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Assessment of Water Quality of Kodiat Rosfa Dam and Suitability For Consumption and Irrigation (Algeria)

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Abstract. The approach adopted for the assessment of Kodiat Rosfa dam water quality, through the respective indexes WQI and IWQI, allowed to highlight the quality of its waters for the intended uses. Indeed, the physicochemical analyzes of the months of February, March, July and December, corresponding to the monthly precipitation and regularized volumes of 2013, 2014, 2015 selected, revealed that 08 samples out of 12 have a WQI within 50 to 100, and 04 samples with WQI lower than 50. This classified the dam waters as good to excellent for consumption. Nevertheless, the results of IWQI index used to assess the quality of dam water Kodiat Rosfa for irrigation show that 7 samples out of 12 present an IWQI within 55 to 70 and 5 samples with IWQI lower than 55. These waters are characterized by moderate (MR) to high (HR) restriction.

Keywords. Kodiat Rosfa, WQI, consumption, irrigation, index, restriction.

I. INTRODUCTION

Among the 43 million cubic meters of water exploited annually in the province of Tissemsilt, 16.8 Hm^3 are of surface water and 18.8 Hm^3 of underground resource. The rest is unconventional water.

By itself, the dam of Kodiat Rosfa provides 9.1 Hm^3 for drinking water supply to 14 municipalities or 54.16% of surface water. As against it contributes only by 6 Hm3/year for irrigation or 35.7% [1].

Given the importance of this resource for the development of Tissemsilt province, the assessment of the water quality of this dam becomes a priority. The method of water quality index is a relevant and unique approach to describe the general state of water quality and provides appropriate responses to the problems raised [2]. It is widely used throughout the world for water quality assessment in United States of America, Canada, Spain, France, Germany, Austria, Italy, Poland and Turkey [3].

By its simplicity, the WQI Initiated by [4,5], expresses a large amount of information in a single number which is dimensionless generally. To calculate this index, Horton (1965) proposed the first formula which takes into account all the parameters necessary for determining the quality of water and reflects the influence of the most important parameters in evaluation and management[6,7].

This approach inspired Meireles et al., (2010) [8], to develop their own IWQI water quality index for irrigation and to give a complete picture of the quality of both surface and groundwater use [9].

The physico-chemical analyzes of the months of February, March, July and December for three years 2013, 2014, 2015, were selected in this study. These months represent the extrema of monthly mean of both volume and precipitation over 10 years.

II. MATERIAL AND METHODS

- **Geographical location**

Administratively, the Kodiat Rosfa dam belongs to the province of Tissemsilt. It is part of the sub-basin of Oued Fodda in the Chéliff. It is located at Lambert coordinates (X = 414.48 km Y = 283.05 km) and covers 440 km² of area which intercepts annually 323 mm of precipitation.

Oued Besbes, Oued Fodda, Oued El mellah, Oued Bou karroucha are the main tributaries of the sub-basin which is characterized by a much branched hydrographic network and extremely irregular runoffs totaling an average annual contribution of 25.4 Hm^3 (Fig.1). The mean altitude of the sub-basin is 904m.

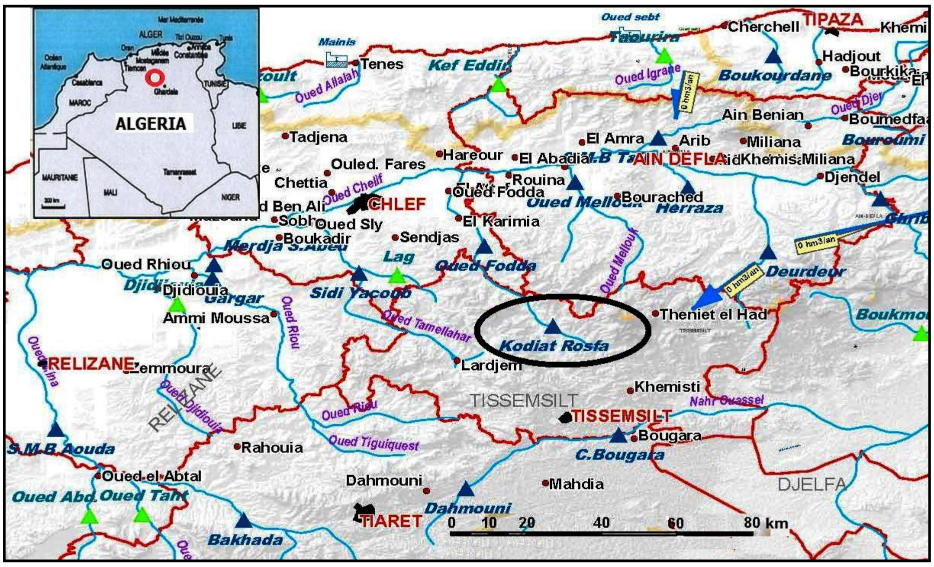

FIGURE.1 Location of dam Kodiat Rosfa [10].

