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Evaluating the Water Quality of the Keddara Dam (Algeria) Using Water Quality Indices

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Abstract: Dams are regarded as crucial pieces of structure that store water for irrigation and municipal uses. Given their vital role, the dam's water quality assessment is considered to be an important criterion and requires constant monitoring. In this research, we attempted to use two water quality indices (WQIs) methods to assess the water quality of the Keddara Dam, which is located on the Boudouaou River, Algeria, using eleven water quality parameters (temperature, pH, conductivity, turbidity, total suspended solids (TSS), full alkalimetric title (TAC), hydrometric title (TH), nitrite ions (NO^{2-}), nitrate ions (NO^{3-}), ammonium ions (NH^{4+}), and phosphate ions ($PO_4{}^{3-}$)) for data recorded from 29 December 2018 to 3 June 2021. Application of The Canadian Council of Ministers of the Environment (CCME) WQIs and the Weighted Arithmetic Method (WAM) indicated that the Keddara Dam's water quality parameters were within the WHO's permissible level, except for the conductivity and turbidity values. The results of the CCME WQI ranged from acceptable (81.92) to excellent (95.08) quality, whereas the WAM WQI ranged from 9.52 to 17.77, indicating excellent quality. This demonstrates that the Keddara Dam is appropriate for agriculture and municipal use. The water quality indices (WQIs) methods are recommended as valuable tools that allow both the public and decision-makers to comprehend and manage the water quality of any aquatic environment by providing flexibility in choosing variables.

Keywords: water quality index; surface water quality; water quality assessment

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1. Introduction

Surface water pollution has become a serious environmental issue on a global scale that needs to be continuously assessed and monitored at all scales to ensure the sustainability of ecosystems [1]. Surface water quality monitoring requires a thorough process that involves numerous chemical studies of water [2]. Throughout the world, river systems are significantly impacted by pollution. The primary reason for this is the extremely rapid urbanisation that forces the flow of treated and untreated wastewater into river systems. Harmful chemical pesticides, insecticides, fertilisers, and herbicides are used more frequently as a result of the rapid expansion of industrial facilities along rivers and the increase in agriculture [3]. Water resources, particularly surface water, have gradually declined as a result of this and continuously affect human health, as diseases are largely spread through contaminated water [4]. Every year, water-borne illnesses claim the lives of roughly 1.8 million individuals in developing nations, most of whom are children [4]. Consequently, to protect water resources against harmful contaminants, it is crucial to monitor changes in water quality.

Due to its limited water resources, with annual rainfall of less than 200 mm, Algeria is recognised as an arid and semi-arid region. This results in notable regional and temporal fluctuations in water availability [5]. Approximately 87% of Algeria, covering 2.4 million km^2, is composed of desert which sees little to no rainfall, ranking it among one of the driest countries in the world [6]. Over the past two decades, Algeria's water resources have undergone severe stress due to factors such as urbanisation, climate change, and inadequate water usage planning [5] that, in turn, affect the availability and quality of water. Climate change in Algeria has disrupted weather patterns such as precipitation and the water cycle, which has affected groundwater recharge and soil moisture [5]. In addition, the demand for water for various reasons is rising as a result of the expanding population [7] and increased usage of land for agriculture [8]. Furthermore, numerous types of pollution are degrading the condition of rivers in Algeria. The availability of water resources has decreased and they are difficult to use, and are frequently in contact with large volumes of effluent [9]. There have been concerns about diverse pollution sources causing water quality degradation in some dam lakes over the past few decades [10–14].

To assess the water quality and chemistry in aquatic environments, a variety of methods have been used. Water quality indices (WQIs) are the most efficient way to communicate to the public, decision-makers, and user communities to detect threats to many different uses of water, including habitat for aquatic life, irrigation water for agricultural areas, recreation, aesthetics, and drinking water supplies [9,15]. The WQI model, a mathematical method, is frequently used to evaluate aquatic ecosystem quality from various sources using a set of chosen water quality criteria [16]. The model simplifies a large amount of water quality data into a single composite number [16]. The WQI model is an effective tool that makes it easier to comprehend the overall condition of an aquatic ecosystem based on a single index, in contrast to traditional methods of water quality assessment which involve lengthy lists of parametric water quality values. Understanding this index helps to inform the public and the government about the worldwide condition of the water quality in a certain area [9].

