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Statistical Assessment of the Water Quality using Water Quality Index and Organic Pollution Index —Case study, Oued Tighza. Morocco

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Abstract

To characterize the spatial and temporal variability of surface water quality of Oued Tighza in Morocco. Two indices were used. The water quality index was calculated from nine physicochemical parameters (pH, T°, Electrical Conductivity Dissolved O_2 NH_4^+ NO_3^- SO_4^{2-} PO_4^{3-} BOD_5) and the Organic Pollution Index was determined from 3 organic pollution indicator parameters (NH_4^+ PO_4^{3-} BOD_5) measured during 12 months on 7 sampling stations. The values that were obtained are between 427.64 as the minimum value at station 7 and 581.717 as the maximum value at station S2 for the WQI and between 1 and 1.33 for the OPI at all stations. The results of both indices corroborate and indicated poor water quality in the different stations sampled. The water quality was critical during the study period due to the effects of the discharge of water from the urban wastewater treatment plant. Based on the results obtained, the values of the water parameters far exceed the values of the surface waters according to Moroccan standards and classify the water quality of the study area as poor to very poor.

Keywords: *Water quality, physicochemical parameters, water quality index, organic pollution index, Oued Tighza, Morocco*

1. Introduction

Water resources in Morocco on a global scale are confronted with constraints of different natures, ranging from climate change to different anthropogenic activities such as agriculture, industrial activities, and direct discharge of domestic and other wastewater without any prior treatment, especially outside of large agglomerations [1, 2, 3, 4,5, 6,7]. Several official data confirm the fact that Morocco is under the pressure of a water context in the grip of an accelerated trend of water resources drying up. In addition to this, there are longer and more frequent periods of drought and increasing water needs, especially for the agricultural sector, which consumes more than 80 percent of the water resources of the large dams. Morocco remains the model country in Africa in terms of management and good governance of its water resources. According to the report published in 2020 by the Directorate of Studies and Financial Forecasts (DEPF) a drastic drop in the amount of water ready to be used in recent decades. Between 1960 and 2019, the availability of water per capita dropped from 2,560 m3/ to 650 m3/capita/year [8], this situation can be aggravated by demographic pressure [9], the Green Morocco Plan consuming large quantities of water due to water losses in irrigation systems that can reach 40% and the tourism sector which is one of the pillars of the Moroccan economy. These factors, combined with the impact of climate change on water resources and the impact of socio-economic activities [10, 11, 12, 13, 14, 15, 16], per capita water availability may reach less than 500 m3 by 2030 on a national scale. The Bouregreg Hydraulic Basin, with a surface area of 10,597 km², is one of the most important basins in the kingdom in terms of population (9 million by 2020) and industrial activity (70 per cent of national activity). The irrigable area is about 970,000 ha of which 38,000 ha are irrigated. The water resources of this basin are limited and the various socio-economic activities have a high demand for water. These water resources are experiencing degradation of various kinds in places despite the efforts made by the state by setting up systems to clean up water before it is released. The Oued Tighza, which is part of the Bouregreg Hydraulic Basin, is not exempt from this situation and receives discharges from the water treatment plant of M'rirt and wastewater from the slaughterhouse of this town without any prior treatment. These discharges can impact the biodiversity of this tributary of Sebou and consequently the human health [17, 18, 19, 20, 21]. It is in this context, that we are committed to assess the water quality of this non-permanent stream by two indices, namely, the Water Quality Index (WQI) and the Organic Pollution Index (OPI). These two indices are well chosen and can give accurate and simple information depending on the nature of the water the stream receives [18, 14, 22]. The results of this study can be a database for decision makers [23], for the evaluation of the efficiency of lagoon water treatment system and the area of water use of this Oued.

2. Materials and Methods

2.1. *Location of the study area*

M'rirt town is located in the eastern part of central Morocco near the western edge of the Middle Atlas Causse [24, 25]. It is accessible by the national road 08 joining Azrou to Khénifra, as well as by the main road 7032 that connects Meknès to M'rirt (Fig. 1). This area is marked by the presence of the Jbel Aouam mine (also called the Tighza mine or district) which is located 6 km northwest of Mrirt. This mining area is the most important lead, zinc, and silver district in Central Morocco. Its hydrological origin is made up of ten sources, which are of two types, salty on the right side of the river and soft on the left side. On its upper course, the mountainous massifs receive relatively abundant precipitations which can reach 1000 mm / year.

