Studia Universitatis "Vasile Goldiş", Seria Ştiinţele Vieţii
Vol. 28 issue 2, 2018, pp.95-106

ASSESSMENT OF THE PHYSICO-CHEMICAL AND BACTERIOLOGICAL QUALITY OF THE SURFACE WATERS OF WADIS "BOUKHMIRA, MEBOUDJA AND SEYBOUSE" USED IN IRRIGATION IN THE NORTH-EAST OF ALGERIA

[*1]Amira Youbi, [2]Ahmed Houilia, [3]Boudjema Soumati, [1]Houria Berrebbah, [1]Mohammed Réda Djebar, [4]Lynda Souiki

[1]Laboratory of Cellular Toxicology, Department of Biology, University of Badji Mokhtar, Annaba, Algeria.
[2]Laboratory of Soil and Sustainable Development, Department of Biology, University of Badji Mokhtar, Annaba, Algeria.
[3] Laboratory of Biochemistry and Environmental Toxicology, Department of Biochemistry, University of Badji Mokhtar, Annaba, Algeria.
[4]Department of Biology, 8th May University 1945, Guelma, Algeria

ABSTRACT: The use of surface waters of the Boukhmira, Meboudja and Seybouse wadis for agricultural purposes in the far north-east of Algeria is accompanied by health and environmental risks, the evaluation of which requires physicochemical and microbiological characterization. Bi-monthly samples were taken from February to December 2016 at the three studied sites. The results revealed that the waters studied are characterized by low levels of dissolved oxygen (2.90 ± 1.77 mg/l O_2), high levels of suspended matter (TSS) (134.5 ± 17.22 mg/l), Nitrites (0.66 ± 0.25 mg / l) and Orthophosphates (6.54 ± 2.39 mg/l), high values in BOD_5 (32.68 ± 11.04 mg/l O_2), and in COD (95.74 ± 19.14 mg/l O_2), as well as a microbiological pollution noticed by a heavy load of total germs, total coliforms, faecal coliforms and faecal streptococci, which exceed widely the standards of use of waste water in agriculture. The application of Principal Component Analysis (PCA) allowed us to evaluate the quality of wadis waters and to identify the main causes of degradation that are industrial, agricultural and domestic activities.

Keywords: water, irrigation, agriculture, pollution, PCA

INTRODUCTION:

Water is the most indispensable natural source, but also the most threatened by human activities, such as agriculture, which consumes huge quantities of water. Thus, the reuse of wastewater in agriculture is becoming more common practice in Algeria; due to the increasing scarcity of water resources (Hannachi *et al*., 2016). Farmers are required to use different water sources to meet the needs of their crops (El Asslouj *et al*., 2007). In many cases, they are obliged to use untreated urban or industrial wastewater, coming from the wadis; this water represents an important resource, but also a serious risk for the environment and the human health (Bouaroudj and Kadem, 2014).

In the Northeastern Algeria, the wadi Seybouse crosses the provinces of Guelma, Annaba and El Tarf, to pour into the Mediterranean Sea and contributes to the water supply for economic activities (agriculture, industry and agriculture) and drinking water in this region (Chaoui *et al*., 2013); as well the wadi Meboudja, which is a major tributary of the Seybouse. Many studies reported that the water in both wadis is subject to an intensified mineral pollution, by industrial effluents (Djabri *et al*., 2003; Harzouli *et al*., 2007). Moreover, another study proved that the wadi Meboudja, is subject to an inorganic pollution with a high concentration of heavy metals (Chaoui *et al*., 2013). However the wadi Boukhmira (El Tarf) has not been subjected to any study to date; these three wadis are used for the irrigation of agricultural lands.

The present study has two main objectives:

- Determination of the physico-chemical and bacteriological quality of the water in the wadis Boukhmira, Meboudja and Seybouse.
- Assessment of the environmental impact of pollution caused by industrial, urban and agricultural effluents.

MATERIAL AND METHODS:

Description of the study sites

The coastal region of Annaba-El Tarf is located in the far Northeastern Algeria; it is open to various environments, because of its favorable and privileged position:

- The Mediterranean Sea to the North, with more than one hundred (100) km of coastline.

- The sub-littoral plains to the South, especially the great plain of Annaba, and the plains of Bou-Namoussa and Kebir.

- The Tunisian border to the East, which represents a terrestrial link for international exchanges.

- The Lake Fetzara to the West.

This coastal region is completely integrated within the main Mediterranean domain, which defines its climate, relief and vegetation (Attoui, 2014) (Fig.1).

Correspondence: Amira Youbi, Laboratory of Cellular Toxicology, Department of Biology, Faculty of Science, Badji Mokhtar University, Annaba, Algeria. Email: amirayoubi@outlook.fr

Three sites have been prospected in this study: wadi Boukhmira (Site1) (province of El Tarf), wadi Meboudja (Site2) and wadi Seybouse (Site3) (province of Annaba).

Sampling and analysis

Biweekly samples of irrigation water have been taken from the three wadis, for an annual cycle from February to December 2016, in order to cover the seasonal variation. Water samples were collected in glass bottles of 1000 ml for the physico-chemical analysis, and in sterile glass bottles of 500 ml and stored at 4 °C in according to the protocol of Rodier, (2009), then sent to the laboratory within a maximum of 24 hours, for bacteriological analysis. The different analytical methods for physico-chemical and bacteriological indicators are summarized in Table 1.

Statistical analysis

The statistical study is based on the two-factor (site, time) ANOVA analysis; using the software MINITAB version 13.31 and the Principal Components Analysis (PCA); in order to establish a relationship between the different physico-chemical and bacteriological parameters and to better evaluate the effect of human activities, on the water quality; this method is commonly used, to interpret the hydro-chemical data (Chaouki *et al*., 2015; Lakhili *et al*., 2015). XLSTAT version 2014.5.03 has been used for this analysis.

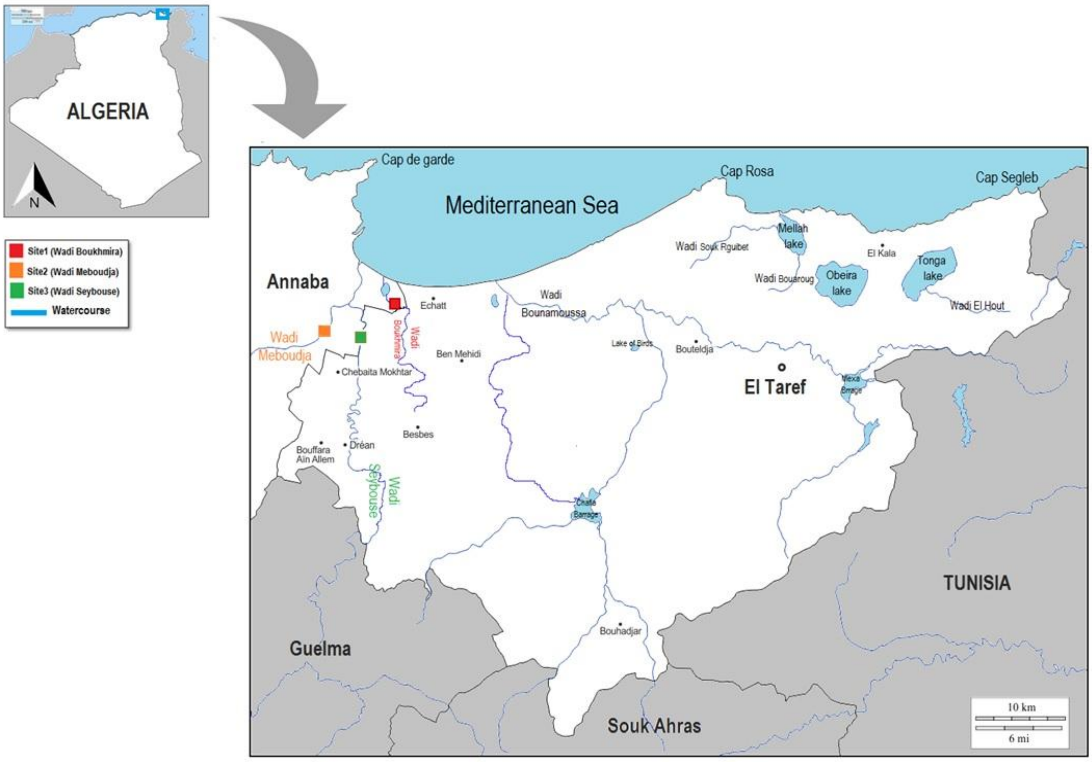


Fig. 1. Location of studied sites.