Based on ten indicators that were considered critical for the majority of waterbodies, Horton developed the first WQI model in the 1960s [17]. In 1965, Brown, assisted by the National Sanitation Foundation (NSF), developed the NSF-WQI, a more exacting iteration of Horton's WQI model [17]. This model was partially incorporated into the Scottish Research Development Department's method (SRDD). Other specific indices have been developed, such as the SRDD-WQI (1973), Bascaron Index (1979), Dalmatian Index, and House Index (1986) [17]. The British Columbia Ministry for Environment, Lands and Parks created the British Columbia Water Quality Index (BCWQI) in the mid-1990s, which was another significant development. It is used to assess the quality status of numerous waterbodies in the Canadian province of British Columbia [17]. The Canadian Council of Ministers of the Environment Water Quality Index (CCME WQI) was created in 2001 [18]. Recently, many nations and organisations have introduced more than 35 WQI methods to assess surface water quality globally [19]. The lack of a sufficient dataset and the numerous alternatives for choosing different sets of indicators and objective values are the key challenges in assessing the performance of WQIs in surface water bodies around the world [20].

The Keddara Dam is regarded as the region's backbone and provides water to Algiers for municipal and agricultural purposes. Limited research has been carried out on the water quality of the Keddara Dam water using WQIs methods. Thus, this study was conducted using the Weighted Arithmetic Method Water Quality Index (WAM WQI) and the Canadian Council of Ministers of the Environment Water Quality Index (CCME WQI), to assess the Keddara Dam's surface water quality for drinking purposes.

The findings of this research will provide valuable and new information to policymakers and managers of water resources, helping them make decisions about water resource management regarding the area under investigation. This methodology is transferable and applicable to any dry or semi-arid region, making it a practical instrument for environmental management and assessments.

2. Materials and Methods

2.1. Study Area

The Keddara Dam is located 6 kilometres (4 miles) northwest of Keddara Town, on the Boudouaou River in Boumerdès Province, Algeria (36°39′03.0″ N 3°24′58.9″ E) (Figure 1). The Keddara Dam is also called the Barrage Keddara. Built between 1982 and 1987, the dam supplies water to Algiers, situated 35 km to the west, for municipal use [21]. With a capacity of 146,500,000 m^3 (118,769 acre-ft), the dam's reservoir can store water collected from drainage via a gallery, the Hamiz Dam, 7.6 km to the west, and by pumping water at a rate of 7 m^3/s from the Beni Amrane Dam, 17 km to the east. River Bouira and River Medea are the main sources of the Keddara Dam. The dam is about 100 km east of Algiers. The population density and land use dynamics are rising in the Boumerdès Province. Thus, research in this area will help us to determine if these factors affect water quality.

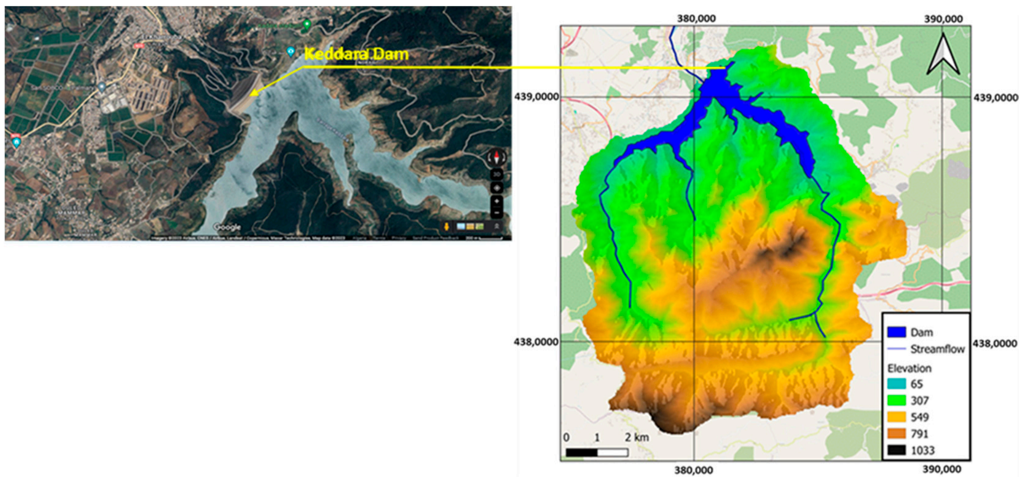

Figure 1. Location of the Keddara Dam (36°39′03.0″ N 3°24′58.9″ E).

