAR: Sodium adsorption ratio, TDS: Total dissolved salt, EC: Electrical conductivity)
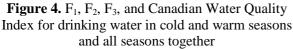
According to equations 1-8 as well as the values obtained from the parameters in cold and warm seasons and all seasons together, F_1, F_2, F_3, and finally CWQI for irrigation and drinking consumptions were calculated. The results are shown in figures 3 and 4.

The results also indicated that among the parameters which failed for irrigation consumption in the warm and cold seasons and all seasons together, HCO_3 had the highest excursion and for drinking water, EC had the highest excursion.
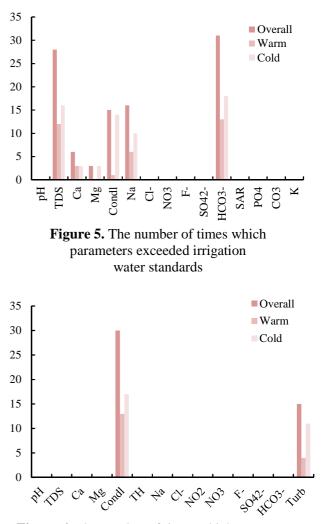

Figure 3. F_1, F_2, F_3, and Canadian Water Quality Index for irrigation consumption in cold and warm seasons and all seasons together

Figure 5. The number of times which parameters exceeded irrigation water standards

Figure 4. F_1, F_2, F_3, and Canadian Water Quality Index for drinking water in cold and warm seasons and all seasons together

Figure 6. The number of times which parameters exceeded drinking water standards

The number of times which parameters exceeded the standards for irrigating and drinking water are shown in figures 5 and 6.

4. Discussion

In this study, water quality of Dorudzan Reservoir in Fars Province, as one of the main sources of water supply for Shiraz,

was investigated using CWQI model for irrigation and drinking use in the cold and warm season's and all seasons together. CWQI is a science-based communication tool that tests multi-variable water quality data against specific water quality standards determined by the user, and finally, it provides an index for overall quality of water resource (15). This index has been developed as a measure to ease the reporting of water quality (14). As shown in figure 3, the CWQI obtained for irrigation consumption was between 73 and 78 in the seasons under investigation. This suggests that quality of the water supply was fair, but its quality falls below the desired level occasionally. As can be seen in figure 3, F_1 shows that the number of parameters that did not meet the desired standards had more negative impacts rather than other factors (F_2 and F_3) on reducing the CWQI, the lower values of these three factors in the warm seasons caused the higher quality (5 units) of the water source for irrigation consumption in the warm seasons. According to figure 5, the parameters of TDS, Ca, EC, Na, and HCO_3 in the cold and warm seasons, and all seasons together, and Mg in the cold and warm seasons, exceeded the specified guideline. TDS and HCO_3 had maximum values in this regard. The maximum excursion from the guideline belongs to HCO_3 parameter. Among the parameters that did not comply with the relevant guidelines, EC and TDS parameters are the most important water quality parameters related to salinity (16). These two criteria have particular importance in irrigation purpose because they can directly affect plant growth by increasing energy requirements of the plant

to absorb water from the soil (17). In this study, the mean TDS exceeded the guidelines about 25-30 units and EC exceeded the guidelines about 283-299 units. The 90% cumulative probability calculated for these two parameters also confirms this. This is showed that if the farms are irrigated using the water from Dorudzan Reservoir; it is likely that the irrigated crop growth is disrupted, and soil salinity increases in the long-term (12). HCO_3 is another parameter that exceeded the guidelines. In general guidelines, HCO_3 > 120 mg/L is the start of concern regarding the potential of soil sodicity if Na > 100 mg/L. High levels of this parameter can cause lime deposit on the leaves and in water supply facilities (16). In a study by Jodari-E-Eyvazi et al. (18) on the relationship between geomorphology and water quality of reservoir water, high concentration of HCO_3 in the reservoir was attributed to erosion of limestone formations in the bottom of the reservoir. Besides, three elements of Ca, Mg, and Na are the main components affecting water quality for irrigation and high concentrations of them can reduce the quality of the soil for the cultivation (19). According to table 2, in the present study, though Ca and Mg met the guidelines, their cumulative probability of 90% exceeded the guidelines set by these elements (66.36 and 24.83, respectively). This suggests that in some cases they exceed the guidelines. Sodium is one of the parameters that exceeded the guidelines. This element not only can have direct toxic effects on plants (20), it can disrupt soil permeability via creating sodic soil condition (21). However, the SAR value calculated in this study

largely reduces the concern about the sodium concentrations in the soil.

Our findings are showed that the physicochemical quality of water in Dorudzan Reservoir for drinking use in the cold and warm season and all seasons together is very good (Table 1). In the other hands, Dorudzan water supply rarely exceeds desired standards. According to figure 4, a number of parameters that did not meet the standards (EC and turbidity) contributed the most in reducing water quality. According to figure 6, turbidity is one of the parameters that exceeded the guidelines in the cold and warm seasons and all seasons together. High turbidity in drinking water, not only leads to esthetic problems, can act as an inhibiting factor against disinfection of drinking water (22). In the present study, despite the mean of this parameter [1.16-1.02 nephelometric turbidity units (NTU)] and its 90% cumulative probability (1.39 NTU) exceeded the guidelines, it does not seem to cause a serious problem for water treatment and using it for drinking consumption. On the other hand, though EC parameters had the highest number of excursion and deviations from the established guidelines, given the mean and 90% cumulative probability, we can conclude that the parameter's distance from the guidelines is not dramatic.