2.2. *Geological and hydrological context*

From a geomorphological, the study area belongs to the plateau of M'rirt with moderate relief (1100m altitude), within which emerges the ridges (Jbel Aouam, Jbel Aarrad), significantly elongated NE-SW and whose altitudes exceed 1300 m. The whole is cut by a hydrographic network whose main watercourse is the Oued Tighza which runs through the

region in an East-West direction while intersecting the structures and ridges obliquely. This area is marked by the presence of the mine of Jbel Aouam which is located 6 km northwest of Mrirt. This mining area constitutes so far, the most important lead, zinc and silver district in Central Morocco [25, 26, 27, 28]. M'rirt belongs to three hydraulic basins notably the hydraulic basin of Sebou by oued Ifrane at the level of tagourt izem, the hydraulic basin of Oum Rabia at the level of the sources Oum Rabia and Tanfnit and the hydraulic basin of Bou-Regreg by oued Tighza which crosses the city from South-North to West.

2.3. *Geological and hydrological context*

The climate of the study area is continental with large temperature variations, it is semi-arid with a sub-humid tendency -humid for the rainy seasons or arid for the dry seasons. The average annual temperature of the region is close to 10°C. Temperatures present important daily and annual amplitudes with very hot summers and cold winters. From the point of view of rainfall, the average interannual rainfall station is around 700 mm recorded at the station of El Hammam at 1200 m altitude.

2.4. *Stations and water sampling*

7 stations were selected according to the objective of the study, i.e., the impact of the water treatment plant on the Oued Tighza and the evaluation of the purifying power of the receiving environment. Table 1 gives the geographical coordinates and the map (Table1, figure.1) shows the distribution of the various stations at the level of Oued Tighza downstream of the water treatment plant. Water samples were taken from different points on the same site without disturbing the stream. These samples were thoroughly stirred to produce an average composite sample [29, 30]. The sampled waters were placed in polyethylene bottles and transported to the lab in a cooler at 4°C for storage and handling of samples according to recommendations [31].

Table 1. Location of the different sampling stations

Sampling stations	Lambert Coordinates	
	X	Y
S1	505218	277947
S2	505101	277946
S3	505099	277977
S4	504546	278036
S5	504447	278058
S6	504345	278058
S7	504345	278128

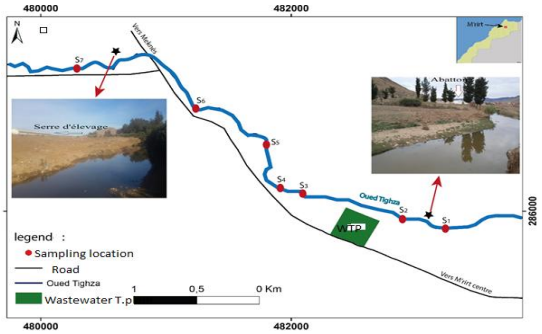

Figure 1. Location of different sampling station

3. Results and discussions

3.1. *Basic characteristics of water parameters*

Physicochemical parameters are considered one of the most important factors that are capable of influencing the aquatic environment [32]. In addition, Water quality is among the most important factors affecting health and safety of its users and the suitability for its utilization in various aspects [33,34]. The descriptive statistical characteristics of the physicochemical variables used in this study concern the minimum, maximum, average, and standard deviation values at each station. (Table.2).

