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Assessment of surface water quality in the Guebli River watershed (Northeast of Algeria)

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Key words: Guebli River, Quality, Surface water, Chemical analysis.

Abstract

The objective of this study is to enhance the data currently available in the Guebli river basin and to provide some information about the quality of surface water. After a few general points designed to give the public and the lay manager the basic knowledge they need to make informed decisions. The overall physico-chemical and microbiological quality was assessed on the basis of eight parameters: conductivity, dissolved oxygen, biochemical oxygen demand, nitrates, total coliforms, faecal coliforms and faecal streptococci, and for heavy metals: plumb, manganese, total iron and chromium III. This study shows that the water quality of the main river of Guebli watershed and its tributaries is good over all or most of its length, with the exception of sections located near the outlet of domestic discharges from large urban areas, which significantly degrade surface water quality. The waters of the Beni Zid dam are of excellent quality and there are no external pollution sources. At the Guenitra dam, the water has a contamination degree of urban and heavy metal as well as Pb and Cr III elements that exceed the maximum admissible limit for drinking water. However, this water is not affected by the salinity and sodium hazard, so it is suitable for irrigation purpose.

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Introduction

The management of water resources requires a good knowledge of its quality and the different sources of pollution that may be affecting it (Derradji *et al.*, 2007). In order to make an effective decision, the manager must have access to simple, synthetic and well-defined data, where it relates to a multitude of descriptors (Oxygen, pH, faecal coliforms etc.), measured at several times and in several places (Billet, 1982). To this purpose, a synthesis and communication tool facilitating the presentation of the state of water river quality to the public and managers should therefore be essential (Margat and Vallée, 1999; Khamar *et al.*, 2000; Taoufik, 2005; Barreteau *et al.*, 2008).

Rivers are the recipients and vectors of the various urban, industrial and agricultural discharges (Dai and Labadie, 2001; Lamri and Hassouni, 2011; Khalfaoui *et al.*, 2014). In this context and to contribute to filling this gap in the state of water quality in this region, we carried out this study between 2010 and 2014, the main objective of which is to assess surface water quality using a spatiotemporal monitoring system covering the hydrographic networks of the Guebli river watershed. The study is based on the monitoring of a set of parameters, some of which are measured in situ and others by physico-chemical and bacteriological analyses carried out in the laboratory. The results obtained allow us to diagnose water quality and propose explanatory hypotheses on the main factors influencing this quality, to carry out a characterization and typology of the rivers that form this watershed.

Material and methods

Studied area

The watershed of the Guebli river belongs to the central Constantine coastal basin (code N°03), (Fig.1). It is drained by the Guebli river and its tributaries. This watershed extends from 6°23' to 6°47' East longitude and from 36°35' to 36°58' North latitude. It covers an area of 993 km² and is almost totally included in the administrative territory of the province of Skikda (Foufou, 2015). The Guebli watershed is limited to the North, by the Mediterranean Sea, to the South and South-West, Est and the North-West by the catchments of Oued-Rhumel, Oued Saf-Saf and Oued Bibi and Coastal zones of Cape Bougaroun respectively.

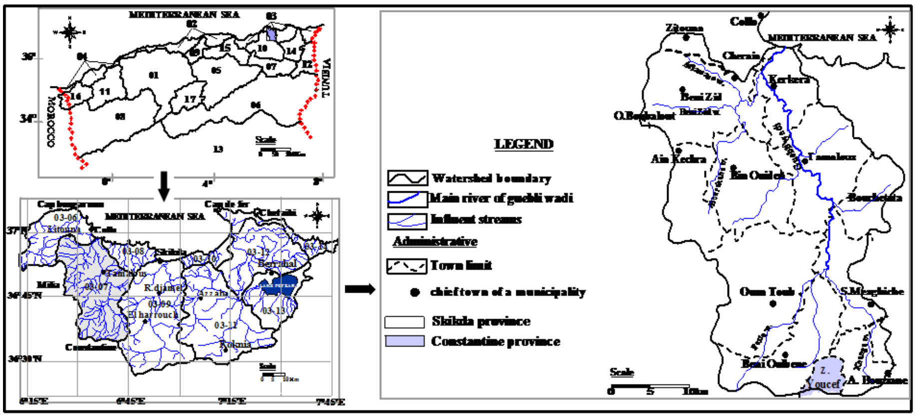

Fig. 1. Location map of Guebli river watershed.

The watershed of the Guebli river belongs to the Algerian eastern tell, which is only part of the Tellian atlas. The geology of the region is very complex (Raoult, 1966; Mahdjoub and Merle, 1990). The studies conducted have shown that the Algerian eastern tell is constituted by a series of layers; there is from north to south: the Kabyle base, the Kabyle ridge, the flyschs series (Mauritanian, Massylian, Numidian and ultra Tellian), the Numidian sandstone series and the constantinois Neritic layer (Bouillin and Raoult, 1971; Mahdjoub *et al.*, 1997). The watershed of the Guebli river is limited both to the South and Southwest by sedimentary formations that belong to the Constantine Neritic mole, and are generally constituted by carbonate formations of Cretaceous age (Raoult, 1975; Gaston and Marre, 1988). As for Paleozoic crystallophyllian formations, they limit it to both the North and North-East by the peridotite base of Cap Bougaroun and in the North-East by the Kabyle base unit and the Oligo-Miocene Kabyle. Alluvial formations are found alongside the Guebli river along its entire trajectory (Bouillin, 1983; Ouabadi *et al.*, 1992).