2.2. Data Collection and Analytical Techniques

This research employed the use of secondary data obtained from the Algiers Water and Sanitation Company (SEAAL). The SEAAL firm adhered to conventional procedures for analysing water and wastewater in all of their analytical methodologies [22]. The sampling period was from 29 December 2018 to 3 June 2021. A total of 338 water samples with 11 water quality parameters for the period of 29 December 2018–3 June 2021 were collected. These were the only data that were accessible. The parameters chosen for this study were based on parameters with sufficient daily measurements. They are Temperature, pH, conductivity, turbidity, total suspended solids (TSS), full alkalimetric title (TAC), hydrometric title (TH), nitrite ions (NO^{2-}), nitrate ions (NO^{3-}), ammonium ions (NH^{4+}) and phosphate ion (PO_4^{3-}). The data had outliers and missing values, which were considered during the analysis. Days with less than five parameters reported were removed.

2.3. Statistical Analysis of the Water Quality Parameters

Daily time steps are typically used for water quality monitoring in water treatment plants to ensure the system is functioning effectively. This generates time series data for different water quality parameters. Data accuracy is essential for the efficient determination of water quality indices [23,24]. Removing the outliers is crucial to avoid any skewing of the information derived from the raw data. Excel software was used for this analysis.

Detection of Outlier and Normality Testing

According to [24], "An outlying observation (outlier) appears to deviate from other members of the sample in which it occurs and should be identified and removed" [24,25]. To find outliers in this study, the box plot method described by Tukey (1977) was applied [26–28]. The interquartile distance (Q3 − Q1), which is equivalent to 1.5 times the box's height, is typically used to calculate whiskers. In these conditions, a value is considered abnormal if it is more than the interquartile gap either above the third quartile (Q3) or below the first quartile (Q1) [27]. Tukey (1977) [26] asserts that the rule of thumb's pragmatic value of 1.5 is based on a probabilistic basis. The outliers are calculated based on the following equations:

$$\text{Minor outlier (Min. Out.)} = Q1 - 1.5 \times (Q3 - Q1) \quad (1)$$

$$\text{Major outlier (Maj. Out.)} = Q3 + 1.5 \times (Q3 - Q1) \quad (2)$$

Upon detection, outliers were removed to prevent calculation interference. After removal, the raw water samples were reduced to 309 samples. The datasets were then subjected to normality testing. This study used one graphic method (quantile regression) and two numerical methods (Shapiro–Wilk, Kolmogorov–Smirnov) [29]. The different normality tests were implemented to compare different normality methods and account for the small sample size.

a. The Shapiro–Wilk test: If the p-value is greater than the chosen significance threshold (e.g., 0.05), the data are mostly consistent with a normal distribution, and the null hypothesis is still true. If the p-value is less than the significance level, on the other hand, it means that the data deviate significantly from normality, and the null hypothesis is rejected [29].
b. Kolmogorov–Smirnov: By demonstrating that the sample did not originate from the selected distribution, the Kolmogorov–Smirnov test rejects the null hypothesis if the p-value is less than the set significance threshold, which is often 0.05 or 0.01. The null hypothesis cannot be ruled out if the p-value is greater than the significance level, and we may reasonably conclude that the sample may originate from the given distribution [29].
c. Quantile regression approach: Using the quantile regression method, the graph of normal quantiles is produced. A regression model is created for a subset of the response variable's limited distribution. The data have a normal distribution if a linear relation can be inferred from this graph. The closer the R^2 is to 1, the better the data distribution [29].