Table 2: Physicochemical characteristics of the water in different stations

St	Parameters	pH	T	EC	Dis.O2	NH_4^+	NO_3^-	SO_4^{2-}	PO_4^{3-}	BOD_5
			°C	µS/cm	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
	Min	7,04	13,5	518	1	5,89	33,71	10,66	0,78	20
	Average	7,73	20,62	1071,58	4,89	8,7	41,53	97,38	0,9	74
	Max	8,38	27,5	2260	8,6	12,03	54,06	170,25	1,04	180
	Std deviation	0,48	4,35	629,05	2,54	2,81	8,98	65,68	0,12	54,96
S1										
	Min	6,93	13,4	539	0,04	5,66	46,9	98,45	2,47	130
	Average	7,38	20,44	1946,17	2,1	8,74	54,55	202,37	3,44	226,67
	Max	8,06	27,3	6320	7,2	10,21	68,41	260,03	4,88	360
S2	**Std deviation**	0,4	4,44	1778,54	2,3	2,14	8,32	71,29	1,08	74,87
	Min	6,99	13,5	827	0	9,1	28,2	109,49	4,27	50
	Average	7,61	20,4	2462,75	1,07	10,86	31,49	213	7,61	163,75
	Max	8,16	26,9	5710	2,94	12,4	36	265,32	10,81	260
S3	**Std deviation**	0,41	4,3	1535,4	0,92	1,52	3,79	72,65	2,8	63,57
	Min	6,99	13,3	844	0	8,01	30,12	112,81	1,78	45
	Average	7,5	20,45	2470,5	1,37	9,86	39,97	198,35	4,22	151,04
	Max	8,08	27,1	5690	3,96	11,5	64,6	246,73	6,45	300
	Std deviation	0,39	4,39	1545,95	1,08	1,45	14,21	60,29	2,13	70,03
S4										
	Min	6,87	13,6	795	0,02	7,3	10,3	189,68	0,81	30
	Average	7,41	20,44	2438,92	1,36	8,66	30,13	207,54	3,24	140
	Max	8,01	27,2	5710	4,67	10,1	38,9	227,86	5,07	230
	Std deviation	0,38	4,29	1562,44	1,27	1,22	11,47	20,18	2,11	59,66
S5										
	Min	6,96	13,1	808	0	7,1	17,9	201,6	1,23	40
	Average	7,44	20,37	2365,83	1,58	8,25	31,16	215,71	1,78	124,58
	Max	8	27,4	5600	4,46	9,7	39	230,65	2,41	180
	Std deviation	0,33	4,43	1525,46	1,19	1,19	8,43	12,69	0,5	44,9
S6										
	Min	6,77	13,4	754	0,68	4,68	18,8	83,44	0,98	65
	Average	7,36	20,47	1496,75	1,93	5,21	35,04	181,22	1,58	177,71
	Max	8,03	27,5	3100	4,47	5,81	44,3	220,55	2,79	450
	Std deviation	0,38	4,43	726,22	1,14	0,5	9,66	65,5	0,82	134,79
S7										

The hydrogen potential (pH) of water is a parameter related to other characteristics of water, including physical properties mainly temperature, chemical characteristics, such as levels of dissolved organic carbon, hardness, as well as alkalinity but also to metabolic activities of microorganisms such as photosynthesis and respiration [35]. The minimum average value of 7.36 is recorded at the S2 station against a maximum average value 7.61 at the S3 station. The results of the different stations show that the pH is slightly alkaline, and meets Moroccan standards of surface waters and classifies the waters in the very good class [36]. For the water temperature, which generally varies according to climatic conditions, the minimum average value is around 20.37°C at S6, compared to a maximum average value of 20.62°C at S1. The temperature at all stations is between 20 and 25°C. According to Moroccan standards of surface water quality, the water quality class of the study site is good. For Electrical conductivity, the average minimum and maximum values are between 1071.58 and 2470.5 µS/cm respectively at S1 and S4. According to the Moroccan standard of surface water, the class of water in the study area is poor. Dissolved oxygen concentration is a function of physiological parameters and exchanges with the atmosphere. It's one of the most important indicators of the quality of water for aquatic life. The minimum average value is 1.36 mg/L at S4 compared to 4.89 mg/L at S1. These values classify the waters of the study area from poor to average to Moroccan standards. The decrease in the concentration of dissolved oxygen is due to the pollutant load of the water coming from the wastewater treatment plant which is located upstream of the S1 plant. Oxygen is used for the degradation of organic matter by microorganisms. For ammonium, the minimum average value is 5.21mg/L at S1 against 10.86mg/L at S3. These values classify the waters of the different stations in the poor to the very poor class. For nitrates, which come from the nitrification of ammonium, the minimum average value is 30.13 mg/L at S5 and 54.55 mg/L at S2. The concentrations recorded in the different stations classify the waters in the average class according to the Moroccan standards for surface waters. For sulfate ions, which come from gypsiferous rocks, the minimum average value is 97.38 mg/l, at S1, against 215.71 mg/L at S6. According to Moroccan standards, the water class is good to average. Orthoposphates record values between 0.9 at the S1 level and 7.61 at the S3 level. These values classify the water in the poor class. The BOD5, which informs about the organic pollution, registers a minimum average value of 74 mg/L at the S1 level and 226.67 mg/L at the S2 level. These values of BOD5 corroborate with the concentration of dissolved oxygen which record very low values and classify the waters in the very bad class.