The Guebli watershed takes its name from the river that results from the junction of two main wadis: the Fessa wadi, which originates from the south-western part of the Sidi Dris numidic chain, the main stream that feeds the Guenitra dam and its various tributaries, and the Khanga wadi, which begins in the south-east of Jebel Bit Eddjazia and Ayata, which is the result of two wadis confluence : the Refref wadi and the Sdira wadi (Tesco Viziterv, 1983; Bouillin, 1979). At the confluence, the Guebli river crosses a series of very steeply sloping gorges (Raoult, 1966; Gaston and Marre, 1988). At the end of the route, the Guebli river flows into the Mediterranean 7 km east of the town of Collo (Fig. 2).

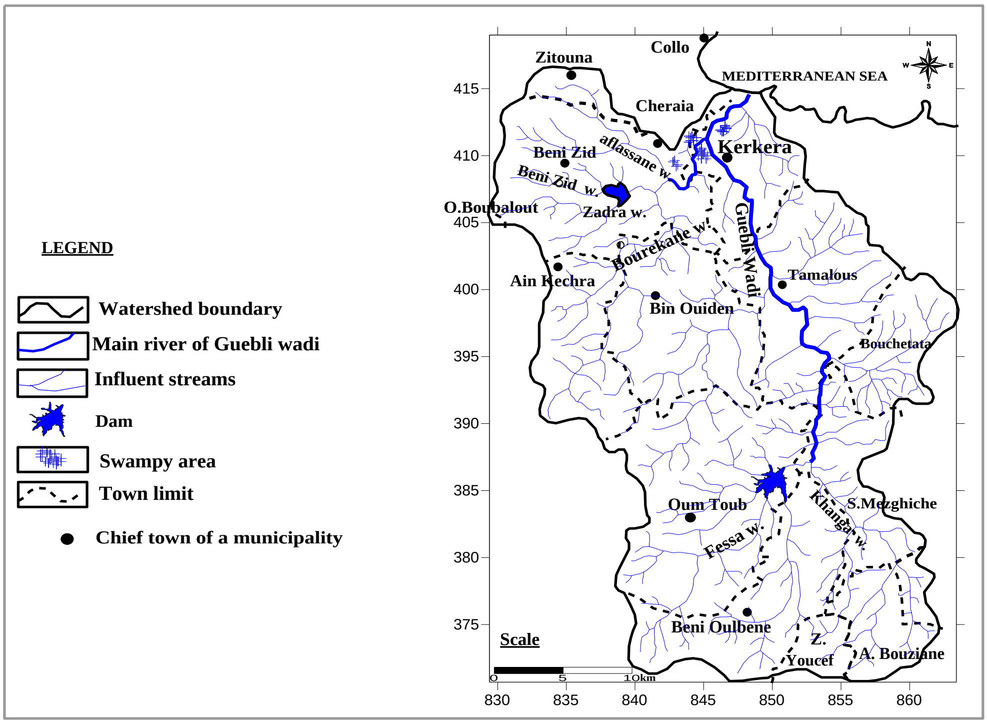

Fig. 2. Hydrographic network map of Guebli river watershed.

In terms of water potential, the average rainfall reaches 813 $mm.yr^{-1}$ over the entire watershed, with 1200mm. yr^{-1} of precipitation at the Zitouna station and 650mm. yr-1 at Guenitra. The average annual contribution of the of the Guebli river is $143hm^3$. yr^{-1}, an estimate of its flow by float gauging during the monitoring period (April and September 2014) gave values that vary between 0.5 and 8.4m^3. s^{-1}. Most of the territories crossed by the watershed of the Guebli river are still rural in nature. It has the advantage of concentrating all the characteristic uses of a mountain territory: agro-pastoralism, livestock, and agriculture.

To assess the quality of surface water in the Guebli river watershed, three sampling areas was chosen: upstream part, downstream part and water of principal dams in the watershed.

Upstream waters

The survey system consists of two (2) water sampling campaigns (first campaign: April 2014; second campaign: September 2014). It is during this time of year that the physico-chemical composition and bacteriological quality of the water are most likely to affect aquatic life and associated uses of these rivers. The sampling protocol includes six (6) stations (Fig.3), one (1) station for each principal tributary or wadi (Charfa, Fessa, Megramene, Mellouh, and Essouk), and one (1) after the confluence of the tributary sorted from Guenitra dam and Khanga wadi. The stations were chosen according to the position of the mining areas, the availability of the structures, and in relation to the existing bridges. The station of each wadi measures the initial state of the water before reaching the Guenitra dam. The last station (St6) shows the state of the water at the outlet of the dam and the beginning of the main canal of Guebli river.