2.4. Application of Water Quality Index (WQI)

The WQI is the most effective method for characterising the overall water quality based on several parameters. As previously mentioned, WQI may compress a large amount of data into a single number to communicate the information in a straightforward and accessible manner, making it understandable and accessible to a wide audience. The Keddara Dam's water quality index was assessed using the selected methodologies: CCME WQI and WAM WQIs. The methodology of [30] was followed in this study to employ the WHO standards as suggestions for irrigation and drinking (Table 1).

These two popular techniques were selected for this study, mainly because of their ease of use and ease of calculation, as well as their excellent track record with several experts who have evaluated the quality of water from various sources all over the world (Table 2).

Table 1. WHO Standard values used for water quality indices [30–34].

Parameters	Standard Value
Temperature	26.5
pH	8.5
Conductivity	1500

Table 1. *Cont.*

Parameters	Standard Value
Turbidity	5
Total soluble solids	30
Total hardness	50
Full alkalimetric title	20
Nitrite ion	3
Nitrate ion	50
Ammonia	<0.5
Phosphate ion	0.5

2.4.1. Canadian Council of Ministers of the Environment (CCME) WQI

The British Colombia WQI Model (BCWQI) served as the foundation for creating the CCME model in 2001 [35]. Three parameters are included in the CCME-WQI, which offers a measure of the deviation of water quality from water quality guidelines. These parameters are scope, frequency, and amplitude [36]. This model has been used in numerous surface water bodies across the globe.

Table 2. The specialised literature used in this study cites case studies using both methods (CCME-WQI and WAM-WQI).

Study		Method Used	Reference
Country	Water Resource Type		
Puebla valley, Mexico	Groundwater	CCME-WQI	[15]
Reghaia, Algeria	Surface Water	WAM-WQI	[36]
Amman-Zaraq, Jordan	Ground Water	CCME-WQI	[37]
Ohaozora, Nigeria	Ground Water	WAM-WQI	[38]
WWTP of Oran City, Algeria	Wastewater	CCME-WQI WAM-WQI	[39]

i. The CCME WQI method follows the following steps for parameter selection

The user is free to choose which water quality parameters to utilise. The CCME WQI model only mandates the usage of a minimum of four [35]. The developers advise using the evaluation procedures for expert panels in order to choose model parameters.

ii. Sub-index calculation

There is no sub-index calculation component in the CCME model. This is a significant flaw in this paradigm relative to the others.

iii. Parameter Weightings

The final WQI can be calculated without the use of parameter weight values.

iv. Aggregation

The CCME uses an aggregation function that is different from other models. It is written as follows:

$$\mathrm{WQI} = 100 - \left[\frac{\sqrt{F_1^2 + F_2^2 + F_3^2}}{1.732}\right] \tag{3}$$

where

F_1 is referred to as the "scope", This is the portion of all parameters that fall short of the desired outcome.

It is expressed as follows:

$$F1 = \left[\frac{\text{Number of failed parameters}}{\text{Total number of parameters}}\right] \times 100 \quad (4)$$

F_2 is referred to as the "frequency". This fraction of individual test values that do not match the objective values is known as the "frequency" (failed tests).

It is expressed as follows:

$$F2 = \left[\frac{\text{Number of failed tests}}{\text{Total number of tests}}\right] \times 100 \quad (5)$$

F_3: This is calculated in three steps.

1. Calculation of excursion: The number of times an individual concentration exceeds (or falls short of, if the target is at its lowest) the objective is known as the excursion.

The excursion for a test value that is below the objective value is computed as follows:

$$\text{excursioni} = \left[\frac{\text{Failed test value}_i}{\text{Objective}_j}\right] - 1 \quad (6)$$

On the other hand, the excursion value is determined as follows if the test value is greater than the objective value:

$$\text{excursioni} = \left[\frac{\text{Objective}_j}{\text{Failed test value}_i}\right] - 1 \quad (7)$$

2. Calculation of the Normalised Sum of Excursion (nse).

The total amount that each test deviates from compliance is known as the normalised sum of excursions. The computation involves adding up all of the test deviations from the goals and dividing the result by the total number of tests (including goal- and non-goal-achieving tests).

$$\text{nse} = \left[\frac{\sum_{i=1}^{n} \text{excursion}_i}{\text{Total of number of test}}\right] - 1 \quad (8)$$

3. Calculation of F_3

An asymptotic function is used to calculate F_3, scaling the normalised total of the deviations from targets to produce a range from 0 to 100.

$$F3 = \left[\frac{\text{nse}}{0.01(\text{nse}) + 0.01}\right] \quad (9)$$

4. WQI evaluation

The CCME model proposed five water quality classes, as shown in Table 3.