Table 3. Relative weight (WI) parameter used in WQI according Moroccan Standard.

Parameters	Moroccan value Standard	Si, Maximal Moroccan standard	1/Si	Wi
pH	6,5-9,2	9	0,111	0,031
T°C	20-30	30	0,033	0,009
E.C	750-2700	2700	,00	0,000
$D.O_2$ mg/L	3-5	5	0,200	0,056
$NH4^+$	0,1-0,5	0,5	2,000	0,056
$NO3^-$	Inf5	50	0,020	0 ,006
$SO4^-$	100-250	250	0,004	0,001
PO_4^{3-}	0,2-1	1	1,000	0,280
BOD_5	3-5	5	0,200	0,056
		∑(1/Si) = 3,569		
		k=1/∑(1/Si) = 0,280		∑ Wi= ,489

3. 2. *Water Quality Index*

The Water Quality Index for Oued Tighza was calculated from nine parameters namely (T°C, pH, DO2, BOD5, E.C, NH4 +, NO3-, SO4-, PO43-) for seven sampling stations to assess the suitability of Tighza River water. The WQI was calculated using the weighted arithmetic water quality index method which was proposed by [14, 37], developed by

[38], and then by [39] in which water parameters are multiplied by a weighting factor and are then aggregated using simple arithmetic mean by these three equations**:** **Qi = (Ci / Si) × 100), (1), Wi= Ki / Si (2),**

Where Ci is the concentration of each parameter, n is the number of parameters, Si is maximal Moroccan standard of (i) parameters, **wi** is the relative weight of the i (parameter) and Qi is the Quality assessment scale of each parameter (i). The unit weight (**wi**) of the various water quality parameters is inversely proportional to the recommended standards for the corresponding parameters.

$$\mathbf{WQI} = \sum_{i=1}^{n} \mathbf{Qi} \times \mathbf{Wi} / \sum_{i=1}^{n} \mathbf{Wi} \quad \mathbf{(3)}$$

Tables 3,4 and 5 shows different step to determine the Water quality Index (WQI) in different sampling stations of area study. The two equations (1 and 2) are used to determine equation 3 which calculates the water quality index (WQI) (Table5).

$$\mathbf{WQI} = \sum_{i=1}^{n} \mathbf{Qi} \times \mathbf{Wi} / \sum_{i=1}^{n} \mathbf{Wi} \quad \mathbf{(3)}$$

Table 4. Qi value of the different parameters

Stations	pH	T	EC	DO	NH_4^+	NO_3^-	SO_4^{2-}	PO_4^{3-}	BOD5
S1	86	687	96	89	174	83	38,9	90	1480
S2	82	681	72	42	174,8	10,91	80,9	34,4	4533,4
S3	84	68	912	214	217,2	62,9	85,2	76,1	3275
S4	83	681	915	274	197,2	79,9	79,3	42,2	3020,8
S5	82	681	903	272	17,32	60,2	83	32,4	2800
S6	83	679	876	316	165	62,3	86,2	17,8	2491,6
S7	82	682	554	386	104,2	70,1	02,4	15,8	3080,8

Table 5. Classification of water quality based on weighted arithmetic WQI method

Stations	WQI	Water Quality Index (WQI) Scale
S1	270,335	Unsuitable for drinking
S2	581,717	Unsuitable for drinking
S3	475,527	Unsuitable for drinking
S4	443,002	Unsuitable for drinking
S5	390,979	Unsuitable for drinking
S6	369,642	Unsuitable for drinking
S7	427, 64	Unsuitable for drinking

