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USE OF QUALITY AND ORGANIC POLLUTION INDICES IN THE PHYSICO-CHEMICAL QUALITY ASSESSMENT OF KÉBIR WADI EAST SURFACE WATERS (REGION OF EL TAREF, EXTREME NORTH EAST ALGERIA)

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Abstract

Surface water is subject to strong anthropogenic pressures caused by the development and the extension of the agricultural activities and also by the industrial and domestic activities. Pollution is a major environmental problem due to discharges into rivers and the excessive use of agricultural fertilizers add to that the discharges from urban and industrial sources. The aim of this study is to assess the quality and the state of the organic pollution of surface water in the Kébir wadi east, based on the Water Quality Index (WQI) and the Organic Pollution Index (OPI) during six sampling campaigns carried out between April and September of the year 2011. Seven stations were studied along the Kébir wadi east downstream from the Mexa Dam.

The results are visualized by the use of GIS through making thematic maps. They revealed that half of the stations show excellent to good water quality and moderated organic pollution except the stations S3, S6 and S4, that have poor water quality and high pollution at S3 and S6 respectively, and non-potable water with very high organic pollution at S4. The anthropogenic environmental deterioration recorded in the wadi is the result of the use of nitrogen and phosphate agricultural fertilizers and especially, the discharge of untreated domestic and industrial wastewater from neighbouring agglomerations. The

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seasonal variation remains discrete and reflects a slight tendency to the deterioration of the waters of El Tarf region during the low waters of the summer period.

Keywords: Kébir wadi East, surface water, physico-chemistry, WQI, water quality index, OPI, organic pollution index, urbain wastes, seasonal variation

1. INTRODUCTION

Water is an essential natural resource for life in any ecosystem. The knowledge of its quality provides an overall view of risks to ensure the resources protection and to identify potential sources of water quality impairment [19], [20].

Water is a natural resource necessary for life in any ecosystem. The understanding of its quality gives a global vision of the risks in order to ensure the protection of the resources and to determine the possible sources of alteration of the water quality [19], [20].

Water sources can be mainly as rivers, lakes, rainwater, underground water, etc. In addition to the need for drinking water, water resources play a vital role in various sectors of the economy of Algeria such as agriculture, forestry, industrial activities, livestock, etc. The availability and the quality of surface or underground water have been deteriorated due to some important factors such as population growth, pollution caused by industrialization as well as urbanization, etc.

Water sources can be found mainly in the form of rivers, lakes, rainwater, groundwater, etc. In more of the needs in drinking water supply, the water resources play a vital role in different sectors of Algeria economy such as agriculture, forestry, industrial activities, breeding etc. The availability and quality of surface and ground water has deteriorated due to some important factors such as population growth, pollution caused by industrialization and urbanization

This pollution has a direct influence on the physico-chemical parameters of surface waters such as hydrogen potential, noted pH, measures the chemical activity of hydrogen ions in solution. In general, it has no direct effect on consumers [28]. However, it is one of the essential parameters for water quality control. Because, it conditions a wide range of physicochemical equilibrium between dissolved gases (CO_2), carbonate and bicarbonate ions [6, 3]. While the measuring of electrical conductivity helps to assess the level of mineralization of water [6]. The temperature plays a major role in changing the physical and chemical properties of water. Temperature is playing a major role in the modification of the physical and chemical properties of the water.

It influences the biological reactions that happen in water [17, 3]. It has a major influence on a number of chemical contaminants and inorganic constituents that may affect the taste of water.

At high temperatures, the GROWTH of microorganisms is favored and the taste, color and odor problems may be increased [28]. Because of their instability and high water solubility in the environment, nitrate contamination of water sources and groundwater is becoming a much more serious concern , The sustained use of chemical or organic fertilizers in agricultural production, septic tanks, animal manures, and effluents (municipal and industrial) are the principal sources of nitrate contamination of water [15, 28 and 3].