Table 3. CCME WQI scale [35].

CCME WQIs	Quality Range	Water Categories
95–100	Excellent	Natural water quality
80–94	Good	Water quality is departed from natural or desirable levels
65–79	Fair	Water quality condition sometimes departs from natural or desirable levels.
45–64	Marginal	Water quality is frequently threatened or impaired; conditions often depart from natural or desirable level
0–44	Poor	Water quality is not suitable for use purposes at any level.

2.4.2. Weighted Arithmetic Method (WAM)

This approach, which is popular and straightforward, combines data for many water quality criteria into an equation that evaluates the quality of the water and gives decision-makers and interested individuals a single, easily comprehensible statistic. It achieves this by calculating the unit weight and quality rating scale for each water quality parameter. Furthermore, it requires fewer parameters than all the water quality characteristics for a specific purpose to characterise surface and groundwater sources' quality that is sufficient for human consumption [39]. To categorise water quality according to the level of purity, the most measurable parameters were used [40].

The weighted arithmetic method's computation is as follows:

$$\text{WQI} = \sum \text{QiWi} / \sum \text{Wi} \tag{10}$$

Each water quality parameter's unit weight (Wi) is determined using the following formula:

$$\text{Wi} = \text{K}/\text{Si} \tag{11}$$

where K stands for the proportionality constant and can also be found using the following equation:

$$\text{K} = \frac{1}{\sum \left({}^{1}/_{S_i} \right)} \tag{12}$$

For every parameter, the quality rating scale (Qi) is computed using the following expression:

$$\text{Qi} = 100 \times [(\text{Vi} - \text{Vo})/\text{Si} - \text{Vo})] \tag{13}$$

where for every parameter, the quality rating scale (Qi) is computed using the following expression:

Vi: the concentration of the ith parameter of the analysed water.

However, the pH = 7.0 and DO = 14.6 mg/L, Vo = 0, which is the ideal value of this parameter in pure water.

Si represents the recommended standard value of the ith parameter.

The weighted arithmetic water quality index method scale [36] is shown in Table 4.

Table 4. WAM WQI Scale [36].

WQI Value	Rating of Water Quality	Grading
0–25	Excellent water quality	A
26–50	Good water quality	B
51–75	Poor water quality	C
76–100	Very poor water quality	D
>100	Unsuitable for drinking	E

3. Results and Discussion

3.1. Descriptive Characteristics of the Keddara Dam

Table 5 displays the descriptive characteristics of the water quality parameters in the chosen the Keddara Dam over the monitoring period from 29 December 2018 to 3 June 2021 based on daily measurements.

The pH is a measurement of how acidic/basic water is. This is an important water quality parameter that determines the solubility and biological availability of different chemical constituents in water. The pH values of the dam water during the study period ranged from 7.5 to 8.32, indicating that the water was within an alkaline range. The values are within the permissible ranges (6.0 and 9.0) described in the WHO guidelines. According to the research carried out by [41], algae use CO_2 in their photosynthetic activity, leading to an increase in pH values due to a shift in the forms of alkalinity present from bicarbonate to carbonate [42].

Table 5. Descriptive characteristics of the Keddara Dam.

