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Spatiotemporal assessment of the quality of surface water the most polluted in the city

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Abstract

In recent years, the quality of Fez city surface water has deteriorated day after day because of the development of various human activities, the thoughtless modernization of the wastewater discharge of unregulated manner and solid waste. This constitutes a real threat to the environment and health of consumers. The objective of this study is to realize a space-time monitoring of parameters assessing the water quality of wadis Tghat and Zhoun in the city of Fez, at a rate of one sample per month for 2017 by the SEQ-SIG approach and by the statistical analysis of variance (ANOVA), after identifying the most polluted. The study of the overall quality of surface waters of both sites S1 and S2 most polluted identified Fez by the SEQ-GIS approach has allowed us to define ten alterations involving physicochemical parameters and faecal coliforms and clean alteration to their metallic charge. She recorded that these waters are endocrine effect loaded with organic pollutants and trace metals and reveals that they are of poor quality. The analysis of variance ANOVA results of the spatiotemporal assessment of the water quality of wadis Tghat and Zhoun says the results of SEQ GIS-based technique alterations definition and calculation of weighted indices, and denotes factor that the site has less influence on each of the parameters analyzed the month factor and the fecal coliforms parameter does not vary significantly with the month.

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Introduction

Around the world, the water quality decline under pressure from anthropogenic activities; namely demographic change, modernization of lifestyles, rapid urbanization, industrialization, economic development and agriculture, rejection of new pathogens and new chemicals from industries and invasive species are the key factors contributing to the deterioration of water quality.

Globally, the United Nations General Assembly aim the improvement of water quality by reducing pollution, eliminating the dumping of waste and minimizing emissions of chemicals and hazardous materials, halving the proportion of untreated sewage and increasing significantly worldwide recycling and reuse safe water (WWDR, 2017). As to Morocco, he faces the degradation of the quality of its resources, increasing the delay in liquid waste disposal, pollution by agricultural activities (nitrates) to seawater intrusion due to overexploitation of tablecloths and industrialization, for the treatment of industrial wastewater, domestic and urban (Chafik, 2014).

Several studies have shown that the city of Fez generates only 40% of the pollution of the Sebou basin, because of effluent from different modernized craft activities and industrial discharged without any treatment (ABHSF, 2015 ; Benmalek & Lahrache, 2017). We quote tanneries (Cr), the brassware (Ni), pottery (Pb), ...) and other types of chemical and agricultural industries (Chemicals-chemicals, agro food industries, transformations and preserves, olive oil mills (vegetable waters), textiles, slaughter houses, dairies, beverage plants etc. (CCIS, 2017). estimated at 65% of the total pollution (RADEEF, 2015) that require excessive water consumption and uncontrolled use of toxic chemicals (pesticides, insecticides, ETM (Cr, Ni, Pb, Cd, Zn).

This work presents the results of the spatiotemporal monitoring of physico-chemical parameters and bacteriological analyzed water at a rate of one sample per month during 2017, Evaluating their overall quality, with the techniques of SEQ-Water and GIS and the effect of the period of collection and site activities on the parameters analyzed by statistical analysis (ANOVA). We selected only these two sites, following several previous studies (El Allaoui, 2018 ; El Madani *et al.*, 2019) confirming and identifying that they are the most polluted sites. The analysis and representation of data collected and the results of the overall water quality by the SEQ-Water studied are shown through of the Geographic Information System (GIS) tools.

Materials and methods

Study Areas

The spatial distribution of wadis Tghat and Zhoun most polluted in the city of Fez are shown graphically by the Geographic Information System GIS in the card the Fig. 1.

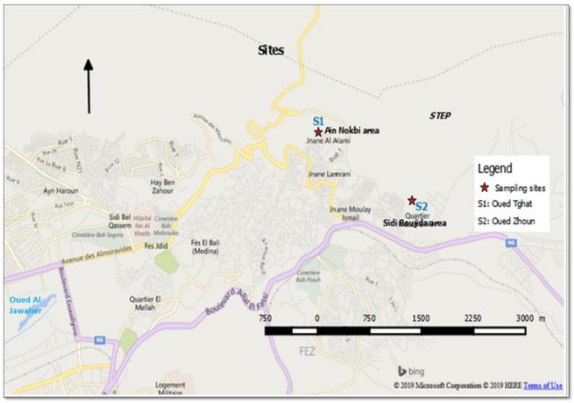


Fig. 1. Spatial distribution of the most polluted wadis of Fez GIS.