The presence of the oxygen in the water is essential for the respiration of aerobic aquatic living beings. Below a certain concentration of oxygen, the fish will suffer from asphyxia. The oxygen in the water also allows the oxidation process of organic matter (self-purification), but this decomposition depletes the aquatic environment of oxygen. The five-day biological oxygen demand is an indicator of pollution by biodegradable organic matter. It represents the amount of oxygen used by bacteria to partially decompose or totally oxidize, the oxidizable biochemical materials present in the water and which constitute their carbon source (fats, carbohydrates, surfactants, etc.).

Phosphates, also called orthophosphates, are the simplest and most common form of phosphorus in water. Phosphates and associated nitrates contribute to the excessive and anarchic development of algae, this development gives rise to the phenomenon of eutrophication.

The Water Quality Index (WQI) is a simple method used as part of the analysis of general water quality using a group of parameters reducing large amounts of information to a single number, usually dimensionless, in a simple and reproducible way [1].

This method was originally proposed by Horton and Brown. To calculate this index, Horton proposed the first formula that takes into account all the parameters necessary to determine surface water quality and reflects the composite influence of different parameters important to the assessment and water quality management [16, 26].

The organic pollution index was proposed in 1986 and has been used by the General Directorate of Natural Resources and Environment since 1996. It is based on 3 parameters resulting from organic pollution: Ammoniacal nitrogen, nitrites and orthophosphates and a synthetic parameter the biological oxygen demand for five days, for each of these parameters, 5 classes of levels have an ecological significance linked to the modifications that these substances induce in the algal populations. The IPO thus allows to give a synthetic account of the existing organic pollution at the sampling points.

Water quality is an important benchmark for meeting both demand and provision for water. Ensuring the quality of fresh water adapted to human and ecological needs is therefore an important aspect of integrated environmental management and sustainable development. To clearly represent water quality, different water quality indices are used to assess surface water quality. The WQI Global Water Quality Index and OPI organic pollution index were very useful for making the right decision and benchmarking comparatively the water quality and the pollution degree over time and space across the watershed [24, 10]. This work is based on the use of Global Water Quality Index (WQI) and Organic Pollution Index (OPI) according to the physico-chemical parameters of the surface waters of El Tarf watershed. The aim is to assess the quality and the state of the organic pollution of surface water at seven stations located downstream of the Mexa dam (El Tarf region, NE, Algeria) for six compaigns of the year 2011. The final thematic maps of the distribution of the WQI and the OPI were prepared using the geographic information system GIS.

2. PRESENTATION OF THE STUDY AREA

The Kébir Wadi East, is one of the Wadis of the region El Tarf. It takes its sources in Tunisia. Its flow extends for over 75 Km, it is widely used for irrigation, fishing, livestock watering and even swimming [4].
The study area is located in the eastern coastal basin of Constantine. It is bounded to the South by the basin of medjerda, to the North by the Mediterranean Sea. Its area covers nearly 2870 Km^2.
The study area has a temperate climate characterized by two seasons, the first is humid from September to May and the second is dry from May to September. This climate is influenced by: An annual average precipitation of 760.09 mm/year and an annual average temperature of 17.19 °C [5].
The value of the vegetation cover is confirmed by the existence of two protected natural areas: El-Kala National Park and the Beni Salah Ecological Park and Landscape Areas, which contain a multitude of plant species: Maritime pine, aleppo pines, cork oaks, Zen oaks.
The Constantine East coastal watershed is drained by two main tributaries: Kébir Wadi East and Bounamoussa Wadi, that receive domestic discharges from agglomerations throughout their upstream rivers, also the wastes from the agriculture developed in the valleys of the two wadis.
The flows recorded at the Ain Assel station vary from 0 m^3/s (low-water period) to 300 m^3/s, during the periods of heavy rain, they reach a value of 585.20 m^3/s, where there is a close relationship between precipitation and the flow regime, because the low flows recorded correspond to the low precipitation deficit year and the high flows correspond to the high precipitation surplus year.
The stratigraphy of the principal outcrops encountered shows clearly that the oldest sites are those of the Secondary, as for the most dominant sites throughout the territory of this basin, especially in the mountainous domain, they are those of the Eocene and the Oligocene that can be grouped under the name of numidian lands that outcrop with a series of clays and sandstones, these lands are usually napped on which rest miocene argilo sablo conglomerate lands dated from the Pontian. Finally, it should be noted that the most recent sites in the region are those

of the Quaternary, both marine and continental. But it is very likely that the Pliocene is included or confused with those of the ancient Quaternary.