Tab.1.
Methods of analysis of physico-chemical and bacteriological indicators.

	Parametrs	Methods of determination	References
Physicochemical indicators	Temperature pH Conductivity Dissolved O_2	Multi parameter probe	HQ40d multi /NACH
	TSS	Spectrometric (HACH : DR5000)	NF T 90-105
	DOB_5	Manometric method	NF, T90-103
	COD	Oxydation dichromate de potassium	NF, T90-101
	NH_4^+	Spectrometric method	ISO 7150/1-1984
	NO_3^-	Spectrometric method with 2,6-dimethyl phenols	ISO 7890-1:1986
	NO_2^-	Spectrometric method	ISO 6777-1984
	PO_4^{-3}	Spectrometric method	ISO 6878/1-1998
	Fe	Spectrometric method	NF T90-017
	Zn	Spectrometric method	FD T 90-112
Bac teri	Total germs	General method by seeding in a nutrient agar culture medium	ISO 6222 :1999

	Total Coliforms Fecal Coliforms	General method by enrichment in liquid medium (N.P.P)	ISO 9308-2:1990
	Fecal streptococci	Streptometry by membrane filtration	ISO7899-2 :1984

RESULTS AND DISCUSSION:

Physico-chemical characteristics of the water in the three sites

The results obtained are presented in the figures (2) to (7). The water temperature is an important ecological factor, which causes significant ecological repercussions (Leynaud, 1968). The water temperatures vary slightly between the different sites; with extreme values ranging from 14 to 22.3°C in site 1, 15.3 to 24.1°C in site 2, and 14.6 to 23.8°C in site 3 (Fig.2a), These temperatures still less than 30°C, considered as limit value, for direct discharges into the environment (J.O.R.A, 2006) and also an indicative limit value for the wastewater used in the irrigation (J.O.R.A, 2012). These temperature variations follow those of the climate of the region; which confirms the previous studies of Derradji *et al*. (2014). The difference in mean equalities between the sites is not significant ($p = 0.836$).

The pH is used to quantify the concentration of H^+ ions in the water, which gives it its acidic or basic character. This measure provides information on the water quality (Franck, 2002); the pH of the irrigation water in the studied sites ranges from 7.14 to 7.8 for site 1, from 7.25 to 7.95 for the site 2, and from 7.42 to 7.93 for site 3, so the pH is slightly neutral. A slight reduction in pH has been recorded for the three sites in October, which can be expressed by the dilution of water (Fig. 2b). These values meet the Algerian standards for the quality of wastewater used for the irrigation (J.O.R.A, 2012) and are also in the interval recommended by the Food and Agriculture Organization (FAO) (6.5-8.4). These findings are in concordance with those reported by Guerraiche, (2017); Kahoul and Touhami, (2014). The difference in means equalities is not significant ($p = 0.432$) from one site to another.

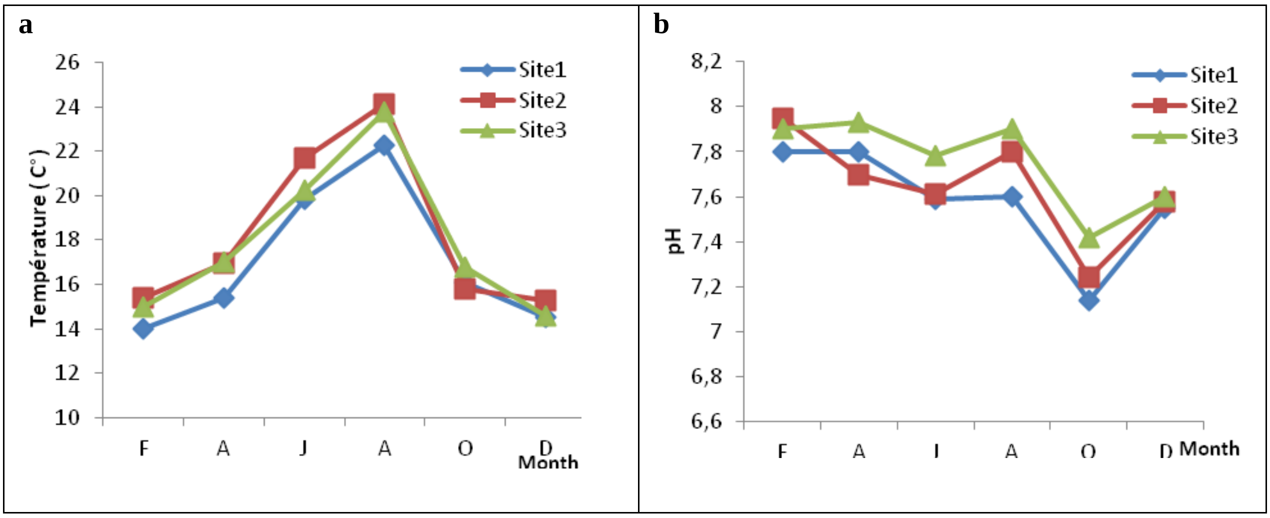


Fig. 2. Spatio-temporal variation of the temperature (**a**) and pH (**b**) during the study period in the three sites, 2016.

The electrical conductivity reflects the rate of global mineralization and provides information on the salinity (Lakhili *et al*., 2015). The values of the electrical conductivity revealed fluctuations in the studied sites (Fig.3a); ranging from 970 to 1400 µs/cm, for the site 1 with a mean of 1216.33 ± 162.06 µs/cm, from 1200 to 2650 µs/cm for site 2, with a mean of 1910.5 ± 658.16 µs/cm, and 1279 to 2240 µs/cm for site 3, with a mean of 2009.83 ± 366.51 µs/cm. The water is then saline and strongly mineralized; according to Rodier, (2009) (conductivity of 1000 to 3000 µs/cm: saline water). The high salinity of the irrigation water induces undesirable effects on both physical properties of the soil and the crop yields (Ayers and Wastcot, 1994). These results are in agreement with those reported by Reggam *et al*. (2015) in Morocco. The difference in means equalities is significant ($p = 0.015$) between the sites.

The dissolved oxygen (O_2) is a very important parameter, since it defines the state of several mineral salts, the degradation of organic matter and the aquatic life (HCEFLCD, 2007). The dissolved oxygen in our study recorded values ranging from 4.66 to 6.58 mg/l O_2, for site 1, with a mean of 5.89 ± 0.64 mg/l O_2, from 0.77 to 5, 14 mg/l O_2 for site 2, with a mean of 2.90 ± 1.77 mg/l O_2, and 3.75 to 6.81 mg/l O_2 for site 3, with a mean of 5.46 ± 1.11 mg/l O_2 (Fig.3b). The dissolved oxygen content is higher in the rainy season than in the dry season. The site 2 is characterized by low values (<5 mg/l O_2), which does not meet the Algerian standards; this low dissolved oxygen amount is the result of the high organic charges generated by the effluents. The difference in equalities of means is highly significant (p=0.002) between sites.

