Application of CCME-WQI and Trend Analysis for Water Quality Assessment of the largest Dam in Algeria

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Abstract The main goal of this paper is to study the water quality of the Beni Haroun (BH) Dam for different purposes using the Canadian Council Ministers Environment (CMME) index, which included 22 physicochemical parameters observed during 11 years. A principal component analysis (PCA) was performed to reduce the number of dimensions. To identify the sources of possible pollution, data from two other stations, Ain Smara (ST1) and Menia (ST2), situated upstream of the dam are also used. The results show that the calculated values of CCME indices at BH dam for drinking, irrigation, industry, and aquatic life purposes were 17, 40, 42, and 32, respectively, during the period from 2000 to 2010. These indices indicate a poor water quality according to CCME categorization scheme. In this context, Richards Diagram identified two kinds of irrigation water quality in the studied sites, including C3S1 (poor quality) and C4S1 (bad quality). Time series plots and Mann–Kendall test showed a positive trend in the water quality of the BH Dam. This study demonstrates the advantage of CCME index for interpreting spatial and temporal variations in surface water quality.

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Keywords Water quality · CCME index · Trend analysis · Beni Haroun Dam · Algeria

1 Introduction

Water is considered the most important resource sustaining human life and has various uses, such as drinking, irrigation, industry,…etc. Studies on water quality have become increasingly widespread in recent years as a result of their terrible degradation due to climate change and industrial pollutants. In this context, we adopted several techniques and methods such as water quality indices (WQIs) and time series analysis to give an overall picture of water quality at the BH dam for different uses, i.e., drinking, irrigation, industry, and aquatic life. The study also aims to identify the sources that led to deteriorating the quality of water.

2 Materials and Methods

The study area is located in the northeast of Algeria at the Kebir–Rhumel Watershed which covers about 8815 Km^2. The BH Dam is the largest in Algeria based on its storage capacity of 960 Mm^3 [4]. It is located 15 km away from Mila province. This dam is fed by two main streams, Wadi Rhumel (WRH) in the south and Wadi Enndja (WEN) in the west (Fig. 1).

Data used in this study were collected from three sampling stations, i.e., "Ain Smara," "Menia," and "Grarem" (BH station) located in WRH (Fig. 1). Monthly

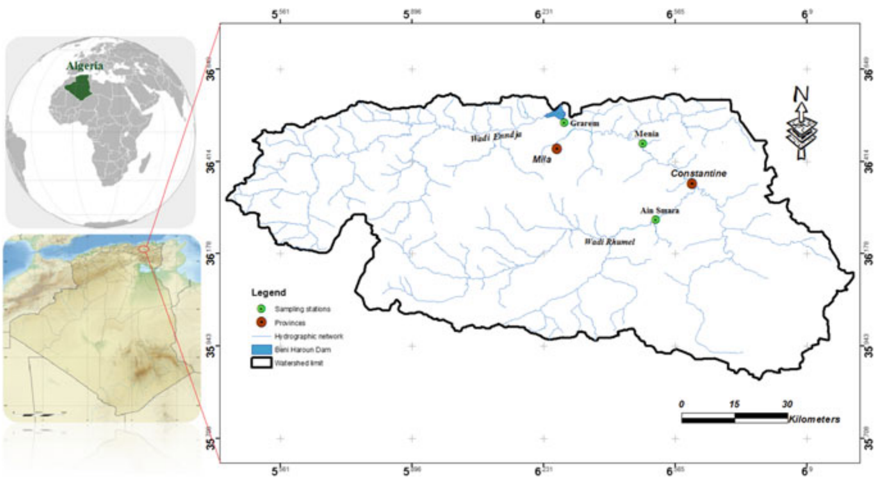


Fig. 1 Hydrographic map of Kebir–Rhumel watershed and the location of BH Dam. Source: [2]

sampling campaigns had been performed by the National Agency of Hydraulic resources (NAHR) for 11 years (2000–2010). Measured parameters include Temperature (T), Dissolved Oxygen (DO), pH, Electrical Conductivity (EC), Total Suspended Solids (TSS), major cations and anions (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, HCO_3^{-}, Cl^{-}, SO_4^{2-}), NO_3^{-}, NO_2^{-}, NH_4^{+}, PO_4^{3-}, COD, BOD, and heavy metals (Cu, Zn, Fe, Mn). In the present investigation, the different computations of WQIs for Drinking (DWQI), Irrigation (IWQI), Industry (InWQI), and Aquatic Life (ALWQI) were implemented using CCME WQI software prepared in Visual Basic by CCME. The CCME categories for water quality classification are (0–44) poor; (45–64) marginal; (65–79) fair; (80–94) Good; (95–100) Excellent. For more details on the calculation of the CCME WQI, please refer to the following reference [1, 3].