Sampling

We carried out a composite spatial sampling and independent based on Order defining the gate quality of surface water (SEEE, 2008) we defined diagnosis (El Madani *et al.*, 2019).

The assessment of water wadis quality in the most polluted studied held monthly throughout the year of 2017. All samples were stored, transported and analyzed according to the AFNOR standards set by RODIER (Rodier, 2009).The physical parameters measured in situ are temperature, pH, conductivity, turbidity and dissolved oxygen. The chemical and biological parameters examined are nitrates,

ammonium, total phosphorus, chemical oxygen demand (COD), biological oxygen demand (BOD5) and fecal coliforms. The parameters are analyzed metallic arsenic, cadmium, chromium, nickel, lead and zinc. The results of these parameters have helped us calculate nonchalantly weathering clues in order to assess a comprehensive water quality by the SEQ according to the quality of surface water from a river (Table 1 (SEEE, 2008).

Table 1. Water quality classes by alteration index.

Quality class	excellent	good	Average	bad	Very bad
Index	100 80	80 60	60 40	40 20	20 0

Calculating the index of alteration is based on the distribution of a weight fluctuating between 0 and 100, the various parameters analyzed according to their priority in the water pollution (SEEE, 2008) :

IPPA = Ii + [(Is - Ii) / (bs - bi)] × (bs - pa)

Or :

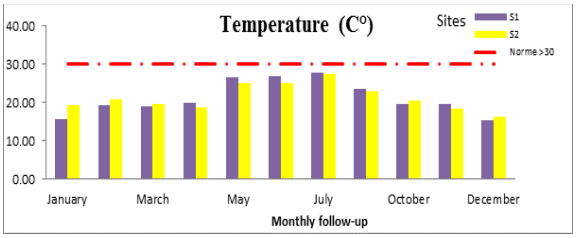
- Ii: Lower Index
- Is: Higher Index
- bi: Lower limit
- bs: Upper limit
- pa: Parameter analyzed

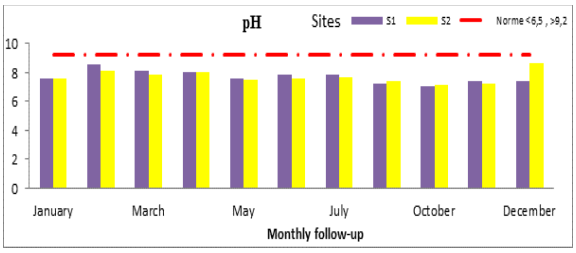
The lowest index of alteration represents the overall quality of the sites. The results are plotted as spatial maps System tools via Geographical Information (GIS). The statistical treatment of parameters characterizing the waters of the most polluted wadis throughout the study period took place through the application of analytical tests united diverse, fixed model, each of the measured variables.

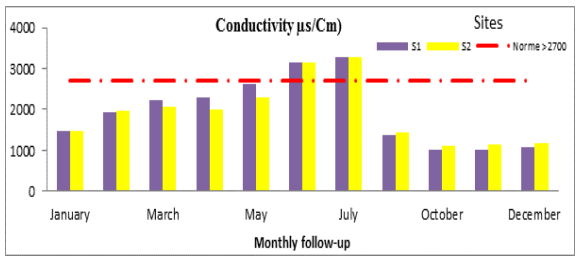
Results and discussions

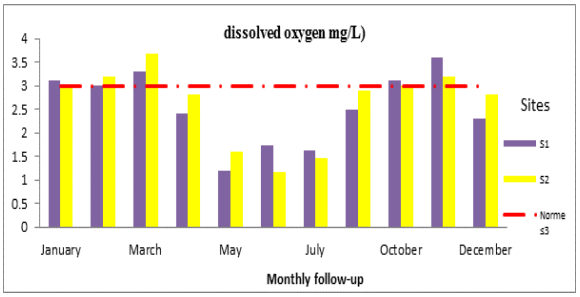
Monthly spatiotemporal quality assessment of physicochemical parameters, bacteriological and metal water S1 and S2

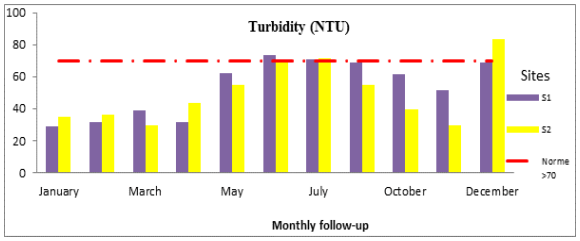
Monitoring results spatiotemporal parameters assessing the quality of surface waters of both sites S1 and S2, are in line with the Moroccan norms surface water (Official Bulletin, 2016) who are represented in Fig. 2.