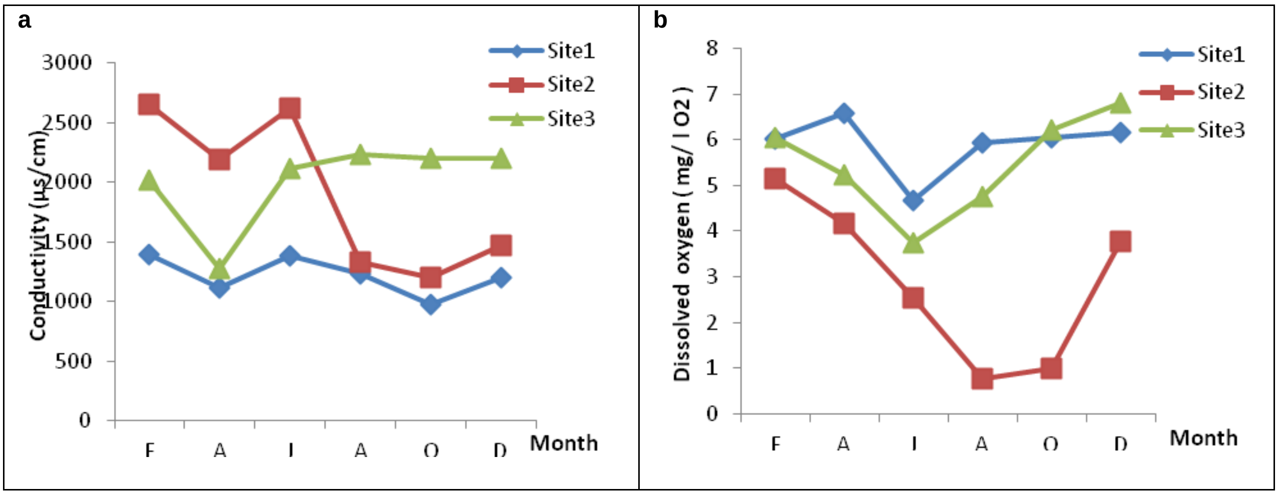


Fig. 3. Spatio-temporal variation of the conductivity (a) and dissolved oxygen (b) during the study period in the three sites, 2016.

The suspended matter represents all the mineral and organic particles in the water. It depends on the nature of the lands crossed, the season, the rainfall, the flow regime, the nature of the effluents, etc. (Ould Mohamedou, 2006). The values of suspended matter range between 38 to 95 mg/l with a mean of 68.16 ± 22.30 mg/l for the site1, between 115 and 157 mg/l with a mean of 134.5 ± 17.22 mg/l for the site 2, and between 93 and 145 mg/l with a mean of 116 ± 21.34 mg/l for the site 3. The highest rates have been recorded during the low-flow season; for the three sites (fig.4); this result is often related to the important load of organic and mineral matter. The presence of suspended matter, in quantities exceeding the standard recommended by the World Health Organization (WHO) (30 mg/l) may result in soil clogging, with damaging effects on the agriculture (Abouelouafa *et al*., 2002). The average values of the suspended matter are close to those reported by Ounoki and Achour, (2014) in the city of Ouargla (Algeria) and remain inferior to those obtained by Souiki *et al.* (2008). The difference in means equalities is very highly significant (p = 0.00) from one site to another.

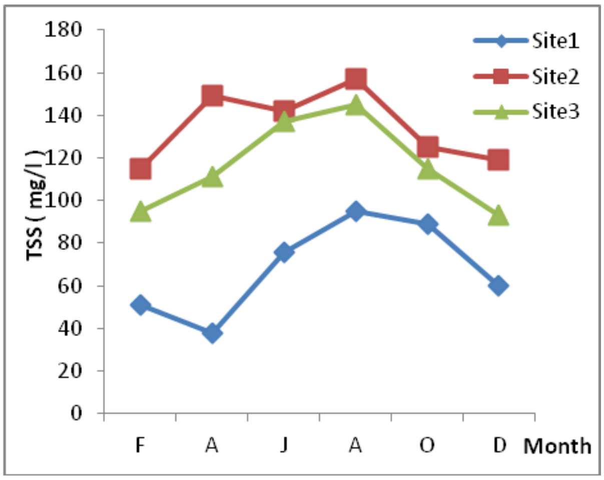


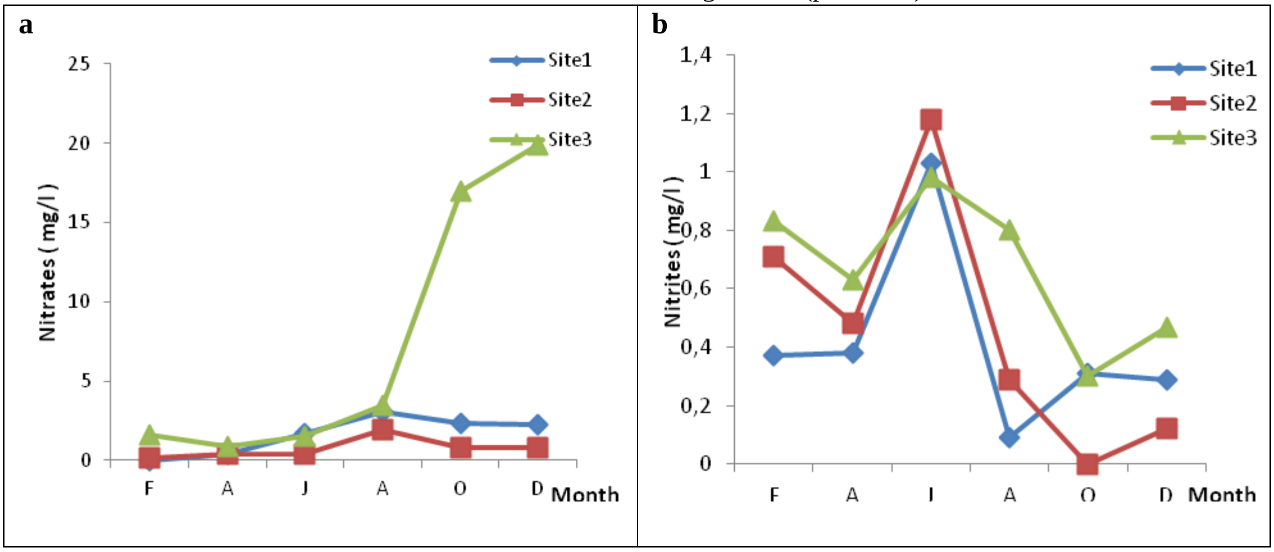
Fig. 4. Spatio-temporal variation of the Matter in Suspension during the study period in the three sites, 2016

The nitrate ions (NO_3^-) represent the most soluble nitrogen form, its presence in the surface water is related to the intensive use of fertilizers (chemical and organic) (Lgourna *et al*., 2014). The analyzes revealed nitrate concentrations ranging from 0 to 3.05 mg/l in site 1 with a mean of 1.63 ± 1.18, from 0.17 to 1.95 mg/l in site 2, with a mean of 0.76 ± 0.62 mg/l, and 0.88 to 19.89 mg/l with a mean of 7.40 ± 8.64 mg/l in site 3. The highest concentrations have been recorded in October and December with 17.01 and 19.89 mg/l respectively in site 3 (Fig.5a). The comparison of nitrate rates, recorded are lower than 30 mg/l (J.O.R.A, 2012), these results are similar to those reported by Abboudi *et al.* (2014) in Morocco; conversely, they are inferior to those published by Pardeep *et al.* (2015) in India. The difference in means equalities is not significant (p = 0.077) between the sites.

The nitrite contents reached average values of 0.41 ± 0.32 mg/l in site 1, 0.46 ± 0.43 mg/l in site 2, and 0.66 ± 0.25 mg/l in site 3 (Fig.5b). The average nitrite concentrations remain below the WHO limit value of 1 mg/l (OMS, 1989); these low concentrations are therefore the result of the rapid transformation of this unstable element into nitrates, by the bacteria (El Khokh *et al*., 2011; Souiki *et al*., 2008). These values are more or less comparable to those published by Chaib and Samraoui, (2011), and are inferior to those obtained by Haddad and Ghoualem, (2014). The difference in means equalities is not significant (p = 0.459) between the sites.