3. METHODOLOGY AND USED DATA

3.1. Database

For this study, the used data includes the data related to physico-chemical analysis of the surface waters of Kébir Wadi East, located in El Tarf region [5]. The sampling was carried out during six campanions over six months successively during : April, May, June, July, August and September. The sampling stations were selected based on the different activities identified in the study area (domestic, industrial and agricultural wastewater). Thus, 42 water samples were collected at 07 stations along the Kébir Wadi East (Fig. 1).
An S1 station has been chosen as a reference station at the upstream of the watershed near the Mexa Dam, and away from any source of pollution. The other stations were located from the upstream to the downstream and within the Kébir wadi East.
The physico-chemical parameters include pH, dissolved oxygen DO, electrical conductivity EC, the temperature T measured (in situ) in the field, and sulphates (SO_4^{2-}), biological oxygen demand after 5 days (BOD_5), Orthophosphates (PO_4^{3}), Ammonium (NH_4^+) and Nitrates (NO_3^-) analysed in the laboratory. These parameters were determined according to the recomended methods by the norms Afnor and Rodier [21].
The evaluation and visualization of the results were carried out using the excel 2010 software, statistica and the software for the geographic information system GIS (Mapinfo).

3.2. The calculation of Water Quality Index (WQI)

Nine important parameters (pH, DO, EC, T, SO_4^{2-}, BOD_5, PO_4^{3-}, NH_4^+ and NO_3^-) were selected to calculate the WQI. This index is a water quality classification technique based on the comparison of water quality parameters with Algerian international or national standards in our study case. In other words, the WQI summarizes large amounts of water quality data in simple terms (Excellent, Good, Bad, Very Bad, etc.). This method was originally proposed by Horton [12].
In this study the WQI index was applied to estimate the influence of natural and anthropogenic factors on the base of several key parameters of the surface water chemistry of the Kebir Wadi East. This index was calculated using the weighted arithmetic index method [8, 9 and 29].

In this approach, a numerical value called relative weight (Wi), specific to each physico-chemical parameter, is calculated (Tab.1) according to the following formula:

$$w_i = \frac{k}{s_i} \tag{3.1}$$

Where:
k = Proportionality constant and can also be calculated using the following equation:

$$k = \frac{1}{\sum_{i=1}^{n}(1/s_1)} \tag{3.2}$$

n is the number of parameters
S_i is the maximum value of the Algerian surface water standard [13] of each parameter in mg/l except for pH, T and electrical conductivity.
Then, a quality rating scale (Qi) is calculated for each parameter by dividing the concentration by the standard of that parameter and multiplying the set by 100 as in the following formula:

$$Q_{i=\left(\frac{C_i}{s_i}\right)\times 100} \tag{3.3}$$

Q_i: Scale for evaluating the quality of each parameter,
C_i: The concentration of each parameter in mg/l,
Finally, the overall water quality index is calculated by the following equation:

$$WQI = \sum_{i=1}^{n} Qi \times Wi \Big/ \sum_{i=1}^{n} Wi \tag{3.4}$$

Five quality classes could be identified according to the WQI values (Tab.1).

Table 1. Classification and possible use of water by WQI

Class of WQI	Water type	Possible use
0 - 25	Excellent quality	Drinking water, irrigation and industry
> 25 - 50	Good quality	Drinking water, irrigation and industry
> 50 - 75	Poor quality	Irrigation and industry
> 75 - 100	Very poor quality	Irrigation
> 100	Non-potable water	Appropriate treatment required before use

Source: [8, 9 and 2].