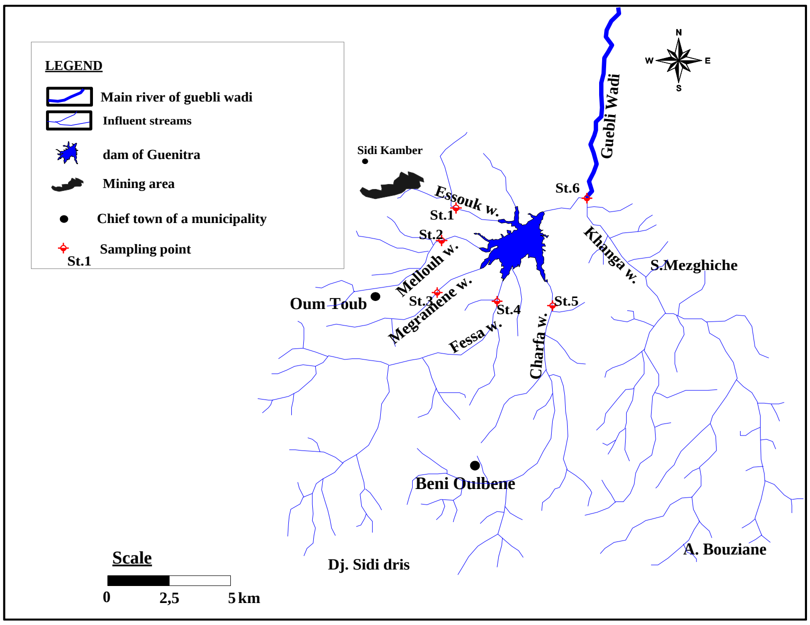

Fig. 3. Sample locations in the upstream part of Guebli river watershed.

Temperature, Ph, electrical conductivity and dissolved oxygen

Temperature, pH, electrical conductivity and relative amount of dissolved oxygen in the water were measured directly at each station using a YSI 6600 electronic multisensor. The readings were taken at the centre of the water column. The oximeter electrode and pH electrode have been systematically calibrated on a daily basis according to the manufacturer's recommendations.

Nitrites and nitrates

The water samples used to measure NO_x^- were collected in 20ml glass vials. At each station, approximately 10ml of water filtered at 0.2µm using a syringe with a 22mm filter holder was duplicated. The samples were immediately acidified to approximately pH 2 by adding concentrated sulfuric acid in the field. They were stored in the refrigerator at a temperature of 4°C until the time of analysis.

Fecal coliforms, Escherichia coli, total germs and fecal Streptococci

On the upstream Guebli river and its tributaries, water withdrawals were made based on the protocol applied by the Algerian water authority to quantify viable fecal coliforms. Sterile 1500ml plastic bottles were used and precautions were observed to avoid contamination (wearing gloves, triple rinsing with medium water, opening the bottles upstream while the manipulator is placed downstream). The bottles were all filled by immersion about 150mm below the water surface, taking care to leave a residual volume of air. The bottles were then placed in a cooler in a dark place (about 4°C).

Chemical element analysis

A complete analysis of the chemical elements was carried out for this study: the major elements (Ca^{2+}, Mg^{2+}, Na^+, K^+, Cl^-, SO_4^{2-} and HCO_3^-), trace heavy metals (total iron, manganese, chromium III, plumb).

As well as suspended solids (SS), turbidity, biological oxygen demand (BOD_5) and chemical oxygen demand (COD).

The sampling techniques used (ultra-clean), filtration and sample storage techniques were used for both campaigns. Water samples from the wadis were taken using Teflon bottles, previously cleaned with nitric acid, and stored in hermetically sealed polyethylene bags. Filtration was carried out under a portable laminar flow hood. The filtered water was stored in hermetically sealed Teflon vials and wrapped in a polyethylene bag.

Bacteriological and physico-chemical quality index (BPQI)

This index should make it possible to assess water quality according to all potential uses (i.e. swimming, water activities, drinking water supply, protection of aquatic life and protection of the water body against eutrophication) and not according to a specific use (Béron and Valiquette, 1982).

It also had to be a simple, sensitive and adaptable mathematical tool, but sufficiently developed to be able to convey interesting information for both managers and scientists (Couillard and Lefebvre, 1985). One of the main qualities sought in this index was finally that it avoids masking the most important information, namely that concerning the descriptor limiting the full use of water of the river. It requires the measurement of a number of descriptors, the conversion of the measured concentration into a dimensionless sub-index using a water quality assessment curve (Gustafsson, 1992).

The proposed classification system is based on quality criteria of the Quebec Ministry of the Environment 1992 (Fig. 4). The Bacteriological and Physico-chemical Water Quality Index (BPQI), which is dimensionless and can range from 0 to 100, defines five quality classes:

- A (80-100): good quality water generally suitable for all uses, including swimming;
- (60-79): water of satisfactory quality generally allowing most uses;
- (40-59): water of questionable quality, some uses may be compromised;
- D (20-39): poor quality water, most uses may be compromised;
- E (0-19): very poor quality water, all uses may be compromised;

The determination of the IQBP is done by aggregating the different sub-indices according to the concept of the limiting descriptor. Its value is thus equivalent to the sub-index with the lowest ranking and serves as a criterion for establishing the quality and possible uses of the water resource. Through its aggregated approach based on the limiting descriptor, the IQBP inevitably leads to a loss of information. However, it is simple to determine and has the added advantage of facilitating communication with non-specialists. The descriptors considered are: Fecal coliform; pH; BOD_5; concentration of nitrites and nitrates; Turbidity; Suspended solids and total phosphorus concentration.

Downstream waters

It consists of a monthly survey, during the period from May to September 2014, with the analysis of a majority of physico-chemical parameters. The water is sampled from 15 stations located in the main canal of Guebli river. The sampling interval is compressed near the industrial areas and more distant in undeveloped zones. To assess the water quality three indicators are defined: The biodegradability index for domestic use, the Richards classification for irrigation and the Larson ratio (corrosivity index) for industrial activities.

Biodegradability index (BI)

The COD/BOD_5 ratio or biodegradability index (BI) is important for the definition of the effluent treatment chain. Indeed, a low COD/BOD_5 ratio indicates the presence of a high proportion of biodegradable materials and makes it possible to consider biological treatment. Conversely, an important value of this ratio indicates that a large part of the organic matter is not biodegradable and, in this case, it is preferable to consider a physico-chemical treatment.