The ammonium is the product of the final reduction of nitrogenous organic substances and inorganic matter, in water and soil. It also comes from the excretion of living organisms and the reduction and biodegradation of the dung, without neglecting the inputs from domestic, industrial and agricultural sources (Dimane *et al*., 2017). The concentrations in ammonium ion range from 1.3 to 3.72 mg/l in the site1 with a mean of 1.83 ± 0.93 mg/l, from 1.03 to 17.43 mg/l in the site 2, with a mean of 5.47 ± 6.48 mg/l, and from 1.6 to 2.1 mg/l, with a mean of 1.42 ± 0.4 mg/l recorded in the site 3 (Fig.5c). The site 2 is characterized by a high ammonium content in October, which represents an index of recent pollution (Dussart, 1992; Peirce *et al*., 1997). The average value in the site 2 is superior to the standard of irrigation water recommended by the FAO, requiring rates <2 mg/l, nevertheless those in the sites 1 and 2 remain within the interval of irrigation water (FAO, 1985; OMS, 1989). The transformation ammonium into nitrite and nitrate is done by oxidation, this reaction is rapid in the presence of oxygen. The high CO_2 content and the low oxygen content increase the ammonium concentration in the water (Debieche, 2002). Our results are superior to those reported by Mehanned *et al*. (2014). The difference in means equalities is not significant (p = 0.160) between the sites.

The bi-monthly evolution of orthophosphate concentrations in the three sites showed that site 2 is more concentrated with an average value of 6.25 ± 2.40 mg/l and extreme values of 2.82 to 9.94 mg/l. The average orthophosphate content is 2.08 ± 2.49 mg/l with extreme values of 0.75 to 7.1 mg/l for the site 1, and an average value of 1.54 ± 1.34 mg/l with extreme values of 0.37 to 4.05 mg/l recorded in the site 3 (Fig.5c). These values exceed the threshold of 2 mg/l, which the standard for discharges into the receiving environment prescribed by (J.O.R.A, 2006) and are notably superior to those recommended by the FAO for irrigation water (FAO, 1985). The variability of orthophosphate rates can be explained spatially by the additional discharges of neighboring agglomerations and industrial units and by the leaching of agricultural soils, treated with fertilizers. The concentrations of orthophosphates are inferior to those obtained by Messai *et al*. (2016), but they are higher than those found in the southeast of Côte d'Ivoire (Eblin *et al*., 2014). The difference in means equalities is highly significant (p = 0.003) from one site to another.



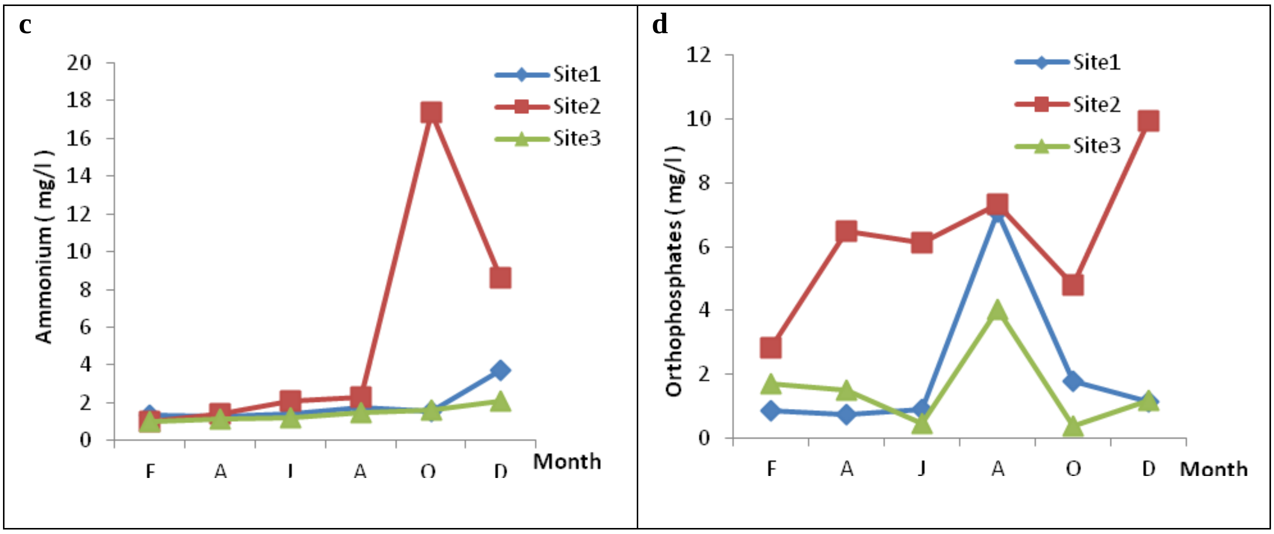


Fig. 5. Spatio-temporal variation of nitrates (a), Nitrites (b), ammonium (c) and orthophosphates (d) during the study period in the three sites, 2016.

The parameters BOD_5 and COD allow evaluating the quantity of organic matter present in water (Lamhasni *et al.*, 2013). The BOD_5 values in the three sites studied ranged from 12.9 to 22.4 mg/l O_2 in site1 with a mean of 16.96 ± 4.17 mg/l of O_2, from 23 to 52 mg/l in site 2, with a mean of 32.68 ± 11.04 mg/l of O_2 and from 10 to 35 mg/l of O_2, with an mean of 20.51 ± 8.81 mg/1 of O_2 in site 3 (Fig.6a). The average values recorded in site 1 and 3 are in accordance with the Algerian norms; nevertheless the site 2 revealed a mean superior to 30 mg/l considered as limit value, recommended by J.O.R.A, (2012). These values are lower than those recorded in Gongo Akatumbila *et al*. (2016) and superior to those found by Khan *et al*. (2016) in India. The difference in means equalities is significant ($p = 0.015$) between the sites.

The bi-monthly evolution of the COD, in the three sites varies between 26.3 and 43.2 mg/l of O_2, in site1, with a mean of 34.08 ± 6.9 mg/l of O_2, between 69.8 and 128 mg/l of O_2 in site 2 with a mean of 95.74 ± 19.14 mg/l of O_2, and between 31.2 and 51.9 mg/l of O_2, with mean of 38.26 ± 7.46 mg / l of O_2 in site 3 (Fig.6b), an excessive pollution in COD, exceeding the standard for irrigation water (90 mg/l O_2) (J.O.R.A, 2012) has been recorded in site 2. Our findings are inferior to those found in the wastewater of the city of Azilal in Morocco Idriss *et al*. (2015), and superior to those recorded for the surface water Mekaoussi, (2014). The difference in means equalities is very highly significant ($p = 0.00$) between the sites.

For a better appreciation of the origin of the studied wastewater, the calculation of the ratios COD / BOD_5, BOD_5 / COD and the estimation of the Oxidizable Material (OM) are highly important (Table 2) in order to recommend an appropriate treatment.

The ratio COD / BOD_5 ranging from 1.89 to 2.92 confirms that the water of the wadis studied receive domestic wastewater with COD / BOD_5 ratio less than 3 (Rodier, 2009), hence the wastewater from these urban discharges have a high organic load and they are easily biodegradable.

To characterize an industrial pollution, the BOD_5 / COD ratio gives very important indications on the origin of water pollution and its treatment options. The tributaries studied have a high BOD_5 / COD ratio, superior to 0.3, which confirms that this water is highly loaded with organic matter. This result is confirmed by the estimation of Oxidizable Material. The ratios obtained are similar to those reported by Abbou *et al*. (2014) for irrigation water in Morocco, Derradji *et al*. (2015) for wastewater, where the ratio of COD / BOD_5 is less than 3.