Based on the values of WQI, the water quality assessment was classified in Table 3. The results of WQI calculation for assessment of river water quality at Tighza (M'Rirt) during the 12 months of sampling showed that the water quality at the 7stations in the study area is very poor as the values of WQI exceeds 100. The results obtained at the different stations studied show that the value of the Water Quality Index far exceeds the values of the different water classes mentioned in the table (6). It can be concluded that the water quality of Oued Tighza suffers from very high pollution at all stations sampled. This degradation of water quality can be explained firstly by the discharges of the wastewater treatment plant (lagoon system) of the urban municipality of M'Rirt, and secondly, the low flow of Oued Tighza does not allow self-purification.

3. 2. *Organic Pollution Index*

The determination of the degree of organic pollution of the water is based on the organic pollution index (OPI). The organic pollution parameters used are (NH4+, PO43-, and BOD5). The calculation of the water class of a station is the

average of the class numbers of the different parameters used (Table 2) [8, 14, 22], and the table (6, 7) shows the degree of organic pollution according to the average of the class numbers of the parameters used. According to [14, 22], tables 2, 6 and 7 are used to calculate the Organic Pollution Index (OPI) of different sampling stations of Oued Tighza (Table. 8).

Table 6. Number of the classes of the different parameters used for the organic pollution

Parameters	$BOD_{5\ mg}$/L	NH_4^+ mg/L	PO_4^{3-} µg/ L
Class 5	< 2	< 0.1	15
Class 4	2 – 5	0,1– 0.9	16 – 75
Class 3	5.1 – 10	– 2.4	76 – 250
Class 2	10.1 – 15	2.5 – 6.0	251 – 900
Class 1	> 15	> 6	> 900

Table 7.: Organic Pollution Index and degrees of organic pollution according to Leclerc, 1987

Organic Pollution Index (OPI)	Degrees of organic pollution
5.0 - 4.6	No organic pollution
4.5 - 4.0	Low organic pollution
3.9 - 3.0	Moderate organic pollution
2.9 - 2.0	Organic pollution
1.9 - 1.0	Very high organic pollution

Table 8. Pollution Organic Index and Degrees of organic pollution in different stations of Oued Tighza

Parameters	NH^{4+} mg /L	$PO4^{3-}$ mg /L	BOD_5 mg /L	OPI	Water class	Degrees of organic pollution
S1	8,7	0,9	74	1,33	1,9 – 1,0	Very high organic pollution
S2	8,74	3,44	226,67	1	1,9 – 1,0	Very high organic pollution
S3	10,86	7,61	163,75	1	1,9 – 1,0	Very high organic pollution
S4	9,86	4,22	151,04	1	1,9 – 1,0	Very high organic pollution
S5	8,66	3,24	140	1	1,9 – 1,0	Very high organic pollution
S6	8,25	1,78	124,58	1	1,9 – 1,0	Very high organic pollution
S7	5,21	1,58	177,71	1,33	1,9 – 1,0	Very high organic pollution

The Organic Pollution Index (OPI) calculated for the different stations downstream of the wastewater treatment plant varies only between 1.33 at the two stations S1 and S7 as the maximum value and 1 at the other stations. According to the table (OPI), the values of the Organic Pollution Index are in the range 1.9 to 1, which indicates a very high organic pollution. These results corroborate with the calculated water quality index (WQI). According to Moroccan surface water standards, the water of Oued Tighza cannot be used for any purpose.

Conclusion

The determination of physico-chemical parameters of water samples collected on 7 different sites during one year in the Oued Tighza was evaluated. The results obtained from the different parameters were used for the determination of the water quality index and the organic pollution index. The results obtained by the water quality index corroborate with those of the organic pollution index. The values of the two indices calculated showed that the quality of water at the study site is very degraded and far exceeds the standards of surface water in Morocco. This deterioration of the water is mainly due to the discharge of water from the wastewater treatment plant of the city of M'rirt.

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