Richards diagram

This diagram is based on the values of the sodium absorption ratio (SAR) and the electrical conductivity of the ions contained in the water.

The objective was to represent the samples on the Richards diagram in order to facilitate the characterization of the water on its suitability for irrigation.

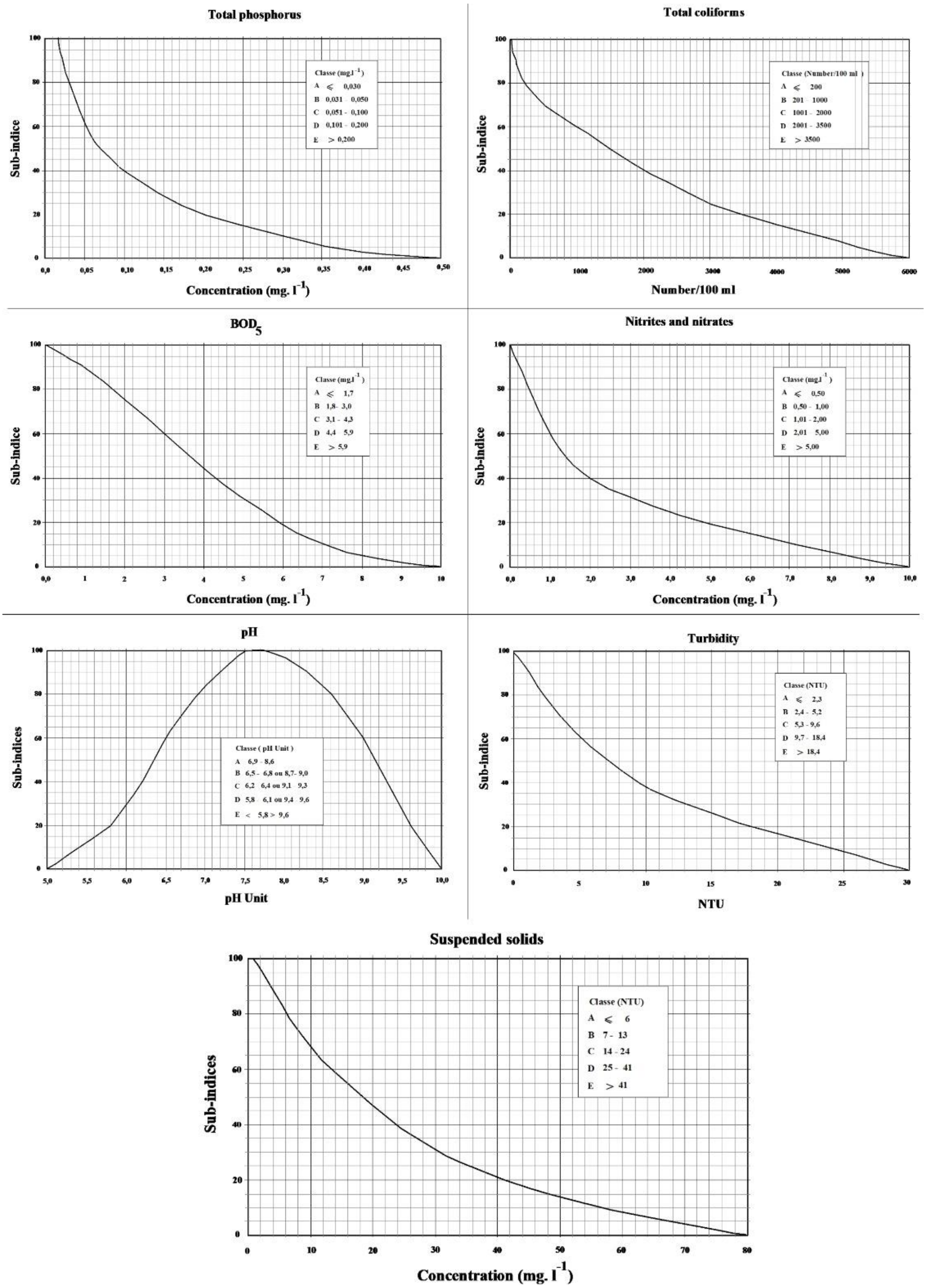

Fig. 4. Assessment of water quality with respect to the different descriptors (MENVIQ, 1992).

Larson ratio (corrosivity index)

The Larson Ratio (LR) describes the corrosivity of water towards mild steel.

The index is the ratio of the twice moles per liter (mol/L) of sulfate (SO_4^{2-}) plus chlorides (Cl^-), to the moles per liter of alkalinity (in form bicarbonate and carbonate):

$LR = (Cl^- + 2*SO_4^{-2})/HCO_3^-$... (1)

If LR is: < 0.2 .... No probability of corrosion

Between 0.2 and 0.4 .. Low probability of corrosion

Between 0.4 and 0.5 ... Slight probability of corrosion

Between 0.5 and 1 ...... Moderate probability of corrosion

> 1 .... Clear risk of corrosion

This empirical formula is based on numerous experiments carried out by the Americans Larson and Skold. This index makes it possible to determine the corrosivity of water from the concentrations of chloride, sulphate and bicarbonate ions. However, it does not take into account calcium and magnesium ions which slow down the corrosion phenomenon.