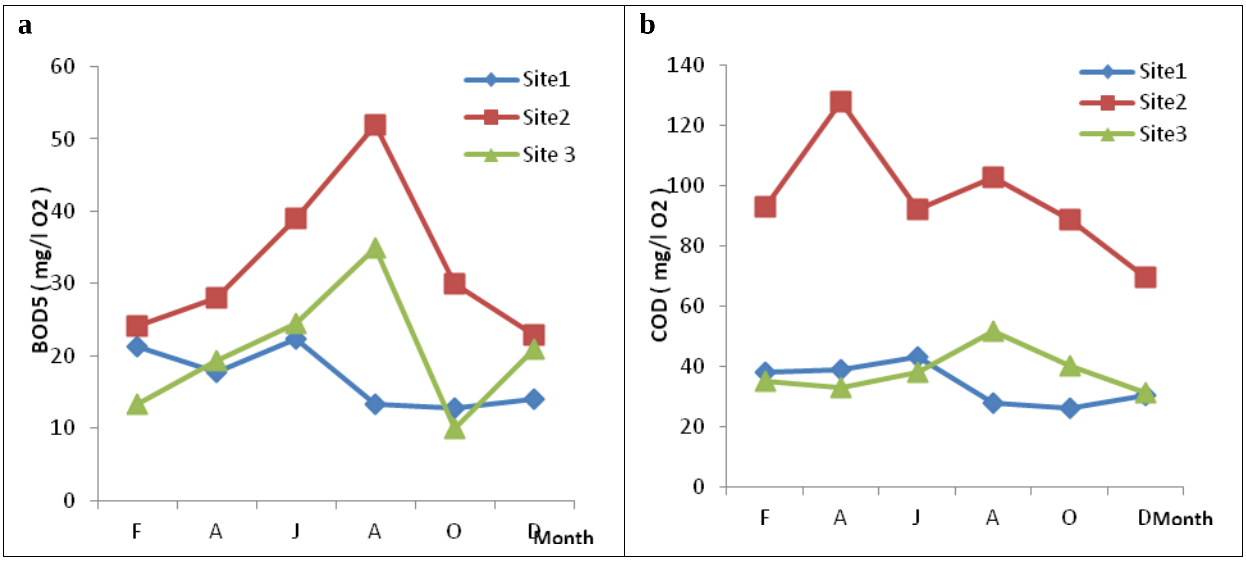


Fig. 6. Spatio-temporal variation of BOD_5 (a) and COD (b) during the study period in the three sites, 2016

Tab. 2.
Ratios of the pollution global parameters of wastewaters

Parametrs / Sites	BOD_5/COD	COD/BOD_5	Oxidizable matter (OM)* (mg/l)
Site 1	0.49	2	22.48
Site 2	0.34	2.92	53.7
Site 3	0.53	1.89	26.42

$*OM = COD + 2(BOD5)/3$ (Boeglin, 1999)

Many human activities are responsible for the metallic pollution of the water. The total iron concentrations range from 0.39 to 1.07 mg / l in site , with a mean of 0.72 mg/l, from 0.67 to 1.32 mg/l, with a mean of 0.97 ± 0.27 mg/l in site 2 and from 0.25 to 1.38 mg/l, with a mean of 0.81 mg/l in site 3 (Table 3). The rate of total Fe showed notable fluctuations in the site 2, which can be explained by the industrial discharges into the wadi, these values are close to those found by Boughrira *et al.* (2014) in the same region and are superior to those obtained by Fouad *et al.* (2014) in Casablanca (Morocco). The difference in means equalities is not significant (p = 0.455) between the sites.

Regarding the Zinc rate, we noted low concentrations in sites 1 and 3, with a higher mean value recorded in site 2 (Table 3). The rate of metallic trace elements revealed values that meet the quality requirements, for the irrigation water (J.O.R.A, 2012). The lowest rates have been recorded during the flood period; which can be related to the dilution effect, resulting from the inflow of rainwater. These results are consistent with those found by (Fouad *et al.*, 2014). The presence of these metals in water, even with low concentrations induces adverse ecological and health effects (OMS, 2013). The difference in means equalities is not significant (p = 0.381) between the sites

.Tab. 3.
Variation of heavy metals (Total Iron, Zinc) in the three sites.

Sites / Parametrs	Mean ± SD (Min-Max)		
	Site 1	**Site 2**	**Site 3**
Total iron (mg/l)	0,72±0,30 (0,39-1,07)	0,98±0,27 (0,67-1,32)	0,81±0,45 (0,25-1,38)
Zinc (mg/l)	0,04±0,03 (0,02-0,1)	0,11±0,13 (0,01-0,35)	0,1±0,05 (0,03-0,15)
SD,Standard deviation; Min, minimum ; Max, maximum			

Bacteriological characteristics of the water in the three sites

The results of the bacteriological analyzes of the water in the three wadis are presented in Table (4).

The spatio-temporal variation of bacteria indicative of faecal contamination showed fluctuations, during the study period. The average total germ (TG) load is 11.46 x10^5 germs/100 ml in site 1, 19.48 x10^5germs/100 ml in site 2 and 12.4 x10^5 germs/100 ml in site 3. The difference in means equalities is not significant (p= 0.116) from one site to another.

Regarding the total coliforms (TC), the mean values are 50.2 x10^3 germs/100 ml in site 1, 68.25 x10^3 germs/100 ml in site 2 and 34.96 x 10^3 germs /100 ml in site 3. The sites 1 and 2 are more charged than the site 3 in terms of bacterial load. The decrease in total coliforms during the rainy season is possibly due to the dilution effect. The difference in means equalities is not significant (p = 0.542) between the sites.

For faecal coliforms (FC), the average values reached 10.28 x 10^3 germs/100 ml in site 1, 20.55 x 10^3 germs/100 ml in site 2 and 11.65 x 10^3 germs/100 ml in site 3. The microbial charges are higher in August and October. This water is inappropriate to be used in the agriculture since they greatly exceed the limit value, fixed by the Algerian standard for irrigation water (1000 germs/100 ml) (J.O.R.A, 2012). These bacterial rates remain higher than those reported by (Labar *et al*., 2014; Dimane *et al*., 2017). The difference in means equalities is not significant (p = 0.473) from one site to another.

The fecal streptococci (FS) reach respectively 24.5 x10^2 germs/100 ml in site1, 22.5 x10^2 germs/100 ml in site 2 and 9.33 x10^2 germs / 100 ml in site 3. These rates are superior to the standard recommended by the WHO (1000 germs/100 ml) (OMS, 1989). The bacterial loads of the studied water are inferior to those recorded by (Derradji *et al*., 2014; Abbou *et al*., 2014), and superior to those found by (Derwich *et al*., 2008). The difference in means equalities is not significant (p = 0.179) between the sites.

The presence of faecal coliforms and faecal streptococci in the water indicates faecal pollution (Rodier, 1984). That is probably due to the use of animal dung as fertilizer in the close cultivated areas and also the discharge of sewage from the urban units. The use of wastewater for irrigation can cause contamination of vegetables, and presents a real risk for the human health (Mara et Cairncross, 1991; Niang, 1996).

The FC / FS ratio for the three effluents is greater than 1, which indicate that the faecal pollution is of human origin.

Tab. 4.
Bacteriological analyzes in the three sites.

Sites / Parameters	Mean ± SD (Min-Max)		
	Site 1	**Site 2**	**Site 3**
TG (gm/100ml) (x10^5)	11,46±1,50 (10-14)	19,48±9,40 (7,8-31,1)	12,40±6,94 (2-20)
TC (gm/100ml) (x10^3)	50,20±50,68 (4,80-110)	68,25±59,91 (7,50-140)	34,96±40,74 (4,80-110)
FC (gm/100ml) (x10^3)	10,28±9,26 (2,80-24)	20,55±21,62 (2-55)	11,98±11,73 (1,1-30)
FS (gm/100ml) (x10^2)	24,50±16,05 (10-55)	22,50±16,54 (10-50)	9,33±10,03 (0-23)
SD,Standard deviation; Min, minimum ; Max, maximum			

The Principal Component Analysis (PCA) allows creating and summarizing a dataset, thus to study the linear links between the variables (correlations). A raw data matrix with 13 physico-chemical and 4 bacteriological variables has been used for the three sites. The results obtained are presented in Fig.7.

- The correlation circle (Fig.7a) revealed that the F1 axis has a variance of 50.21% expressed by temperature (T), suspended matter (TSS), nitrates (NO_3^-), ammoniums (NH_4^+), orthophosphates (PO_4^{-3}), total iron (Fe) and Zinc (Zn). This axis is dominated by nitrogen and phosphorus compounds and heavy metals, coming from urban and agricultural pollution. The second contributing component for 19.34% of the total variance is positively correlated with dissolved O_2 (DO), which reflects seasonality.