- **Bioclimatic characteristics**

According to the classification of Mediterranean climates established by Emberger, the bioclimate of the study area is semi-arid with a cold winter. The mean annual precipitation in the region is 323 mm. Mean monthly precipitation ranges from 2.4 mm in July to 52.7 mm in February. Monthly evapotranspiration measurements in the region range from 35 mm to 264 mm. The mean annual evapotranspiration is 1549 mm. The superposition of the mean monthly rainfall values on those of potential evapotranspiration [11], allowed distinguishing the water deficit period which extends from February to December (Fig. 2). The total annual deficit is 1225 mm.

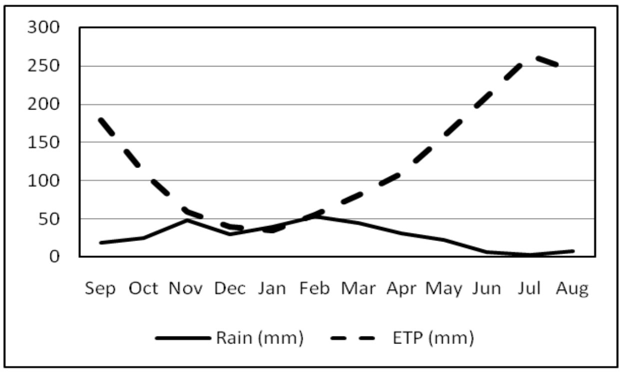

FIGURE 2. Climatic characteristics.

- **Basic data**

The physicochemical analyzes correspond to the months of February and July for monthly rainfall (Max and Min). April and December for monthly (Max and Min) regularized volumes for each year studied (2013, 2014, 2015). The effects of dilution and diffuse pollution generated by runoff at wet season as well as the increased pressure on the resource accentuated by evaporation in the dry season have dictated the choice of these months which represent the extrema of mean precipitation and mean monthly regularized volumes recorded at the dam for a period of 10 years (Fig. 3 and 4).

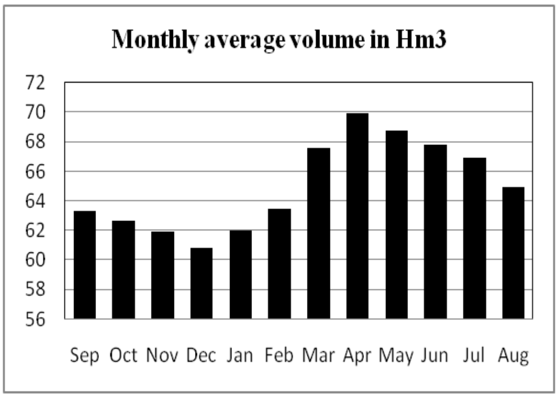

FIGURE 3. Mean monthly regularized volume in Dam KR.

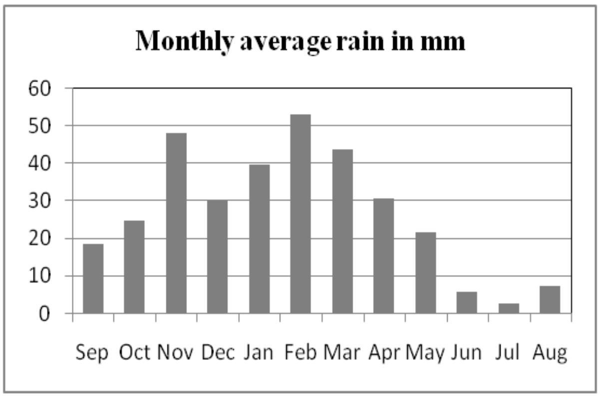

FIGURE 4. Mean monthly rain at the Dam KR.