Dam waters

In order to understand the evolution of the water quality of dams, the results of chemical analyses carried out by the National Hydraulic Resources Agency (N.H.R.A) of Constantine province have been taken in this work. The data are carried over a period of 23 years (1990-2013) for the Guenitra dam and 7 years (2006-2013) for the Beni Zid dam. The annual concentration of physico-chemical data in our study represents the average of the values recorded during a hydrological year (four samples per year). The purpose of interpreting these physico-chemical analysis results is to make spatial and temporal comparisons of the various parameters of water potability at these two dams.

Result and discussion

Quality of upstream waters

Physico-chemical parameters

The recorded temperatures range from 19.3°C in April to 22.9°C in September. This variation depends mainly on climatic conditions. The analyzed waters show pH values between 7.2 and 7.8.

The measured conductivities range from 811 µs.cm^{-1} (September) to 605 µs.cm^{-1} (April). This variation is due to the dilution of water by the contribution of rainwater. Dissolved oxygen concentrations, as well as pH values, are one of the most important parameters for determining good water quality. Dissolved oxygen values at the Guebli river during the year fluctuate from 7.1 to 10.5mg. l^{-1}.

The results of the chemical and bacteriological analyses of the surface waters in the upstream part of the Guebli river watershed are presented in Table 1.

Table 1. Physicochemical and bacteriological parameters of surface water samples in the upstream part of the Guebli river watershed.

Parameters	Units	April 2014				September 2014			
		MIN	MAX	MEAN	SD	MIN	MAX	MEAN	SD
Sulfate	mg.l^{-1}	88.20	220.20	148.05	53.30	74.20	188.30	130.85	54.79
Chloride	mg.l^{-1}	80.20	190.20	126.17	37.65	40.10	170.10	95.87	46.49
Bicarbonate	mg.l^{-1}	50.60	225.30	126.62	79.68	42.20	211.30	102.85	65.39
Sodium	mg.l^{-1}	26.60	45.90	36.02	7.67	17.30	36.50	25.40	7.45
Potassium	mg.l^{-1}	2.50	10.20	4.77	2.81	3.20	12.70	7.80	3.33
Calcium	mg.l^{-1}	50.40	96.40	68.53	15.48	49.30	106.20	74.93	23.87
Magnesium	mg.l^{-1}	30.50	41.10	35.32	4.39	20.10	30.30	26.92	3.77
Phosphorus	mg.l^{-1}	0.05	0.16	0.09	0.04	0.05	0.18	0.10	0.04
Turbidity	N.T.U	2.60	8.70	5.88	2.16	7.80	12.30	10.07	1.74
Suspended solids	mg.l^{-1}	9.80	14.90	12.97	2.21	16.20	25.70	20.38	3.72
BOD_5	mg.l^{-1}	3.20	7.10	4.53	1.44	3.70	7.80	5.47	1.35
COD	mg.l^{-1}	34.50	55.30	42.63	8.52	40.50	60.80	49.85	7.39
OTC	mg.l^{-1}	67.50	106.70	84.87	16.66	14.10	53.50	31.08	14.75
Nitrate	mg.l^{-1}	1.10	2.70	1.88	0.62	1.09	2.40	1.78	0.65
Total iron	mg.l^{-1}	0.10	1.10	0.52	0.38	0.10	1.90	1.05	0.84
Plumb	µg.l^{-1}	3.50	28.10	17.63	10.55	3.80	30.80	20.13	11.78
Manganese	µg.l^{-1}	0.60	80.40	25.60	30.62	5.10	140.80	63.35	63.06
Chromium III	µg.l^{-1}	1.00	30.80	13.67	11.75	2.10	40.70	17.82	14.84

Parameters	Units	April 2014				September 2014			
		MIN	MAX	MEAN	SD	MIN	MAX	MEAN	SD
Escherichia Coli	n/100ml	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total germs at 22°C	UFC/ml	0.00	0.00	0.00	0.00	20.00	100.00	44.17	29.40
Total germs at 37°C	UFC/ml	30.00	90.00	63.33	23.38	100.00	280.00	150.00	67.53
Total coliform at 37°C	NPP/100ml	300.00	2500.00	758.33	856.98	350.00	1200.00	750.00	360.56
Fecal coliforms at 44°c	NPP/100ml	150.00	2000.00	536.67	721.85	500.00	3500.00	1075.00	1193.21
Fecal Streptococci at 37°C	NPP/50 ml	20.00	30.00	23.33	5.16	180.00	350.00	238.33	69.40

With regard to the major elements, the water analyzed remains in compliance with the standards of potability, both Algerian found in the official journal of Algerian republic democratic and popular (OJARDP, 2011) and WHO (2011). The interpretation of the results of the chemical analyses of the waters shows the presence of two dominant chemical facies: one is bicarbonate calcium, which characterizes the waters of the Fessa Charfa wadis. This type of water results from the dissolution of the Cretaceous carbonate formations existing in the area upstream of these wadis (Sidi Dris Mountain). The second type of water is calcium sulphate to calcium chloride found in the waters of Essouk, Mellouh and Megramene wadis, due to the oxidation of pyrite, and the dissolution of clay formations and marl formations located at the first sterile bed (mine residues remaining after the extraction of the deposits of a series of sulphide-mineralized seams, the main mineralogical parts of their composition are galena (PbS), blende (ZnS) and baryte (Bouillin and Kornprobst, 1974; Ouabadi, 1994; Tandjir and Djebar, 2007). They have a long mining history that begins from Roman times to 1984 (Brunet, 1993).