Parameters	Temp. °C	pH	EC µS/cm	Turb. NTU	TSS mg/L	TH F^0	TAC F^0	NO_2^- mg/L	NO_3^- mg/L	NH_4^+ mg/L	PO_4^{3-} mg/L
Minimum	11.70	7.5	988	1.30	1.30	29.0	15.60	0.00	2.27	0.00	0.015
Q1	14.50	7.82	1147	3.68	3.59	39.0	17.20	0.02	3.96	0.015	0.015
Median	16.90	7.96	1231	5.90	6.40	42.8	17.80	0.02	6.31	0.015	0.015
Mean (Q2)	17.74	7.93	1243	6.72	6.68	42.18	17.57	0.03	6.68	0.023	0.025
Q3	20.90	8.04	1358	9.08	8.86	45.40	18.00	0.03	5.85	0.019	0.032
Max (Q4)	25.30	8.32	1525	23.70	22.00	50.60	20.80	0.22	10.00	0.23	0.095
Min outlier	4.9	7.49	830.5	−4.42	−4.32	29.4	16	0.003	−0.97	0.01	0.011
Maj outlier	30.5	8.37	1674.5	17.18	16.77	55	19.2	0.049	12.18	0.025	0.058
Permissible limit (WHO)	26.5	8.5	1500	5	30	50	20	3	50	≤0.5	0.5

Turbidity is a crucial factor in drinking water, as it can affect consumers' acceptability of water and its utility in some industries. In addition, difficulties in the treatability of water may be encountered in some water treatment plants [43]. The turbidity readings for the Keddara Dam's surface water ranged from 1.3 NTU to 23.70 NTU, exceeding the threshold permitted by the WHO.

The salinity of water can be identified based on electrical conductivity (EC) or the total dissolved solids (TDS). It is an expression of the ability of water to carry an electric current and is directly related to major ions and the amount of TDS. Moreover, it is important as it impacts the taste and user acceptance of the water as potable [44]. High conductivity can originate from human activity, like sewage and industrial effluent, or it can occur naturally as a result of the weathering of some sedimentary rocks [44]. The Keddara Dam's water has conductivity values ranging from 1015 µS/cm to 1523 µS/cm, slightly exceeding the recommended levels set by the WHO (Table 5).

The hardness of water is indicative of a large concentration of dissolved minerals leading to an increase in conductivity. It is a crucial indicator of water quality that determines whether it is suitable for use in agriculture, industry, and residential settings or not. For area under investigation, the WHO criterion of 50 F^0 was met by the dam water, as the TH ranged from 29 F^0 to 50.60 F^0. The water's overall alkalinity is influenced by these ions. In addition to this, the geology of the region the river passes through determines the hard water level. The mean TAC for dam water ranged from 15.60 F^0 to 20.80 F^0, within the WHO standard limit.

NH_{4+}, NO_3^-, NO_2^- and PO_4^{3-} totally referred to as essential nutrients for algal growth. They recorded low concentrations in dam water and none of them exceeded the standard limit for WHO standards (Table 5). The low mean values of nutrients in the Keddara Dam's water indicated less contamination from the catchment area.

3.2. Outlier Detection Normality Testing

The distribution of the raw data of water from the Keddara Dam (before outliers were removed) for water quality parameters is represented in Figure 2.

After the outliers were removed, normality tests were performed (Table 6). The box plots show that the distribution of the measured values is asymmetric, except for TSS. For temperature, EC, turbidity, NO_2^-, NH_4^+, and PO_4^{3-}, the distribution spreads towards the large values. On the other hand, for pH, TH, TAC and NO_3^- values, the distribution spreads towards small values. This means that for all parameters, the data are not normally distributed, except for TSS. In this context, removing outliers proves to be an effective data processing operation to determine significant WQIs.

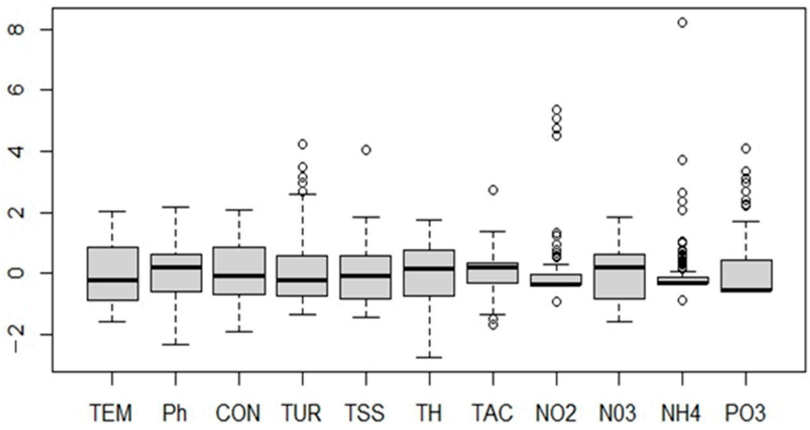

Figure 2. Boxplot of the Keddara data before removal of outliers.