- **Calculation of water quality index for consumption (WQI)**

The water quality index is a practical tool that makes it possible to synthesize the composite effects on water quality and to assess the influence of natural and anthropogenic factors on the basis of several parameters, the most important of which are (EC, pH, DO, SO4, BOD5, COD, TSS, N-NH4, N-NO3, Ca, Mg, Na, Cl, HCO3, and PO4). It is used in this study to classify the water quality of Kodiat Rosfa according to WHO and national standards. The WQI defines 5 quality classes [9], (Table 2). It is calculated by the weighted arithmetic index method [5-14]. The specific relative weight of each physicochemical parameter (Wi) is calculated according to the following formula:

$$W_i = \frac{k}{S_i}$$

With :
k: Proportionality constant calculated using the following equation:

$$k = \frac{1}{\sum_{i=1}^{n}\left(\frac{1}{S_i}\right)}$$

n : Number of parameters
Si : Maximum of standard values for surface water quality (Table I).

(*) WHO standard values, (2011)

– Quality rating scale:

$$Q_i = \left(\frac{C_i}{S_i}\right) * 100$$

Qi: rating scale for the quality of each parameter.
Ci: Measured concentration of each parameter in mg/l

$$WQI = \sum_{i=1}^{n} Q_i * \frac{W_i}{\sum_{i=1}^{n} W_i}$$

- **Classification and possible use of water**

Five water quality classes can be defined according to the values of the WQI water quality index (Table II).

TABLE 1. Algerian and who standards of water quality intended for drinking [15,16].

Parameters	Units	WHO & National (2011) Standard values
pH	-	≥ 6,5 et ≤ 9
EC	(µs/cm)	2800
DO	%	30
Ca	(mg/l)	200*
Mg	(mg/l)	150*
Na	(mg/l)	200*
Cl	(mg/l)	600
SO_4	(mg/l)	400
HCO_3	(mg/l)	300*
NO_3	(mg/l)	50
NH_4	(mg/l)	4
PO_4	(mg/l)	5*
BOD_5	(mg/l)	7
COD	(mg/l)	30
TSS	(mg/l)	25

TABLE 2. Classification of wqi values for human consumption [9-19].

Class	WQI range	Water type
C1	<50	Excellent water
C2	50 - 100	Good water
C3	100 - 200	Poor water
C4	200 - 300	Very poor water
C5	>300	Unfit for drinking

- **Calculation of index water quality for irrigation (IWQI)**

Many researchers have developed several indices to measure the quality of water according to specific conditions and objective [2]. The IWQI model was developed by [8]. Simsek & Gunduz (2007) [20], Jerome1 and Pius (2010) [21] and Rokbani et al. (2011) [22], introduced irrigation water quality index (IWQI) as a management tool. In the first stage, the parameters identified for the model were considered more relevant to the irrigation use. In the second stage, a definition of quality measurement values (qi) and aggregation weights (wi) was established. Values of (qi) were estimated based on each parameter value, according to irrigation water quality parameters proposed by the University Of California Committee Of Consultants - UCCC and by the criteria established by Ayers and Westcot (1999) [23], as shown in Table 8. Water quality parameters were represented by a non-dimensional number; the higher value is the better water quality [24].

The irrigation water quality index (IWQI) was estimated using:

$$IWQI = \sum_{i=1}^{n} q_i * W_i$$

Values of qi were calculated using the Equation 2, based on the tolerance limits shown in Table.3 below and water quality results determined in laboratory:

$$qi = qi_{max} - [(xij - x_{inf})* x_{iamp}) / x_{amp}]$$

Where qi_{max} is the maximum value of qi for the class; xij is the observed value for the parameter; x_{inf} is the corresponding value to the lower limit of the class to which the parameter belongs; x_{iamp} is class amplitude; x_{amp} is class amplitude to which the parameter belongs. In order to evaluate x_{amp}, of the last class of each parameter, the upper limit was considered to be the highest value determined in the physical-chemical and chemical analysis of the water samples.

The parameters used to assess the suitability of irrigation water supply for agricultural purpose are given as follows (Table . 3): Electrical Conductivity, Sodium Absorption Ratio (SAR), Chlorine (Cl-), Total Hardness (TH), and Sodium (Na+). SAR* has been used by several researchers in assessing and classifying irrigation water quality.

TABLE 3. Parameter limiting values for quality measurement (qi) calculation [23].

q_i	EC	SAR	Na	Cl	HCO_3
85-100	200≤EC<750	2≤SAR<3	2≤Na<3	1≤Cl<4	1≤ HCO3<1.5
60-85	750≤EC<1500	3≤SAR<6	3≤Na<6	4≤Cl<7	1.5≤ HCO3<4.5
35-60	1500≤EC<3000	6≤SAR<12	6≤Na<9	7≤Cl<10	4.5≤ HCO3<8.5
0-35	EC<200 or EC≥3000	SAR>2 or SAR≥12	Na<2 or Na≥9	Cl<1 or Cl≥10	HCO3<1 or HCO3≥8.5

(*) The SAR describes the quantity of sodium in excess compared to the cations of calcium and magnesium by the relationship $SAR = \frac{Na^+}{\sqrt{\frac{Ca^{2+}+Mg^{2+}}{2}}}$

- **Weights for the IWQI parameters**

W_i is the standardized weight of the i^{th} value (Table IV). In this study EC, SAR, Na+, Cl- and HCO3 were unified to obtain a particular number that indicates the irrigation water quality [9]. The parameter limiting values for quality measurement (q_i) and weights for IWQI parameter estimation according to [8], are shown in the Tables 1 and 2.