At stations located downslope of the Sidi Kamber mining area: Essouk, Mellouh and Megramene wadis (St1, St2 and St3 respectively) concentrations of heavy metals in water are generally higher than those found at Fessa and Charfa wadis stations (St4 and St5) both in rainy and dry periods (Table 1). The average Pb concentration was measured at station St1 ($29.5 \mu g.l^{-1}$) located on the Essouk wadi, which crosses the sterile deposits and mining areas whose primary objective was to extract lead and baryte, at the time of sampling its flow was low (about $3\ l.s^{-1}$ in dry period). The Essouk wadi feeds the Guénitra dam, has a total volume of $1.86 hm^3.\ yr^{-1}$, or 6.2% of the regularizable water potential (Fig. 6). Pb concentrations in the water of Mellouh and Megramene wadis are high in September and higher than those found in April, due mainly to the vane leaching of mine residues.

The concentration of Pb largely exceeds the average concentration of uncontaminated natural fresh water ($0.2 \mu g.\ l^{-1}$) (Trefry and Presley, 1976) and exceeds the average concentration of natural fresh water ($3 \mu g.\ l^{-1}$) (Bowen, 1979).

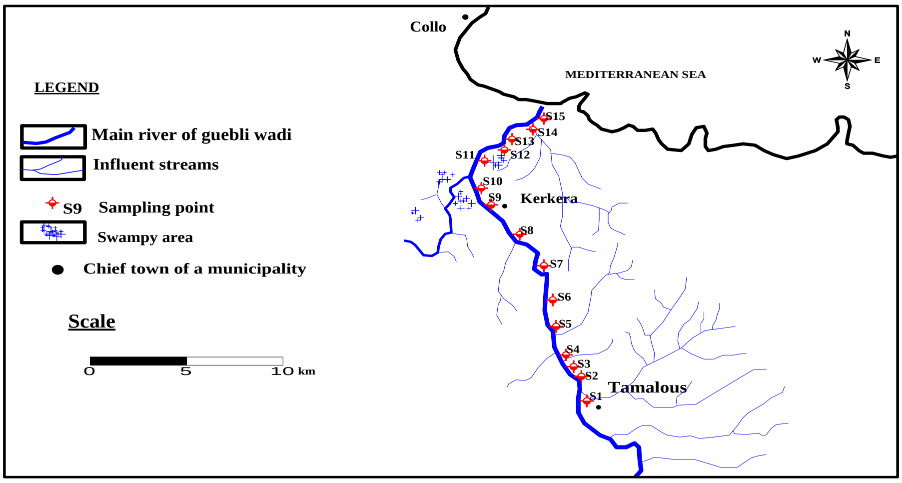

Fig. 5. Sample locations in the downstream part of Guebli river watershed.

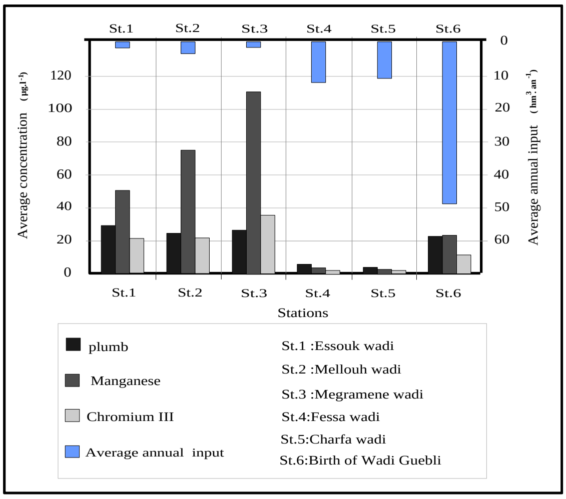

Fig. 6. concentrations of heavy metals in the upstream part of the Guebli river watershed.

In terms of quality, the Pb concentrations in the waters of Essouk and Mellouh, wadis and Megramene wadis are over the standards of Algerian potability (10µg. l^{-1}) (OJARDP, 2011). This surface water is of a bad quality and requires physical and chemical treatment and disinfection for the production of drinking water. However, according to the same standard and as a consequence of the Pb concentration, surface water at Sidi Kamber can be used for irrigation ([Pb] < 5000µg. l^{-1}). Concentrations are lower at the junction of Fessa and Khanga wadis (birth of Guebli river; 23mg. l^{-1}), due to the dilution effect of other inputs of Fessa and Charfa wadis (5.9mg. l^{-1} and 3.6mg. l^{-1}), total a volume of 21.87hm^3. yr^{-1}, or 73% of the regulating water potential in the Guenitra dam. As for Pb, the highest concentrations of other heavy metals are observed below the Sidi Kamber mining area at stations St1, St2 and St3, with concentrations reaching 40.4µg. l^{-1} for chromium, 1.9mg. l^{-1} for total iron, and 140.8µg. l^{-1} for manganese. At station St6, there is a decrease in the concentrations of chromium III (12.4µg. l^{-1}), total iron (0.6mg. l^{-1}) and manganese (27.5µg. l^{-1}), due to the effect of dilution with water of Fessa and Charfa wadis with low concentrations.