3.3. Calculation of the Organic Pollution Index (OPI)

By Leclercq [14] Organic Pollution Index (OPI) was also used to assess the organic amount in the wadi. In which the principle of the OPI is to divide the values of pollutants into 05 classes (Tab.2). This index is obtained by the values of ammonium, nitrite, BOD_5 and phosphates. The principle of calculation is to divide the values of the four pollutants into five classes and to determine from the values obtained in the study, the corresponding class number for each parameter using the average data in Table 2. The final organic pollution index is the average of the pollution classes for all parameters (Tab.2).

Table 2. Class grid of the Organic Pollution Index

Classes	NH_4^+ (mg/l)	NO_2^- (µg/l)	PO_4^{3-} (µg/l)	BOD_5 (mgO_2/l)	OPI	Organic pollution
5	< 0.1	5	15	< 2	4,6 - 5	Null
4	0.1 - 0.9	6 - 10	16 - 75	2 - 5	4 - 4.5	Low
3	0.9 - 2.4	11 - 50	76 - 250	5.1 - 10	3 - 3.9	Moderate
2	2.4 - 6	51 - 150	251 - 900	10.1 - 15	2 - 2.9	Strong
1	> 6	> 150	> 900	> 15	1 - 1.9	Very strong

Source: [14].

4. RESULTS AND DISCUSSION

4.1. Calculation of WQI and OPI and assessment of water quality water quality index WQI

In this study, the global quality of the surface waters of the Kébir wadi east was evaluated by the WQI method. The relative weight (Wi) of each physico-chemical parameter and the proportionality constant k were first calculated using the maximum values of the Algerian standard drinking water norm [19] of the physico-chemical parameters studied (Tab.3). Indeed 9 important parameters in the study of surface water quality: pH, T, EC, DO, NH_4^+, NO_3^-, SO_4^{2-}, PO_4^{3-} and BOD_5 were taken in count in the calculation of the WQI value.

Table 3. Weight of physico-chemical parameters and Algerian surface water quality standard

Parameters	Algerian standard	S_i (Maximum standard Value, Algeria)	$1/S_i$	W_i
pH	6.5 – 8.5	8.5	0.118	0.047
T (°C)	25	25	0.040	0.016
Conductivity (µs/cm)	2800	2800	0.000	0.000
DO (mg/l)	3 - 7	7	0.143	0.057
NH_4^+ (mg/l)	0.5	0.5	2,000	0.792
NO_3^- (mg/l)	50	50	0.020	0.008
SO_4^{2-} (mg/l)	200 - 400	400	0.003	0.001
PO_4^{3-} (mg/l)	2.68 – 6.70	6.70	0.150	0.059
BOD_5 (mgO_2/l)	2 - 20	20	0.050	0.020
		$\sum(1/S_i)$	2,524	1
		$k = 1/\sum(1/S_i)$	0.396	

Source: Own elaboration based on Data from [13].

After the calculation of the WQI water, quality index using the results of physico-chemical, analysis and the standard values of the Algerian drinking water norms [13] the water quality class is determined for the 42 samples from the 07 sampling stations (Tab.4).

Table.4. Calculation of the average of the WQI and surface water quality class of the Kébir wadi east, during the six campaigns of 2011

Stations	WQI	Quality class
S1	20.42	Excellent quality
S2	18.21	Excellent quality
S3	63.52	Poor quality
S4	214.79	Non-potable water
S5	41.88	Good quality
S6	69.65	Poor quality
S7	40, 93	Good quality

Source: Own elaboration.