- The projection of the bacteriological variables on the factorial plane F1-F2 (Fig. 7b) showed that the total coliforms and the faecal streptococci are positively correlated to the axis F1 which cumulates 48.49% of inertia. The second component, with the captured variability of 40.86%, indicated that total and fecal coliforms contribute positively to the expression of this axis. The presence of these bacteria in the water of the wadi Boukhmira, used in the irrigation prove that they are subject to an anthropogenic influence.

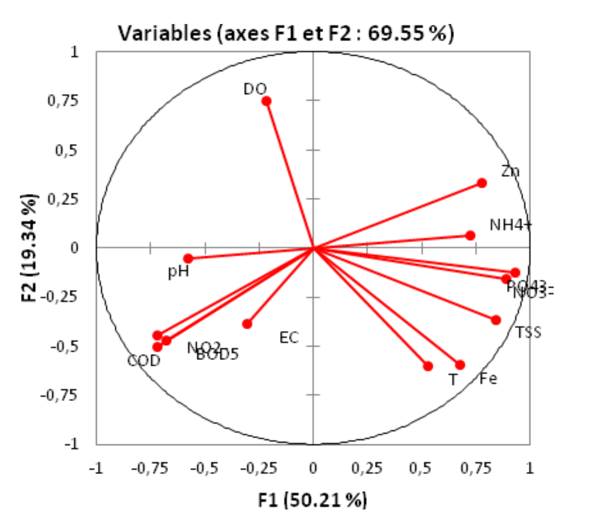
- In the correlation circle (Fig.7c) the first component (F1), contributing with 41.32% of inertia is defined by parameters characterizing the nitrogen and phosphorus nutrients: nitrates, ammoniums and orthophosphates, as well as total Iron. The second component (F2) represents only 29.83% of informations, it is determined by temperature, pH,

BOD_5, COD, suspended matter, nitrites (NO_2^-), and Zinc. These variables are mainly dependent on anthropic activity, particularly human activity (Elhatip *et al*., 2008; Omo-Irabor *et al*., 2008).

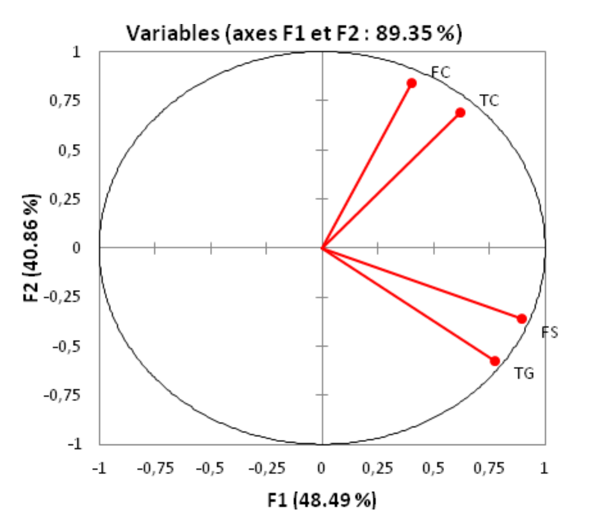
- On the factorial plane F1-F2 (Fig.7d) describes the water overload by total coliforms, faecal coliforms and faecal streptococci in the first F1 component, with an inertia of 47.84%. The total germs contribute positively to the second component F2, which accumulates only 23.88% of the variability captured. These different variables are indicators of faecal pollution and are largely of human origin.

- The figure (7e) summarizes 71.99% of the information, the axis F1 has a variance equal to 46.67%, constituted by temperature, pH, BOD_5, COD, suspended matter, nitrites, orthophosphates and Zinc. This axis therefore includes most of the parameters that describe organic-type pollution and eutrophication of aquatic environments (Mounjid *et al*., 2014). While the axis F2 represents only 25.32% of inertia, it is determined by EC, dissolved O_2, nitrates, ammonium and total iron. This component highlights the organic and mineral inputs that can be related to industrial, agricultural, and domestic activities.

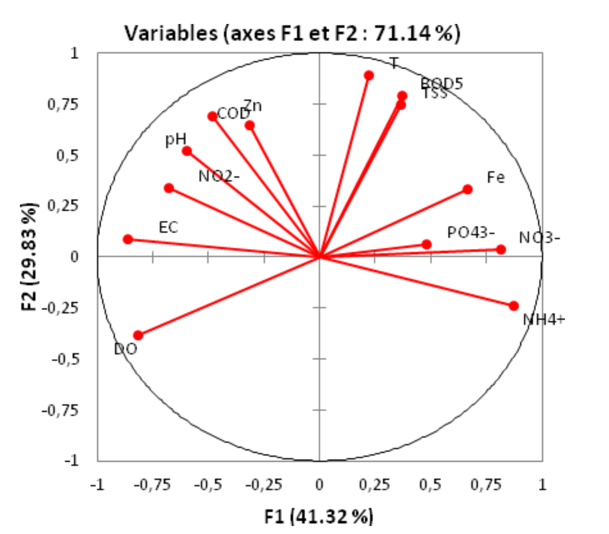
- The space of the bacteriological variables of the factorial plane F1-F2 (Fig. 7f) shows that this plane expresses 71.69% of the variance expressed. The factor F1, with a variance of 49.66%, is determined by total germs, total coliforms and faecal coliforms, F2 with 22.03% of the variance expressed by faecal streptococci. The presence of these bacteria confirms the influence of human activities on the water of wadi Seybouse.



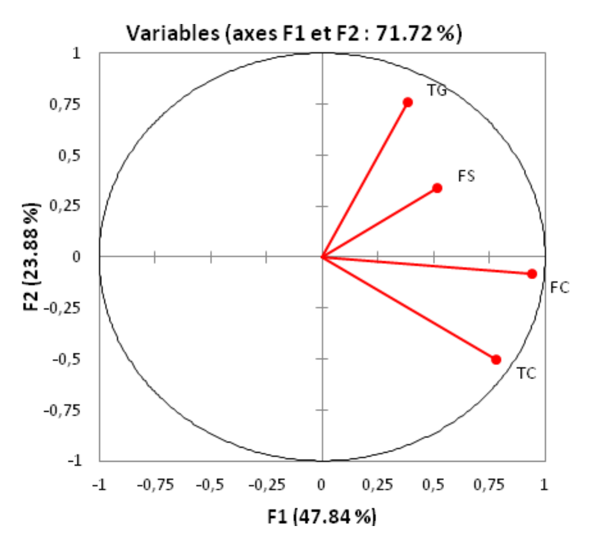
a. Projection of physicochemical variables (S1) on the factorial plane F1-F2 of the PCA.



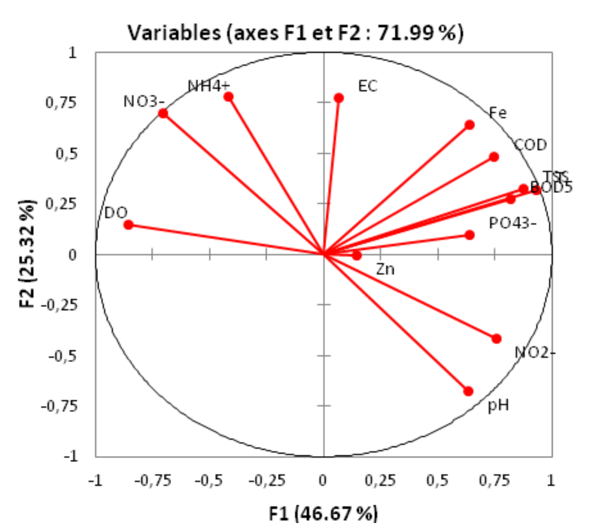
b. Projection of bacteriological variables (S1) on the factorial F1-F2 of the PCA.