3 Results

Kaiser–Meyer–Olkin test value (KMO = 0.743) revealed that there is a relevance of PCA application. PCA has been applied to reduce the number of 22 parameters which are deemed as an input in the CCME WQI calculator to produce the four output indices, i.e., (DWQI, IWQI, InWQI, and ALWQI). However, the result of PCA application showed that all of 22 variables should be taken into account for the computation of WQIs. The obtained results from Table 1 showed that WQIs (DWQI,

Table 1 CCME WQIs values of (ST1), (ST2), and (ST3) during 11 years

Year	Water quality indices											
	DWQI			IWQI			InWQI			ALWQI		
	ST1	ST2	ST3	ST1	ST2	ST3	ST1	ST2	ST3	ST1	ST2	ST3
2000	18	17	20	40	31	37	64	44	67	34	29	65
2001	26	34	17	50	48	45	75	80	72	47	50	59
2002	26	18	14	39	27	29	44	32	34	36	28	28
2003	28	33	23	38	55	36	45	79	35	41	60	42
2004	23	32	20	55	56	33	77	78	34	69	53	36
2005	39	31	43	57	51	60	76	72	74	70	65	75
2006	18	17	47	42	32	66	45	40	87	35	34	91
2007	35	27	52	44	46	67	73	76	87	66	57	83
2008	17	33	48	41	57	71	45	79	88	35	59	83
2009	36	41	54	48	54	70	51	80	88	49	65	90
2010	49	23	64	55	35	72	77	42	100	84	37	100
MIN	**17**	**17**	**14**	**38**	**27**	**29**	**44**	**32**	**34**	**34**	**28**	**28**
MAX	**49**	**41**	**64**	**57**	**57**	**72**	**77**	**80**	**100**	**84**	**65**	**100**
2000–2010	**14**	**15**	**17**	**37**	**31**	**40**	**44**	**39**	**42**	**27**	**29**	**32**

IWQI, InWQI, and ALWQI) had the lowest variation in 2002. The highest variation of WQIs is recorded in 2009–2010. Station 2 had the lowest WQI scores (17, 27, 32, and 28 for DWQI, IWQI, InWQI, and ALWQI, respectively), and station 3 had the highest Indices (64, 72, 100, and 100 for DWQI, IWQI, InWQI, and ALWQI, respectively). The overall value of all WQIs for each use during the period (2000–2010) as follows: 14, 37, 44, and 27 at (ST1); 15, 31, 39, and 29 at (ST2); and 17, 40, 42, and 32 at (ST3) for DWQI, IWQI, InWQI, and ALWQI, respectively.