Thus, the excellent and good quality classes were identified during the April, May, June, July, August and September campaigns for stations S1, S2, S5 and S7; poor

and non-potable quality classes were recorded at stations S3, S6 and S4 respectively (Tab.4 and Fig.1).
The map Shows clearly a progressive deterioration of the water quality mostly all over the wadi, marked by an bad pollution, non potable water and then becomes good to bad again. The high values of this index could be explained by the high levels of nitrites, phosphate, ammonium and BOD_5. The evolution of the WQI values along the stations shows that this degraded state of the water quality of the Kebir wadi east is due to the discharges of the domestic wastewater coming from the agglomeration as well as the agricultural runoff. The stations S1 and S2 are explained by the release of the dam waters, which permitted the dilution of the polluting elements and also by low flow discharge.
The station S3, represents a bad quality with regard to the two first stations, and this is due to the increasing discharge flow.
For the station S4, we notice a non-potable waters, this is explained by the very high flow of the discharges, the runoff of the agricultural lands and the oxygen inlet in the living environment.
At the stations S5, S6 and S7 the quality becomes good to bad despite the high flow of the agricultural runoff discharges. This is explained by the auto-purification potentials of the wadi, because at these stations there has been an increase of the dissolved oxygen rate.

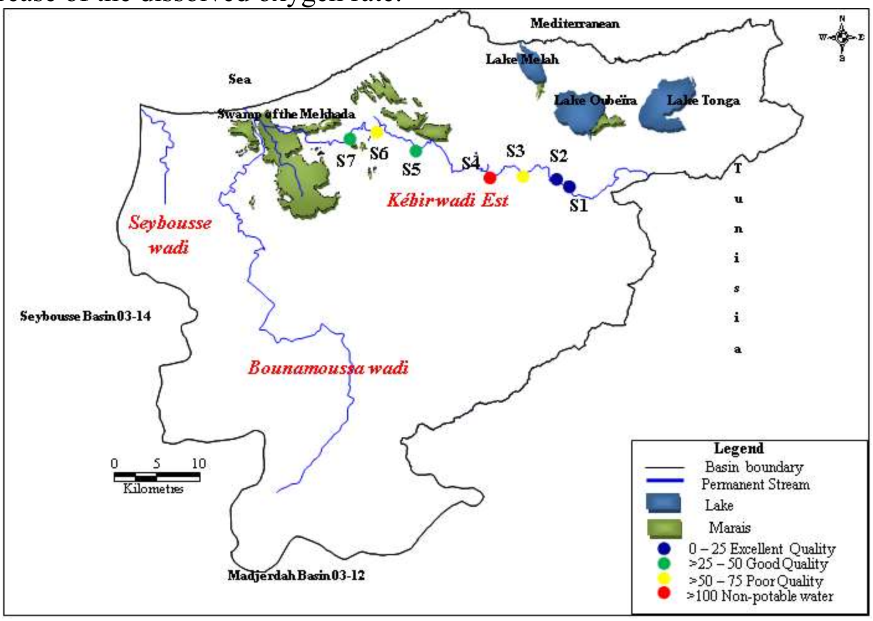

Fig. 6. Thematic map of the Kébir East Wadi Surface Water WQI Global Quality Index, during the April, May, June, July, August and September 2011 marketing years, source: Own elaboration

4.2. Organic pollution index (OPI)

In order to obtain a more meaninful result, we chose the mean of the different concentrations for six months for all of the stations.

Table. 5. Calculation of the mean of OPI and the quality class of surface waters of Kebir wadi east along six compains in 2011

Classes	OPI	Quality classes
S1	3.50	Moderate
S2	3.50	Moderate
S3	2.50	strong
S4	1.75	Very strong
S5	2.75	Strong
S6	2.75	strong
S7	2.75	strong

Source: Own elaboration.

The OPI has registered fluctuation values between 3.50 (moderate pollution) and 1.75 (very strong pollution), we notice the dominance of the strong pollution (Tab.5).

The map shows clearly a progressive deterioration of the water quality all along the wadi, marked by a moderate organic pollution, strong, very strong, and then strong again, the low values of this index are explained by the very hugh nitrites content, phosphate and the BOD_5.

The evolution of the OPI values all along the stations shows that this deteriorated state the water quality of the Kebir wadi east, is due to the domestic wastewaters coming from the agglomerations as well as the agricultural runoff.

The station S1 represents a moderated organic pollution due to an income of nitrogen and phosphate transported by water.

The station S2 represents a pollution statement that is relatively less important with regard to the one of S3. This is explained by the release of the dam waters which permitted the dilution of the polluating elements and and also by the low flow of the discharges.