Finally, the quality values of the dam water for drinking consumption in the cold and warm seasons and all seasons together were 16, 12, and 16 units higher than those for irrigation consumption. This shows the better quality of the reservoir water for drinking consumption. It can be said that the greatest threat regarding the quality of the water source for irrigation purpose comes from parameters of TDS, EC, and Na. Regarding the use of the reservoir water for drinking purposes, since additional treatment are applied before consumption, no concern is felt about its physicochemical quality. This study used the CWQI and measured 17 physicochemical parameters to assess water quality of Dorudzan Reservoir for irrigation and drinking use over a year. The results were indicated that the quality of this water resource was better for drinking use than for irrigation consumption so that the calculated CWQI values for drinking purpose were 16, 12, and 16 units higher than those of irrigation in the cold and warm seasons and all seasons together, respectively. For irrigation consumption, HCO_3 and TDS and for drinking consumption, EC and turbidity had the highest contribution in reducing the values obtained. Finally, the present study shows that no serious problems exist in using the water source for both irrigation and drinking purposes.

Conflict of Interests
The Authors have no conflict of interest.

Acknowledgement

References
1. Fulazzaky MA. Water quality evaluation system to assess the Brantas River water.

Water Resour Manag 2009; 23(14): 3019-33.

2. Jindal R, Sharma C. Studies on water quality of Sutlej River around Ludhiana with reference to physicochemical parameters. Environ Monit Assess 2011; 174(1-4): 417-25.

3. Singh KP, Malik A, Mohan D, Sinha S. Multivariate statistical techniques for the evaluation of spatial and temporal variations in water quality of Gomti River (India)--a case study. Water Res 2004; 38(18): 3980-92.

4. Rosli NA, Zawawi MH, Bustami RA. Salak River water quality identification and classification according to physico-chemical characteristics. Procedia Eng 2012; 50: 69-77.

5. Qadir A, Malik RN, Husain SZ. Spatio-temporal variations in water quality of Nullah Aik-tributary of the river Chenab, Pakistan. Environ Monit Assess 2008; 140(1-3): 43-59.

6. Sanchez E, Colmenarejo MF, Vicente J, Rubio A, Garcia MG, Travieso L, et al. Use of the water quality index and dissolved oxygen deficit as simple indicators of watersheds pollution. Ecol Indic 2007; 7(2): 315-28.

7. Alexakis D. Assessment of water quality in the Messolonghi-Etoliko and Neochorio region (West Greece) using hydrochemical and statistical analysis methods. Environ Monit Assess 2011; 182(1-4): 397-413.

8. Arabi-Yazdi A, Alizadeh A, Mohammadian F. Study on ecological water footprint in agricultural section of Iran. Journal of Water and Soil 2010; 23(4): 1-15. [In Persian]

9. Edalatgostar MD, Farzadian A, Amiri SN. Presentation of a stochastic model for the drought prediction in Shiraz city. Proceedings of the National Conference on Water Crisis Management; 2010 Mar 7; Mrvdasht, Iran. [In Persian]

10. Mohan A, Singh R, Jain V. Assessment of water quality in industrial zone of Moradabad: Physico-chemical parameters and water quality index. J Envir Protect Sci 2007; 27(11): 1031-5.

11. Karami B, Dhumal KN, Golabi M, Jaafarzadeh N. Optimization the relationship between water quality index and physical and chemical parameters of water in Bamdezh Wetland, Iran. J Appl Sci 2009; 9(21): 3900-5.

12. Baghapour MA, Nasseri S, Djahed B. Evaluation of Shiraz wastewater treatment plant effluent quality for agricultural irrigation by Canadian Water Quality Index (CWQI). Iranian J Environ Health Sci Eng 2013; 10(1): 27.

13. Hurley T, Sadiq R, Mazumder A. Adaptation and evaluation of the Canadian Council of Ministers of the Environment Water Quality Index (CCME WQI) for use as an effective tool to characterize drinking source water quality. Water Res 2012; 46(11): 3544-52.

14. Khan AA, Khan H, Paterson R. Modification and application of the Canadian Council of Ministers of the Environment Water Quality Index (CCME WQI) for the communication of drinking water quality data in Newfoundland and Labrador. Water Qual Res J Canada 2004; 39(3): 285-93.

15. de Rosemond S, Duro DC, Dube M. Comparative analysis of regional water quality in Canada using the Water Quality Index. Environ Monit Assess 2009; 156(1-4): 223-40.

16. Duncan RR, Carrow RN, Huck MT. Turfgrass and landscape irrigation water quality: Assessment and management. Boca Raton, FL: CRC Press; 2008.

17. Hasheminia M. Water management in agriculture. Mashhad, Iran: Ferdowsi University of Mashhad; 2007. [In Persian]

18. Jodari-E-Eyvazi J, Moghimi E, Yamani M, Mohamadi H, Issaee AR. Effects of ecogeomorphological parameters on chemical water quality case sudy: Kor River and Doroodzan Dam Lake. Geography and Environmental Planning 2010; 21(1): 17-32. [In Persian]

19. Dhembare AJ. Assessment of water quality indices for irrigation of Dynaneshwar Dam Water, Ahmednagar, Maharashtra, India. Arch Appl Sci Res 2012; 4(1): 348-52.

20. Lazarova V, Bahri A. Water reuse for irrigation: Agriculture, landscapes, and turf grass. 1st ed. Boca Raton, FL: CRC Press; 2004.

21. Metcalf and Eddy, Inc. an AECOM Company, Asano T, Burton F, Leverenz H, Tsuchihashi R, Tchobanoglous G. Water reuse: Issues, technologies, and applications. 1st ed. New York, NY: McGraw-Hill Education; 2007. p. 5049.

22. Schwartz J, Levin R, Goldstein R. Drinking water turbidity and gastrointestinal illness in the elderly of Philadelphia. J Epidemiol Community Health 2000; 54(1): 45-51.