In terms of quality, high values were found for chromium III and total iron and acceptable for manganese. Chromium III concentrations reach 40 ug.l^{-1} and 1.9mg. l^{-1} in total iron. These concentrations largely exceed the drinking water quality standards of OJARDP (2011). Nitrate concentrations are between 1.1 and 2.7mg. l^{-1}, these concentrations are still very low and do not exceed the water potability standards of 50mg. l^{-1} according to OJARDP (2011). These low values indicate that the water is well oxygenated. High concentrations of BOD_5 are recorded in September, with an average of 5.5mg. l^{-1}, indicating bad water quality when it exceeds 5mg. l^{-1}. If this water is used for drinking, an appropriate treatment is required.

Bacteriological analyses

Bacteriological analysis may reveal faecal water pollution. The pathogenic organisms that can be present in water are very numerous and varied.

– *Total germs*

Their presence in the water indicates the existence of faecal contamination. In the present study, the total germs at 22°C were found in September samples, while for the total germs at 37°C, their presence is constant throughout the year with a high increase in September (dried period).

– *Total coliform*

Total coliforms are present in water throughout the year with a number ranging from 220 to 3500 NPP/100ml.

– *Fecal coliforms and fecal Streptococci*

The presence of fecal coliforms and fecal streptococci is an indicator of contamination, largely of human origin, the occurrence of streptococci has been found throughout the year and especially in September (dried period).

– *Escherichia Coli*

Analyses showed a total absence of Escherichia Coli throughout the year. Microbiological analyses have also shown that average bacterial contamination can be of human, agricultural or animal origin. This contamination is due to the villagers' domestic water discharges as well as to the excrements of livestock animals located near the Guebli river. According to the Algerian classification of surface water, the analyses classify this surface water as of bad bacteriological quality, so it cannot be used for drinking water supply. Prior treatment is essential to eliminate any bacteriological pollution.

Bacteriological and physico-chemical quality index (BPQI)

The BPQIs presented in Table 2 clearly show that the water quality of Guebli river decreased drastically between its upstream (C) and downstream (E), with its five sampled tributaries appearing to contribute to this trend. BPQIs indicate that swimming was compromised over the entire sampled section in the upstream part of Guebli River.

An examination of the various sub-indices shows that the achievement of low BPQIs restricting most if not all water resource uses was mainly due to BOD_5 in September, to a lesser extent, to total phosphorus in April. These two parameters had low sub-indices at several sampling stations.

Table 2. Bacteriological and physico-chemical indices (%).

Parameters	April 2014						September 2014					
	St.1	St.2	St.3	St.4	St.5	St.6	St.1	St.2	St.3	St.4	St.5	St.6
pH	95	100	87	100	100	100	85	92	85	95	92	97
Turbidity	76	57	57	47	60	43	36	34	32	42	47	36
Fecal coliform	73	78	40	78	83	80	69	70	20	67	63	70
Phosphorus	61	37	26	46	50	42	61	42	24	40	42	40
Suspended solids	69	56	65	58	60	56	43	36	55	51	53	44
BOD_5	37	46	30	56	54	10	26	27	22	33	50	6
Nitrites and nitrates	36	50	33	57	45	39	57	57	50	37	36	36
Class	D	D	D	C	C	E	D	D	D	D	D	E

Quality of downstream waters

Water quality for irrigation

The highest conductivity values were found at stations near the outlet of the Guebli river. All water points present a low to moderate risk according to the SAR diagram for irrigation (plants and soils), except stations S12, S13, S14 and S15 located near the outlet of the Guebli river where the risk is high. The results obtained from the interpretation of Richard's diagram (Fig. 7) show that the waters studied are in three (03) classes: acceptable representing 60%, mediocre 13.3%, and out of range 26.6%.

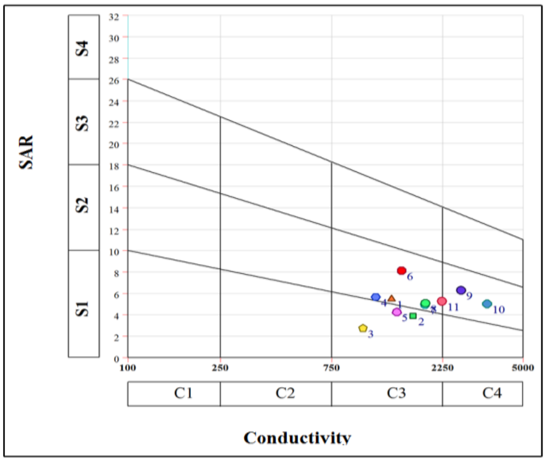

Fig. 7. Plots of surface water samples in Richards's diagram (Downstream part).

Indices of water pollution

– *Biodegradability index (BI)*

The spatial variation of the COD/BOD_5 ratio shows a biodegradability index between two (2) and three (3) (Fig. 8). These values indicate that the water is biodegradable along the river with some selected strains, requiring a combined treatment (biological and physico-chemical).

– *Fecal coliform*

The waters of Guebli river show microbiological quality indices indicating high faecal contamination from stations S1 to S10, ranging from 1040 to 326 CFU per 100ml. They also show lower faecal contamination for stations S11 to S15, due to sterility caused by high salinity near the outlet of the sea. The quality standards for this parameter are 200 CFU per 100ml of water for swimming, and 1000 CFU / 100ml for indirect contact activities, such as fishing and canoeing. The presence of fecal coliforms is mainly due to manure spreading and non-compliant or inadequately maintained septic faeces.

Quality of industrial water: Larson Index (corrosivity index)

This index helps to determine the corrosivity of water according to the concentrations of chloride, sulphate and bicarbonate ions. However, it does not take into account calcium and magnesium ions, which slow down the corrosion process. LR is found superior to the 1 (>1) in all sampling stations (Fig. 9), which reveals that the waters in the downstream part of the Guebli river have a clear tendency to corrosion of metals.