The station S3, represents a pollution statement that is relatively important with rergard to the two first stations, this is due to the increase of the discharge flow.

As for the station S4, we notice a very strong pollution; this is explained by the strong discharge flow, the agricultural lands runoff and also the low-oxygen environment.

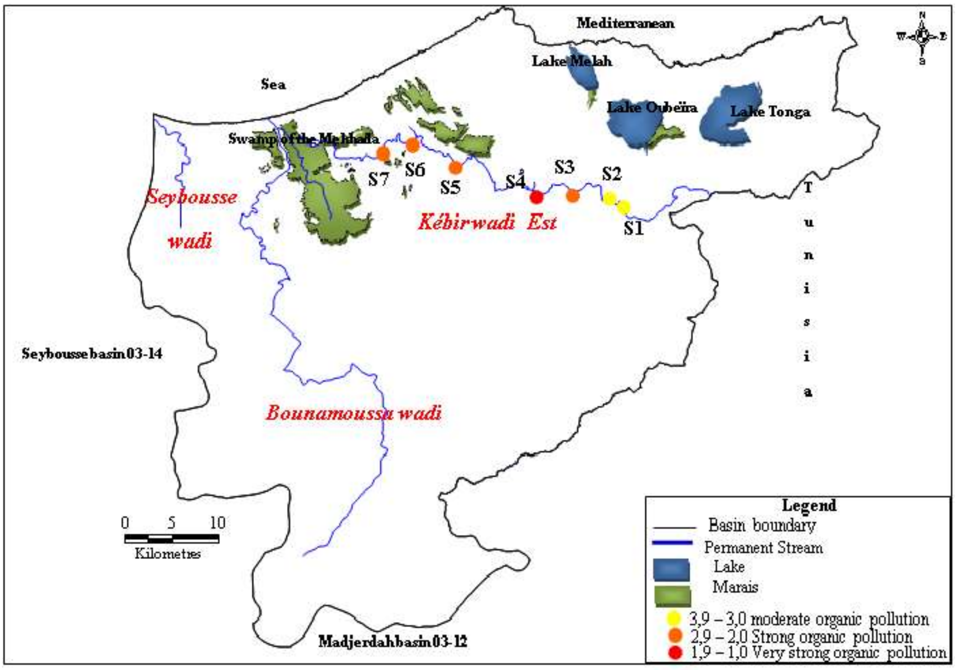

Fig. 2. The thematic map of the organic pollution index OPI of the surface waters of Kebir wadi east, within the comapins of april, may, june, july, august and september 2011, source: Own elaboration.

At the stations S5, S6 and S7 the pollutions becomes strong despite the high discharge flow and the agricultural runoff. This is explained by the self-purification potentials of the wadi, where the OPI increases from 1.75 for S4 to 2.75 for the stations mentionned previously; because at these stations we found the increase of the dissolved oxygen levels.

5. DISCUSSION

The water quality index WQI within the six compaigns april, may, june, july, august and september of the year 2011 indicates that more than the half of the stations (S1, S2, S5 and S7), let's say 57% of the stations, hover from excellent to good quality ($0 < WQI \leq 50$). The three left stations, represent 14% each of the set of the stations, remains with no seasonal change and with bad quality ($50 < WQI \leq 75$) for the stations S3 and S6, also non-potable waters ($WQI > 100$) for the station S4. , (Tab.2 and Fig.1) the increasing level of the water deterioration between the stations (S3, S6) and S4 is related to the increase of the ammonium concentration of S4 with regards to the one of the stations S3 and S6.

This increase naturally causes the formation of nitrates through the oxidative action of microorganisms. The human body readily absorbs ingested nitrates and excretes them rapidly through urine and saliva. Under the bacterial effect, nitrates are biotransformed to nitrites in the mouth and stomach to cause the case of methemoglobinemia, the main known consequence of nitrate ingestion [22]. Methemoglobinemia is the result of hemoglobin iron oxidation. In this form, this protein (hemoglobin) will not be able to fix the oxygen necessary for the cells and consequently causes oxygenation disorders [11].