Table 6. Normality test of the Keddara water quality parameters.

Water Parameters	Sample Size	Shapiro–Wilk Test	Kolmogorov Test	R²
Temperature	309	1.12×10^{-10}	0.8681	0.94
pH	309	4.853×10^{-6}	0.9982	0.97
Conductivity	309	6.243×10^{-6}	0.4846	0.98
Turbidity	309	2.877×10^{-9}	0.9826	0.95
Total dissolved solids (TSS)	55	0.1075	0.7854	0.98
Hydrometric title (TH)	24	0.1599	0.6574	0.95
Full alkalimetric title (TAC)	23	0.3749	0.83	0.96
Nitrogen oxide (NO_2^-)	104	$<2.2 \times 10^{-16}$	0.4472	0.29
Nitrate (NO_3^-)	28	0.2789	0.9841	0.97
Ammonia (NH_4^+)	110	$<2.2 \times 10^{-16}$	0.4472	0.34
Phosphate ion (PO_4^{3-})	104	1.325×10^{-14}	0.4472	0.63

Using Shapiro–Wilk test analysis, the *p*-value of all parameters except TSS, TH, TAC, and NO_3^- was found to be statistically significant at level (0.05) (Table 6). This means that data is not normally distributed. This might be because the Shapiro–Wilk test is used to analyse the normality of small data sizes [33]. On the other hand, the Kolmogorov–Smirnov test of the raw water showed that all parameters were normally distributed (>0.05) except PO_4^{3-}, NH_4^+, and EC. In contrast to the Shapiro–Wilk test, this test is well suited to a long series of data [33]. Aside from NO_2^-, NH_4^+, and PO_4^{3-} values, the quantile regression approach showed that all other parameters represented a good linear relationship with an R^2 that varied from 0.94 to 0.98.

3.3. Assessment of the Keddara Dam's Surface Water Using Water Quality Indices

The outcomes of the monitoring program at the Keddara Dam involve a complex matrix of physical and chemical factors. Each of these factors alone is not sufficient for a dependable assessment of the quality of the water over time. To overcome these challenges, two water quality indices (WQIs) were applied to summarise many monitored parameters into one simple term (Table 7).

According to the computed WQI values obtained using the CCME, the water quality of the Keddara Dam water was good (81.92) during the study period, except during the COVID-19 lockdowns when the dam's water turned out to be of "excellent" quality (95.09) (Table 7). The excellent characteristics during this period can be attributed to low human activities. When the other method (WQI WAM) was used, the results showed that the seasonal surface water quality ranged from approximately 9.52 to 17.77 (excellent condition) and complied with WHO standards (Table 7). The excellent conditions for all seasons compared to the CCME WQI can be attributed to the rating scale used by this method. Consequently, according to both methods, the water quality of the Keddara Dam is suitable for irrigation usage and indicated that the Algerian government have set effective regulations to stop the illegal dumping of waste by industrial and municipal activities since the establishment of Law No. 83-03 on 5 February 1983 relating to environmental protection [45]. This, in turn, helped increase the purity of the Keddara Dam water reaching the water treatment plant.

Table 7. Results for CCME WQI and WAM WQI methods.

	Years	**29 December 2018–29 March 2019**	**3 April 2019–28 September 2019**	**2 October 2019–31 March 2020**	**4 April 2020–29 September 2020**	**2 October 2020–31 March 2021**	**3 April 2021–3 June 2021**
	Season	**Wet**	**Dry**	**Wet**	**Dry**	**Wet**	**Dry**
CCME WQI	Total number of tests	177	383	383	297	348	96
	Number of field parameters	1	1	1	1	1	2
	Number of failed tests	31	76	43	21	63	20
	F_1	9.09	9.09	9.09	9.09	9.09	18.18
	F_2	7.51	7.15	11.23	7.07	18.10	20.83
	F_3	12.69	2.54	3.19	2.06	16.99	14.68
	WQI	86.45	93.16	91.46	95.09	88.34	81.92
	Quality range	Good	Good	Good	Excellent	Good	Good
WAM WQI	WQI	14.68	9.52	11.23	12.45	17.77	15.99
	Quality range	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent

Currently, there is no research evaluating the water quality of the Keddara Dam using the water quality index methods. However, some researchers have evaluated the dam's water quality using laboratory techniques. The results presented in this paper align with those presented in research carried out by Ghemmit-Doulache and Ouslimani [46], who measured the physicochemical, biological, and heavy metal parameters at three sites at the Keddara Dam using laboratory techniques. They revealed that the sites' physical qualities met WHO standards, while the chemical quality showed increased hardness. Another study was performed by Guettache et al., [47] to determine the water quality of the Keddara Dam before and after treatment using laboratory analysis. Based on their findings, they highlighted that the maximum and minimum temperature, conductivity, pH, and nitrate were within the Algerian standards, while the turbidity and ammonia values were above the norm.

A comparison between the Keddara Dam WQI and other Algerian case studies is presented in Table 8.

As shown in Table 8, the quality of the water in our case study is different compared to that of the other studies. This can be explained by the fact that the water mobilised by the Keddara Dam is not overly affected by human activities, especially as the Boudouaou catchment area has neither large urban areas nor industrial activity zones upstream of the dam.

It is worth noting that every WQI method used in this study could be readily implemented and serve as a guide for similar projects aiming to assess the performance of any dam or treatment plant.

Table 8. Comparison between the Keddara Dam WQIs and other Algerian case studies.

Study		Method Used	Water Quality	Reference
Case Study	**Lambert Coordinates**			
Keddara Dam	36°39′03″ N, 3°24′59″ E	CCME-WQI	Acceptable to excellent	This study
		WAM-WQI	Excellent	
Reghaia lake	36°46′17″ N, 3°20′38″ E	CCME-WQI	Unsuitable	[36]
		WAM-WQI	Poor	
Beni Haroun Dam	36°33′19″ N, 6°16′11″ E	CCME-WQI	Poor	[48]
Boukourdane Dam	36°31′40″ N, 2°18′14″ E	NSF-WQI	impaired	[49]
Hammam Boughrara Dam	34°53′03″ N, 1°38′51″ W	CCME-WQI	Poor	[50]
Sikkak Dam	35°02′42″ N, 1°20′27″ W	CCME-WQI	Marginal	[50]
Cheurfa Dam	35°24′11″ N, 0°15′14″ W	CCME-WQI	Marginal	[50]

4. Conclusions and Recommendations

This study will be the first to apply WQI to the Keddara Dam. It allowed us to evaluate the Keddara Dam's water quality using the CCME WQI and WAM WQI techniques. The dam's water quality was assessed using the concentrations of 11 physicochemical parameters such as temperature, pH, conductivity, turbidity, total suspended solids (TSS), full alkalimetric title (TAC), hydrometric title (TH), nitrite ions (NO^{2-}), nitrate ions (NO^{3-}), ammonium ions (NH^{4+}), and phosphate ions ($PO_4{}^{3-}$)). The results revealed that all parameters' concentrations were within the permissible ranges stated in the WHO guidelines, except for turbidity and salinity parameters, for which values exceeding these ranges were recorded. Before establishing the WQI, the measured values were cleansed of outliers and their normal distribution was examined. When using the CCME, the water quality of the Keddara Dam ranged from good to excellent (81.92 to 95.09), while the WAM quality ranged from 9.52 to 17.77 (excellent condition). These results indicated that raw water from this dam is of good quality. Nevertheless, before it can be used for municipal purposes, it still needs to undergo more standard treatment (pre-treatment, clarity, and disinfection).

This study's applied methodology may be relevant to areas with similar characteristics in Algeria and elsewhere. This will help decision-makers manage water resources. In prospective, other analyses such as heavy metals and bacteriological analysis are necessary to develop a control approach to limit any negative impacts of the dam's water. Besides, it is advisable to construct an artificial intelligence model for future analysis of temporal and spatial changes, as well as predictions of water quality in the context of sustainable development and preservation of water resources.

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