TABLE 4. Weights for the iwqi parameters [8].

Water quality parameters	Wi
EC	0.211
Na	0.204
Cl	0.194
HCO3	0.202
SAR	0.189
Total	1.00

- **Analyzes of Kodiat Rosfa dam waters**

The analysis procedures are deduced from the standard methods [25].

- pH, temperature, and conductivity of the water are measured in situ by portable devices HANNA (8014 Hi and Hi 8732)
- Suspended matter (TSS) was filtered by a cellulosic filter and weighed after passage to the drying oven with 105˚C.
- The biological demand of oxygen during five days (BOD_5) was measured by the apparatus BOD meter Oxi-Top.
- Chemical demand of oxygen (COD), was measured by COD meter type photometer Hanna C214.
- The determination of anions is performed by spectrophotometry kind DR2000 (HACH).
- The flame spectrophotometer (Corning 410) is used to determinate the cations.

Monthly samples were taken in the months of February-March-July-September of the years 2013, 2014 and 2015 (Table V).

TABLE 5. Physico-chemical waters analyzes of dam koudiet rosfa.

Parameters	2013				2014				2015			
	Feb	**Apr**	**Jul**	**Dec**	**Fev**	**Avr**	**Juil**	**Dec**	**Fev**	**Avr**	**Juil**	**Dec**
pH	7,80	7,90	8,00	7,50	7,70	8,10	8,00	7,60	7,60	7,80	7,70	7,90
EC (µs/cm)	2220	1822	2300	2170	2030	1713	2000	1870	2110	2000	2140	2400
DO %	92,50	99,80	111,50	88,00	77,80	80,20	90,90	48,70	73,80	98,40	101,40	69,10
TSS (mg/l)	12	18	11	11	12	10	8	8	22	12	11	12
Ca (mg/l)	204	191	133	178	187	161	183	213	226	204	205	226
Mg (mg/l)	57	57	115	91	85	68	83	65	65	58	58	43
Na (mg/l)	225	230	262	242	242	242	265	246	235	242	265	265
Cl (mg/l)	188	174	201	184	178	184	211	194	211	204	218	296
SO_4 (mg/l)	784	818	886	895	972	792	922	846	910	808	872	1015
HCO_3(mg/l)	142	142	146	153	139	157	135	154	167	188	132	162
COD (mg/l)	59	49	49	38	19	19	10	48	59	49	38	50
BO_5D	10,30	8,70	8,60	7,10	3,10	3,50	2,10	8,70	11,50	8,70	7,10	8,70
NO_3 (mg/l)	3	3	2	3	1	3	2	2	2	1	2	1
NH_4 (mg/l)	0,06	0,09	0,27	0,19	0,05	0,12	0,22	0,07	0,10	0,13	0,13	0,14
PO_4 (mg/l)	0,07	0,06	0,10	0,04	0,02	0,03	0,11	0,04	0,04	0,03	0,15	0,04

III. RESULTS AND DISCUSSION

- **Results of WQI index and characterization of Kodiat Rosfa dam water quality**

Out of the 12 samples studied (Table. 6) 8 show WQIs within 50 to 100 and 4 samples with WQIs lower than 50 (Table 6 and Fig. 5), which makes it possible to qualify the waters of this dam as good to excellent for consumption according to the standards adopted (Table. 2).

TABLE 6. Water quality index results of dam kodiat rosfa.

Date	WQI					
	2013		2014		2015	
Feb	61	Good	37	Excellent	63	Good
Apr	58	Good	38	Excellent	57	Good
Jul	60	Good	36	Excellent	53	Good
Dec	51	Good	49	Excellent	54	Good

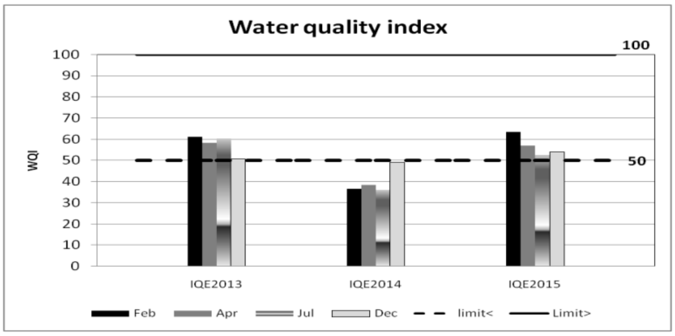

FIGURE 5. Water quality index results of dam Kodiat Rosfa.