The pollution state of the surface waters of Kebir wadi east, calculated as of the organic pollution index OPI, shows that 28 % of the stations (02 stations) represent a moderate organic pollution ($3 \leq OPI \leq 3.9$) and that 57 % of the stations (04 stations) represent a strong organic pollution within the six compaigns of 2011 (april, may, june, juky, august, september). The exception shows up againat the station S4, representing 14 % of the stations, which indicates a very strong organic pollution ($1 \leq OPI \leq 1.9$) (Tab.5 and Fig.2). This pollution is especially related to the relatively high concentrations of the BOD_5 that exceed the algerian norms of the potability which is 20 mgO_2/l [5]. This high BOD5 content is explained by low aeration, which is due to the consumption of dissolved oxygen by micro-organisms for the degradation of organic matter.

The deterioration of the water quality at the level of all of the stations all along Kebir wadi east, is due to agricultural activities and waterwastes with no preliminary treatment [5].

The different index results, i.e the water quality index WQI and the organic pollution index OPI applied en kebir wadi's east surface waters of El Tarf, and studied within the six compaigns of 2011 were compared between each other to test the degree of agreement and / or the unconformity between the different methods. The two indexs WQI and OPI show a complete agreement between all of the stations and all along the six compaigns especially at the stations: S1, S2, S4 and S6. These results are comparable to those obtained by Talhaoui et *al*, [24] and El Hmaidi et *al* [10] at oued Moulouya, North East of Morocco.

As from afar, both the studied water's quality and the organic pollution degree look stable without any apparent change. However, the detailed examination of the results highlights a distinct seasonal variation with slightly a tendency to deterioration. Also, the minimum, average and maximum values of the WQI increase slightly from the wet season april, may and june to the dry season july, august and september of the year 2011. This seasonal variation is comparable to that obtained by Taybi et *al* [25] at the North East Morocco Moulouya wadi, by Talhaoui et *al* [24], El Hmaidi et *al* [10] at the North East Morocco Moulouya wadi, by Vital et *al* [27] at the Menoua West Cameroon watershed, by Serge and Ernest, 2020 at the surface water of the department of Divo Center West of Ivory

Coast and by Miriac et *al* [18] at drinking water in the municipality of Lokossa in the south-west of the Republic of Benin West Africa.
The deterioration of the water quality is translated by an important anthropogenic mineral and organic burden coming from the urbain municipalities of El Tarf region. These waters are very polluted at these municipalities, because of the very high concentrations of the nitrates, ammonium and the BOD_5 that go beyond the standard algerian potability norms sometimes which are: 0.5 mg/l ammonium, 50 mg/l for the nitrates and 20 mgO_2/l for the BOD_5. Results are comparable to those obtained by Bekri et *al* [7] at Moulouya and Ansegmir wadis, Upper Moulouya, North East Morocco.
This deterioration is basically anthropogenic related to the agricultural activities, by the lands runoff full with fertilizers and the urbain wastewaters [5]. Similar reaserches have showed that the increase of the pollution degree in summer would be relative, with no doubt, to the decrease of the Kebir wadi'seast flow, so hoping that the ones of the full of the domestic and indistrual wastewaters effluents coming from the different urbain centers remain importants, These results are comparable to those obtained by Talhaoui et *al* [24] and El Hmaidi et *al* [10] at Moulouya Wadi, North East Morocco.

6. CONCLUSION

The water quality index WQI within the six compaigns april, may, june, july, august and september of the year 2011 indicates that more than the half of the stations (S1, S2, S5 and S7), let's say 57% of the stations, hover from excellent to good quality ($0 < WQI \leq 50$). The three left stations, represent 14% each of the set of the stations, remains with no seasonal change and with bad quality ($50 < WQI \leq 75$) for the stations S3 and S6, also non-potable waters ($WQI > 100$) for the station S4.
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related to the agricultural activities, by the lands runoff full with fertilizers and the urbain wastewaters.

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