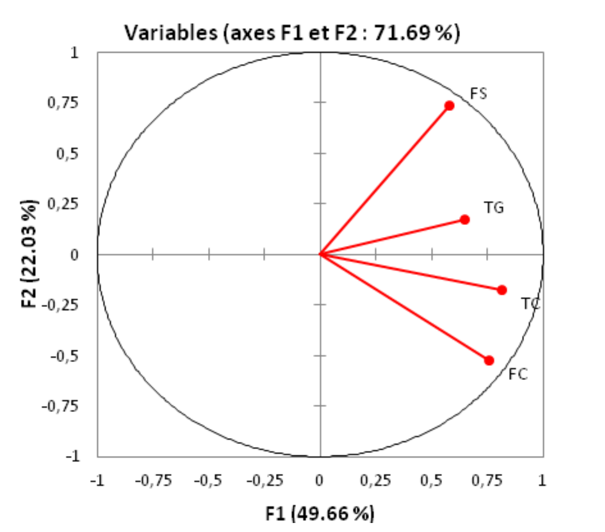
c. Projection of physicochemical variables (S2) on the factorial plane F1-F2 of the PCA.



d. Projection of bacteriological variables (S2) on the factorial F1-F2 of the PCA.



e. Projection of physicochemical variables (S3) on the factorial plane F1-F2 of the PCA.



f. Projection of bacteriological variables (S3) on the factorial F1-F2 of the PCA.

Fig.7. Results of PCA

CONCLUSION:

The characterization of physico-chemical and bacteriological parameters of the water in the wadis Boukhmira, Meboudja and Seybouse, provided a set of data regarding their reuse in agriculture.

The water of the wadis studied in Northeastern Algeria is characterized by low oxygen content, high levels of TSS, BOD_5, COD, ammonium and orthophosphates, as well as a significant presence of total germs, total coliforms, faecal coliforms and faecal streptococci. The COD / BOD ratio indicates that the water of the studied wadis receive the urban wastewater and are easily biodegradable, the high BOD_5 / COD ratio confirms that these waters have a high organic load. It is evident that the majority of parameters analyzed do not comply with national (J.O.R.A) and international (WHO, FAO) standards, for the irrigation water.

The Principal Component Analysis (PCA) of the seventeen variables studied allowed bringing out a global perception of the facts and thus obtaining a site / variable typology. As a result, the studied water receive domestic and industrial wastewater from the surrounding areas and seepage water from the agricultural plains, and should not be reused directly, before being subject to a prior treatment, in order to improve their quality following the required standards.

REFERENCES:

Abbou MB, Fadil F, El Haji M, Évaluation de la qualité des cours d'eau de la ville de Taza utilisés dans l'irrigation des cultures maraîchères (Maroc). Journal of Applied Biosciences, 77, 6462-6473, 2014.

Abboudi A, Tabyaoui H, El Hamichi F, Benaabidate L, Lahrach A, Etude de la qualité physico-chimique et comtamination méttalique des eaux de surface du bassin versant de Guigou, Maroc. European Scientific Journal, 10 (23), 84-94, 2014.

Abouelouafa M, El Halouani H, Kharboua M, Berrichi A, Caractérisation physico-chimique et bactériologique des eaux usées brutes de la ville d'Oujda: canal principal et Oued Bounaïm. Actes Inst. Argon. Vet. (Maroc), 22 (3), 143-150, 2002.

Akatumbila L, Mabiala M, Lubini A, Pwema K, Musibono EA, Contribution à l'évaluation de la qualité physico-chimique de l'eau : Cas de la rivière urbaine Gombe de Kinshasa / République Démocratique du Congo. Larhyss Journal, 26, 7-29, 2016.

Attoui B, Etat de la vulnérabilité à la pollution des eaux des grands réservoirs d'eaux souterraines de la région de Annaba- El-Tarf et identification des sites d'enfouissement de déchets. Thèse de doctorat en science. Option : Hydrogéologie, université d'Annaba, 2014.

Ayers RS, Wastcot DW, Water quality for agriculture. FAO. Irrigation and drainage paper. N° 29 Rev. 1 FAO, Rome, p 174, 1994.

Boeglin JC, Pollution industrielle de l'eau: caractérisation, classification, mesure. Techniques de l'ingénieur 14, 1210-1221, 1999.

Bouaroudj S, Kadem D, Évaluation de la qualité des eaux des oueds Rhumel et Boumerzoug (CONSTANTINE). Revue scientifique et technique, 35-44, 2014.

Bougherira N, Hani A, Djabri L, Toumi F, Chaffai H, Haied N, Nechem D, Sedrati N, Impact of the urban and industrial waste water on surface and groundwater, in the region of Annaba, (Algeria). Energy Procedia, 50, 692-701, 2014.

Chaib N, Samraoui B, Evaluation de la qualité physico-chimique des eaux de l'oued El Kebir-Est et de ses principaux affluents (Nord-Est algérien). Sécheresse, 22, 171-177, 2011.

Chaoui W, Bousnoubra H, Benhamza M, Bouchami T, Etude de la pollution des eaux des oueds

Seybouse et Mellah (Région de l'Est Algérien). Rev. Sci. Technol Synthese, 26, 50- 56, 2013.

Chaouki I, Mouhir L, Fekhaoui M, El Abidi A, Bellaouchou A, El Morhit M, Application de l'analyse en composantes principales (ACP) pour l'évaluation de la qualité des eaux usées industrielles de Salam Gaz – Skhirat. J. Mater. Environ. Sci, 6 (2), 455-464, 2015.

Debieche TH, Évolution de la qualité des eaux (salinité, azote et métaux lourds) sous l'effet de la pollution saline, agricole et industrielle : application à la basse plaine de la Seybouse - Nord-Est Algérien. Thèse de doctorat, de l'université de Franche-Comté, pp: 200, 2002.

Derradji M, Souiki L, Berrebbah H, Djebar MR, Assessment of the bacteriological contamination of the wastewaters in Annaba's main discharges in North-Eastern Algeria. International Journal of Biosciences, 4(1), 112-117, 2014.

Derradji M, Souiki L, Belaze AH, Alayat A, Berrebbah H, Spatial and Temporal Variation of Raw Sewage of City of Annaba Major Discharge (Northeast Algeria). Iranica Journal of Energy and Environment, 6(2), 127-133, 2015.

Derwich E, Beziane Z, Benaabid L, Belghiti D, Evaluation de la qualité des eaux de surface des oueds Fes et Sebou utilisées en agriculture maraichère au Maroc. Larhyss Journal, 7, 59-77, 2008.

Dimane F, Haboubi K, Hanafi I, Andaloussi K, Impact des facteurs de pollution sur la qualité des eaux de la zone aval de la vallée de l'oued Nekor (Al-Hoceima, Maroc). European Scientific Journal, 13(3), 44-60, 2017.

Djabri L, Rani A, Laouar R, Mania J, Mudry J, Louhi A, Potential pollution of groundwater in the valley of the Seybouse river, north-eastern Algeria. Environmental Geology, 44 (6), 738-744, 2003.

Dussart B, Limnologie. L'étude des eaux continentales. Paris, Boubée, pp : 681, 1992.

Eblin SG, Sombo AP, Soro G, Aka N, Kambire O, Soro N, Hydrochimie des eaux de surface de la région d'Adiaké (sud-est côtier de la Côte d'Ivoire). Journal of Applied Biosciences, 75, 6259- 6271, 2014.

El Asslouj J, Kholtei S, El Amrani N, Hilali A, Analyse de la qualité physico-chimique des eaux souterraines de la communauté des Mzamza, au voisinage des eaux usées. Afrique SCIENCE, 03(1), 109-122, 2007.

Elhatip H, Hinis MA, Gülbahar N, Evaluation of the water quality at Tahtali dam watershed in Izmir-Turkey by means of statistical methodology. Stochastic Environmental Research and Risk Assessment, 22, 391-400, 2008.

El Khokh K, Belghyti D, El Kharrim K, Kbibch A, Chentoufi M, Belghyti LR, Physico-chemical characterization of urban wastewater of Mechraa Belksiri city (Gharb, Morocco). Science Lib Editions Mersenne, 110205(3), ISSN: 2111-4706, 2011.