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- **Results of IWQI index and characterization of Kodiat Rosfa dam water for irrigation**

The approach adopted made it possible to characterize the quality of the Kodiat Rosfa dam water for irrigation through the results reported in Table VII and the diagram (Fig. 6). Indeed, out of the 12 samples studied, 7 have an IWQI within 55 to 70 for the years 2013 and 2014. corresponding to a moderate restriction (MR = 55-70) according to characterization standards (Table 7) . The remaining 5 samples of 2015, have an IWQI lower than 55, which results in a high restriction for the use of this water in irrigation according to the same table (HR = 40-55) Table 7).

TABLE 7. Water quality index results of dam koudiet rosfa.

Date	IWQI					
	2013		2014		2015	
Feb	55	MR	57	MR	53	HR
Apr	57	MR	57	MR	54	HR
Jul	54	HR	55	MR	54	HR
Dec	55	MR	56	MR	42	HR

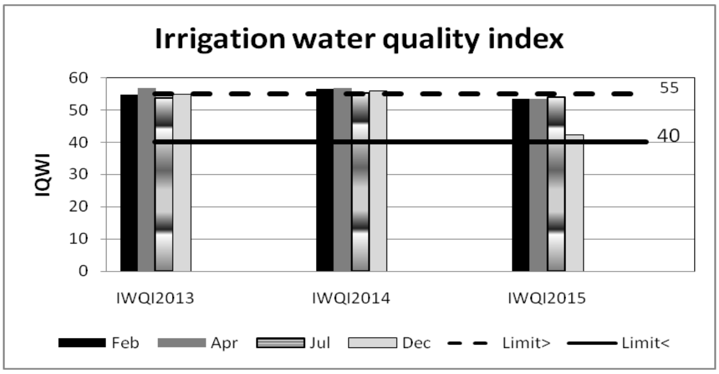

FIGURE 6. Irrigation water quality index results of dam Kodiat Rosfa.

TABLE 8. Water quality index characteristics [8].

IWQI	Water Use Restrictions	Recommendation	
		Soil	Plant
85-100	No restriction (NR)	May be used for the majority of soils with low probability of causing salinity and sodicity problems, being recommended leaching within irrigation practices, except	No toxicity risk for most plants
70-85	Low restriction (LR)	Recommended for use in irrigated soils with light texture or moderate permeability, being recommended salt leaching. Soil sodicity in heavy texture soils may occur,	Avoid salt sensitive plants
55-70	Moderate restriction (MR)	May be used in soils with moderate to high permeability values, being suggested moderate leaching of salts.	Plants with moderate tolerance to salts may be grown

40-55	High restriction (HR)	May be used in soils with high permeability without compact layers. High frequency irrigation schedule should be adopted for water with EC above 2000 µS cm-1 and SAR above 7.0.	Should be used for irrigation of plants with moderate to high tolerance to salts with special salinity control practices, except water with low Na, Cl and HCO3 values
0-40	Severe restriction (SR)	Should be avoided its use for irrigation under normal conditions. In special cases, may be used occasionally. Water with low salt levels and high SAR require gypsum application. In high saline content water soils must have high permeability, and excess water should be applied to avoid salt accumulation.	Only plants with high salt tolerance, except for waters with extremely low values of Na, Cl and HCO3.

IV. CONCLUSION

The approach adopted to assess the water quality of Kodiat Rosfa dam, through the respective indexes (WQI and IWQI), has made it possible to highlight the quality of this water and its use for consumption and for irrigation. Indeed, among 12 samples studied for consumption, 8 have WQIs within 50 to 100 and 04 WQIs lower than 50, which makes it possible to characterize the waters of this dam as good to excellent for consumption according to the WHO and national standards.

Moreover, the results of the second part of approach for the use of this water for irrigation showed that 7 out of 12 samples have an IWQI within 55 to 70, against 5 which have an IWQI lower than 55. This water quality is characterized by moderate (MR) to high (HR) restriction for irrigation use. In this case, a set of recommendations must be observed, especially in the choice of plants with moderate tolerance to salts and moderate to high permeability of soil.

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