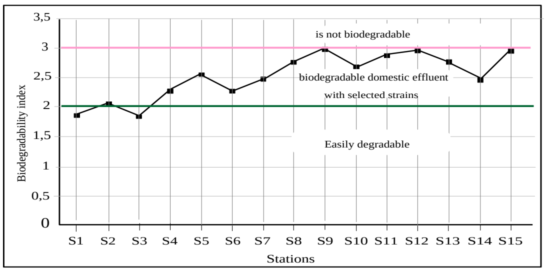

Fig. 8. Biodegrability index variation in the Guebli river.

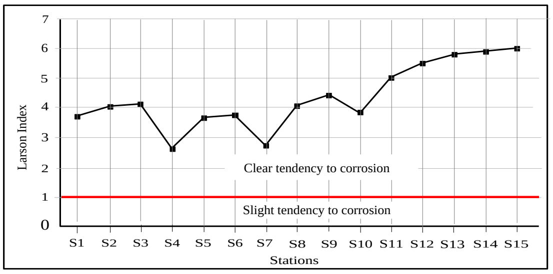

Fig. 9. Larson ratio variation in the downstream part of the Guebli river watershed.

Dams drinking water standards

As for the potability standards of the major elements, the results revealed that the water is of good potability and does not present a danger to the inhabitants. Nitrate values are high at the Guenitra dam. The water of the dam receives all the wastewater discharges from the municipality of Oum Toub.

The high concentrations of nitrate observed during 2012 are in the order of 49mg. l^{-1}. The minimum values were reached in 2008 when the concentrations did not exceed 35mg. l^{-1}. The waters of the Beni Zid dam are of excellent quality (Fig. 10) and there are no external pollution sources. At the Guenitra dam, the waters are contaminated with urban and heavy metals, in particular Pb, which exceeds the maximum admissible limit for drinking water (Fig. 11).

The origin of this contamination is clearly visible in the Sidi Kamber mining area, where there are sterile deposits from former operations used to extract plumb and baryte. The plumb concentrations found at the Guenitra dam are high, exceeding the drinking water standards (10µg.l^{-1}).

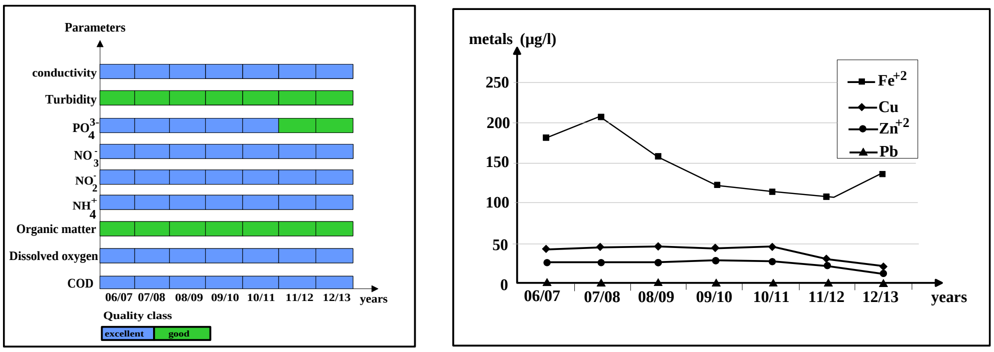

Fig. 10. Water quality of Beni-Zid dam.

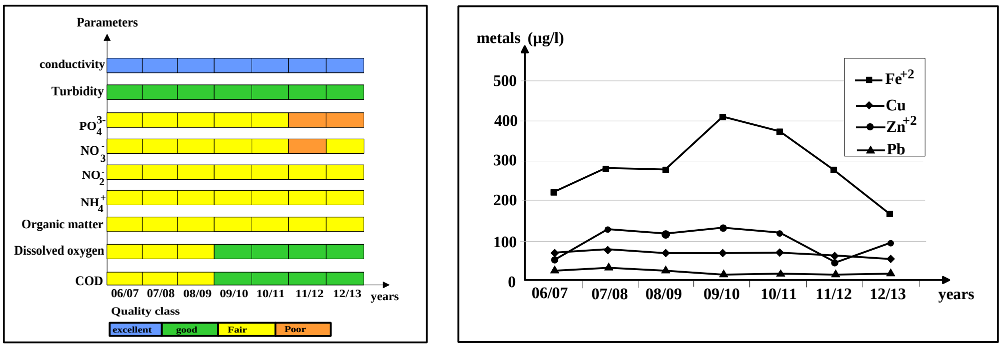

Fig. 11. Water quality of Guenit.

Conclusion

The diagnosis of the quality of water resources in the Guebli river basin shows that, overall, the quality of rivers is fairly good over all or most of their length, with the exception of the sections located near the outlet where domestic discharges from large urban areas significantly affect the quality of surface water.

The waters of the Beni Zid dam are of excellent quality and there are no external pollution sources. At the Guenitra dam, the water has a contamination level of urban and heavy metal contamination that exceeds the maximum acceptable limit for the drinking water. The origin of these heavy metals is related to the mining area of Sidi Kamber, where ancient operations have been developed for the extraction of plumb and baryte. Plum values found at the Guenitra dam are high. They exceed the drinking water standards (10 $\mu g.l^{-1}$). Based on the results of the S.A.R. diagram as a function of conductivity, the dam water has a good quality for irrigation.

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