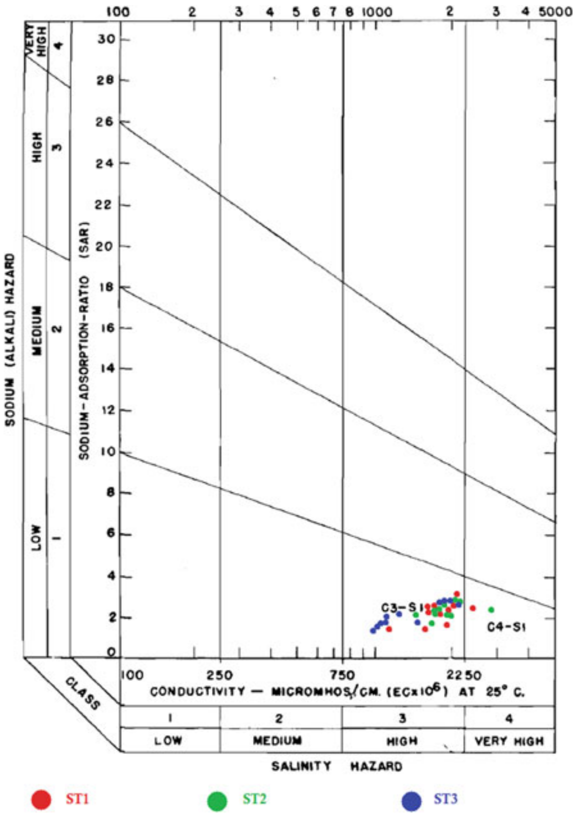
4 Discussion

The three stations can be assessed according to their water quality as poor and classified by the following descending order ST3 > ST1 > ST2. In accordance with these latter results and Fig. 1, we could extract three major remarks: (i) ST1 and ST2 stations in Constantine region are highly contaminated by pollutants where industrial activity is highly intensive [2]; (ii) ST3 had the lowest degree of poor water quality thanks to the reduction of contaminant concentrations by dilution (we deduce that WEN is the reason); (iii) WEN is less polluted than WRH because the WEN basin is characterized by relatively high rainfall (700 mm/year) and a mountainous topography compared to WRH. On the other hand, infiltration properties in the WRH Basin also suggest that the soil is more permeable than in WEN [4]. We observed also that the best value of WQIs in the BH reservoir (ST3) in 2010 because of the implementation of Sidi Merouane Waste Water Treatment Plant (WWTP) which had a treatment capacity of 20,657 m^3/day (start-up in 2009). In the current study, Richards Diagram (Fig. 2) revealed two irrigation water quality categories: C3S1 (poor quality) and C4S1 (bad quality), where (ST1 and ST2) fall in the two categories, whereas ST3 falls in C3S1 category. The temporal variation of WQIs values of the BH dam for each different use is shown in Fig. 3. Using the least squares method (Linear Regression), a positive trend in the water quality of the BH Dam was observed for all WQIs during (2000–2010). The results of the Mann–Kendall (MK) test confirmed the suitability of this method application, in which the all null hypotheses H_0 were rejected, indicating a trend in the data.

5 Conclusions

The overall assessment of the water quality in this case study using CCME WQI during 11 years for different uses showed that the water qualities are considered as "poor." However, the promising thing is a positive trend of water qualities through a temporal variation. This survey demonstrates the usefulness of the several tools used for representing water quality and its evolution with time and space.

Fig. 2 Richards diagram of the 3 stations



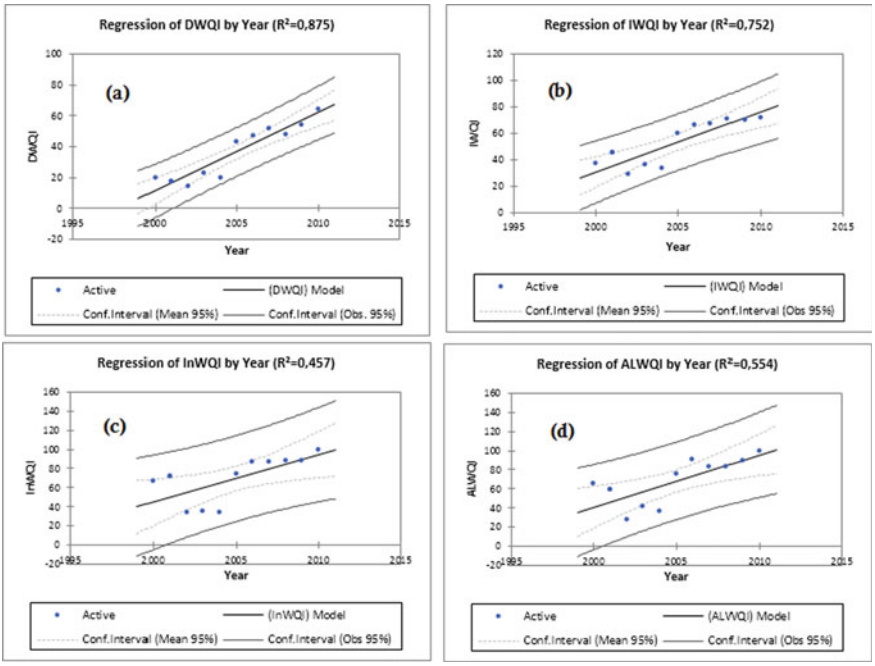


Fig. 3 Temporal variation of all CCME WQIs values for the BH dam (ST3) and their regression trends: **a** Drinking; **b** irrigation; **c** industry; **d** aquatic Life

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