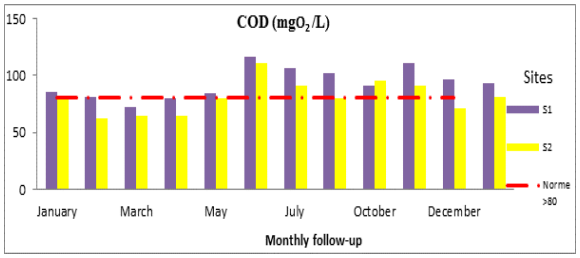












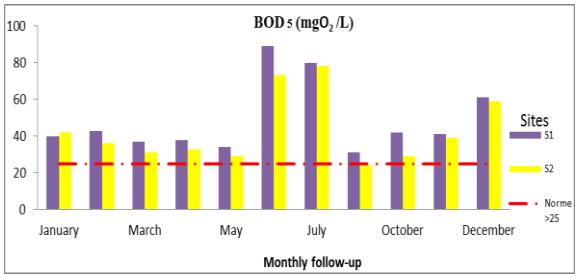


Fig. 2. Spatio-temporal monitoring of physicochemical parameters, bacteriological and metal of the monthly assessment of the water quality of river Tghat and Zhoun during 2017.

The analysis of the results indicates that:

- The water temperatures S1 and S2 sites are between a minimum and a maximum, the minimum value is reached with fall seasons, winter and spring beginning. The maximum value occurred at the end of the spring season and the summer season. All values for the period of study are consistent with the standard of quality of surface water (<30 ° C).
- The pH is close to neutral during most of the period, except from the site 2 water which is slightly basic at least December.
- Dissolved oxygen values between 1.2 mg O2.L-1, Recorded in May and 4.5 mg O2.L-1in the month of February. Low values were assigned during the summer season.This could probably be due to its function in the degradation of organic matter in the water by microorganisms.
- The electrical conductivity is very high during the months of June and July for S1 and S2 sites. She

microseconds respectively 2736 cm -1 and 2765 cm-1 microseconds. This strong mineral filler could be probably due to excessive mineralization of these waters attributed to the salts used in most industrial, craft and agricultural.

- Turbidity is on the edge of the Moroccan norm throughout the study period and for both sites S1 and S2 except that of the S2 site water which was a slight overshoot in the month of December 2017.
- The chemical oxygen demand (COD) fluctuate between 80.5 mg O2.L-1 and 116 mg O2.L-1 then exceeds the norm for the summer and fall seasons. We note that the waters of wadis Tghat carry a non-biodegradable organic load to a lesser degree than the waters of wadis Zhoun. This seems to be due to releases of heavy industrial and craft activities in areas Nokbi Ain and Sidi Boujida.
- The biochemical oxygen demand (BOD 5) greatly exceeds the norm for all months of the year. She has almost tripled the value characterizing the quality of surface waters during the months of June, July and December, and exceeded about 10% during the other months. However, the organic load is in most time of the biodegradable (COD / BOD 5 <3) except the months of September and October.
- High loads of COD and BOD5 could be explained by the coincidence of our study period to the period of Eid Al Adha whose strong skins processing activity took place during these months one hand; and secondly, the olives are pressed.
- Ammonium indicates a maximum value in September reaching 9.23 mg NH4.L-1 for S1 water and 7.98 mg NH4+ .L-1 for those waters S2, showing a significant contribution of anthropogenic activities the study areas. As for the results of the Kjeldahl nitrogen, they state quite large concentrations throughout the study period except for the months of September and October where they undergo a high nitrogen load and reach values exceeding the standard quality of surface water (Official Bulletin, 2016).
- Nitrates are just at the limit of the norm for almost half of the study period outside the autumn and winter. This could be due to different detergents for industrial or domestic origins and also the coincidence of the period of Eid al Adha between September and October (El Allaoui, 2018 ; Idrissi, 2018). In addition to the nearby wadi in industrial and agricultural areas of Ain and Sidi Nokbi Boujida and watering animals, which is also a source of water contamination by nitrates.
- Total phosphorus is exceptional throughout the period of study for its water S1 and S2 sites. The phosphorous pollution comes, probably, of industrial detergents or domestic origins, waste of protein metabolism and disposal in the form of phosphates in the urine by Man (Seghairi, 2014).
- The contamination by fecal coliform (FC) is unlikely because of the limits of these parameters to the Moroccan standard for surface water of a river.
- The majority of trace metals, considered endocrine disruptive, Chromium, arsenic, lead and cadmium, far exceed the Moroccan standard surface water quality for water wadis Tghat and Zhoun. As to the burden of these waters Zinc and Nickel, it meets the standards laid down.