FAO, Water quality for agriculture. R.S. Ayers and D.W. Westcot. Irrigation and Drainage Paper 29 Rev. 1. FAO, Rome. pp : 174, 1985.

Fouad S, Hajjami K, Cohen N, Chlaida M, Qualité physico-chimique et contamination métallique des eaux de l'oued Hassar : impacts des eaux usées de la localité de Mediouna (Périurbain de Casablanca, Maroc). Afrique SCIENCE, 10(1), 91-102, 2014.

Franck R, Analyse de l'eau (Aspects réglementaires et techniques) Ed, Collection biologie technique, 360 p, 2002.

Guerraiche Z, Impact de la pollution urbaine sur les eaux de surface du grand constantinois. Thèse de doctorat en sciences : hydraulique. Université de Biskra, p 103, 2017.

Haddad H, Ghoualem H, Caractérisation physico-chimique des eaux du bassin hydrographique côtier Algérois. Larhyss Journal, 18, 155-167, 2014.

Hazourli S, Boudiba L, Ziati M, Caractérisation de la pollution des eaux résiduaires de la zone industrielle d'El-Hadjar. LARHYSS Journal, 6, 45-55, 2007.

Hannachi A, Gharzouli R, Djellouli Tabet Y, Daoud A, Waste water reuse in agriculture in the outskirts of the city Batna (Algeria). Journal of Fundamental and Applied Sciences, 8(3): 919-944, 2016.

Haut Commissariat Aux Eaux et Forêt et la Lutte Contre la Désertification (HCEFLCD). Etude diagnostique de la zone humide AL Massira-Faija, cercle d'EL Brouj et Cercle de Settat (Maroc), 242p, 2007.

Idrissi YA, Alemad A, Aboubaker S, Daifi H, Elkharrim K, Driss B, Caractérisation physico-chimique des eaux usées de la ville d'Azilal - Maroc-/[Physico-chemical characterization of wastewater from Azilal city -Morocco-] International Journal of Innovation and Applied Studies, 11 (3), 556-566, 2015.

Journal Officiel de la République Algérienne J.O.R.A, Décret exécutif n° 93-160 du 10 juillet, 1993.

Journal Officiel de la République Algérienne J.O.R.A, Les valeurs limites des paramètres de rejet dans un milieu récepteur. Art. n°26 (23 avril), 2006.

Journal Officiel de la République Algérienne, ANNEXE, spécifications des eaux usées épurées utilisées à des fins d'irrigation. N° 41, 18-21, 2012.

Kahoul M, Touhami M, Evaluation de la qualité physico-chimique des eaux de consommation de la ville d'Annaba (Algérie). Larhyss Journal, 19, 129-138, 2014.

Khan MYA, Gani KM, Chakrapani GJ, Spatial and temporal variations of physic-chemical and heavy metal pollution in Ramganga River a tributary of River Ganges, India. Environ Earth Sci, 76, 231, 2016.

Labar S, Djidel M, Benslimane F, Djemai R, Djabri L, Approche physico-biochimique pour le contrôle de la pollution des eaux de surface dans l'extrême Nord-Est Algérien. International Journal of Environment & Water, 3(1), 52-60, 2014.

Lakhili F, Benabdelhadi M, Bouderka N, Lahrach H, Lahrach A, Etude de la qualité physico-chimique et de la contamination métallique des eaux de surface du bassin versant de Beht (Maroc). European Scientific Journal, 11(11), 132-147, 2015.

Lamhasni N, Chillasse L, Abba H, El Haouat S, El Madani M, Typologie des eaux de surface du bassin du Sebou par multi-approche: corrélation entre indice biologique global des réseaux de contrôle et de surveillance (IBG-RCS) et l'approche physico-chimique et microbiologique. Afrique SCIENCE 09(2) 35-49, 2013.

Leynaud G, Les pollutions thermiques, influence de la température sur la vie aquatique. B.T.I. Ministère de l'agriculture, 224-881, 1968.

Lgourna Z, Warner N, Bouchaou L, Boutaleb S, Tagma T, Hssaisoune M, Ettayfi N, Vengosh A, Nitrate contamination of alluvial groundwater in the Ziz basin, southeastern Morocco. Moroccan Journal of Chemistry, 2(5), 447-451, 2014.

Mara D, Cairncross S, Guide pour l'utilisation sans risques des eaux résiduaires et des excréta en agriculture et aquaculture, OMS–PNUE, Genève, Suisse, 1991.

Mehanned S, Chahlaoui A, Zaid A, Samih M, Chahboune M, Typology of the physico-chemical quality of the waters of the dam Sidi Chahed-Morocco. J. Mater. Environ. Sci, 5(5), 1633-1642, 2014.

Mekaoussi N, Comportement des éléments chimiques dans les eaux de surface de Hammam Debagh (Est-Algérien). Mémoire de Magister en Hydraulique, Université El Hadj Lakhdar Batna, p70, 2014.

Messai N, Aouati A, Berchi S, Impact of the surface water physico-chemical parameters on Culicidae (Diptera: Nematocera) of lakeside ecosystem "Sebkhet Ezzemoul" (Oum El Bouaghi -Algeria). Journal of Entomology and Zoology Studies, 4(3), 391-398, 2016.

Mounjid J, Cohen N, Fadlaoui S, Belhouari A, Oubraim S, Contribution à l'évaluation de la qualité physico-chimique du cours d'eau Merzeg (préurbain de Casablanca, Maroc). Larhyss Journal, 18, 31-51, 2014.

Niang J, Gestion des déchets urbains, l'utilisation des eaux usées brutes dans l'agriculture urbaine au Sénégal : bilan et perspectives, 1996.

Omo-Irabor OO, Olobaniyi SB, Oduyemi K, Akunna J, Surface and groundwater water quality assessment using multivariate analytical methods: a case study of the Western Niger Delta, Nigeria. Physics and Chemistry of the Earth, Parts A/B/C, 33, 666-673, 2008.

OMS, Directives OMS pour l'utilisation sans risque des eaux usées, des excreta et des eaux ménagères, Volume 2, chapitre 8, p 125, 2013.

Organisation mondiale de la santé (OMS), Rapport d'un groupe scientifique de l'OMS. Genève, série 778, 1989.

Ould Mohamedou E, Deepened Evaluation of the physic-chemical and metal quality of water of the Senegal River: Case of the Delta Mauritanian located in the town of Rosso, Memory DESA Faculty of Science, University Ibn Tofail Morocco, 2006.

Ounoki S, Achour S, Evaluation de la qualité physico-chimique et bactériologique des eaux usées brutes et épurées de la ville d'Ouargla. Possibilité de leur valorisation en irrigation. Larhyss Journal, 20, 247-258, 2014.

Peirce JJ, Vesilind PA, Weiner RF, Environmental Pollution and Control, 4th ed. Elsevier Science & Technology Books, 379 p, 1997.

Pardeep S, Chaturvedi RK, Ankit M, Lata K, Rishikesh S, Pal BD, Deen DG, Nand LS, Dhanesh T, Pradeep KM, Assessment of ground and surface water quality along the river Varuna, Varanasi, India. Environ Monit Assess, 187(4), 170, 2015.

Reggam A, Bouchelaghem H, Houhamdi M, Qualité Physico-chimique des eaux de l'oued Seybouse (Nord-Est de l'Algérie): caractérisation et Analyse en Composantes Principales. Mater. Environ. Sci, 6(5), 1417-1425, 2015.

Rodier J, L'analyse de l'eau, 7ème édition. Dunod, Paris, 1984.

Rodier J, L'analyse de l'eau. 9ème édition. Dunod. Paris, pp: 1526, 2009.

Souiki L, Rouabhi R, Berrebbah H, Djebar MR, Survey of physico-chemical quality of the wastewaters of Biskra city rejected in Chaabat Roba, Messdour and wadi Z'ommor (Algeria). African J. Environnemental Science and Technologie, 2(8), 231-238, 2008.