It should be noted that during the period of follow-up, we have assisted the coincidence period of Eid Al Adha, the olives are pressed and releases tanneries and other industries.

Indeed, significant changes during monitoring are likely due to the nature and frequency of daily industrial, craft targeted areas. Specifically, intense concentrations of chromium in the waters of S1 and S2 websites endorse the results conducted by (Hayzoun, 2014) that justify the origin of the high burden Chrome comes releases tanneries because of the excessive use of chromium sulfate and other toxic chemicals. In addition to this and according to our diagnosis, we add, releases from olive industries, the use of synthetic fertilizers and manure associated with crops, livestock intensive, the deficient septic systems and the decomposition plant and animal matter.

Our results also corroborate that of (Gouitaa, 2016) who confirmed that aquatic releases are mainly lead-steel industrial origin, that metal exposure has seriously deteriorated with the exponential increase in the use of heavy metals in industrial processes and

products. Similarly, Zhang *et al.*, in 2014 and Baysal & Akman, 2018 have shown that heavy metals such as chromium, which is a toxic element, comes mainly from emissions of industrial activities, specifically tanneries, textiles, steel making, ... (Zhang *et al.*, 2014 ; Baysal & Akman, 2018).

Weighted indexes and alteration of water S1 and S2

Indices and weighting alteration obtained during the monitoring of the water quality of river Tghat (S1) and river Zhoun (S2) during 2017, are shown in Table 2 according to SEQ-water approach.

The measured and analyzed parameters are: Temperature; pH; Dissolved oxygen(DO); Conductivity (C) ; Turbidity (TU); COD; BOD_5; NH_4^+; Kjeldahl Total Nitrogen (KTN) , NO_3^-,Total phosphorus (TP), Faecal coliforms (FC) and the Metallic Trace Element (MTE) which are Arsenic, Cadmium, Chromium, Nickel, Load and Zinc.

To mention the standard for each parameter during monthly monitoring of 2017, each class is determined by a distinctive color, according to the Moroccan guidelines of the standard surface water of a river (Official Bulletin, 2016).

Averaging of alteration indices and physical-chemical and bacteriological weighting reveals wadis Tghat and Zhoun are of poor quality. Almost all of the calculated pollution alterations are non-standard, except for pH alterations, mineralization, suspended particles and fecal coliforms belonging to average quality.

Analysis of the results of the load water studied metallic elements denotes high levels exceeding the standards of quality of surface water (Official Bulletin, 2016).This reflects a poor overall quality dominated by the presence of elements (Cr, As, Pb and Cd) and average culminated by the presence of zinc and nickel. This is proven by the results of the diagnosis on the activities of areas Ain Nokbi and Sidi Boujida crossings respectively wadis Tghat and Zhoun and exhibited a significant human impact particularly from industrial and artisanal releases these wadis without prior treatment. Chromium is mainly originating in and characterized by overall poor quality dominated Cr, As, Cd and Pb. An average quality Zinc arriving at 1.63 and 1.58 mg L^{-1}, successively in the two sites. While, Ni is classified a good quality. Accordingly, the toxicity of Cr, As, Pb and Cd exceeds standards (Official Bulletin, 2016). with poor quality throughout the year, up to 0.06mg L^{-1}.

Table 2. Indices of alteration and physicochemical weight, water bacteriological and metal wadi Tghat and Zhoun during 2017.

	Sites	S1	S2
Alteration	Indices Ia Ip &	100 80	80 60
(1) Temperature	I a_1 =IP_T	80.8	82.8
(2) Acidification	I a_2 =IP_{PH}	58.6	57.8
(3) Organic substances and oxidizable	IP_{DO}	23.3	22.1
	IP_{BOD5}	17.4	18.2
	IP_{COD}	20.1	21.0
	Ip_{NH4+}	31.4	35.9
	Ia_3 =(Ip3 + Ip4 + Ip 5 + Ip6) / 4	23.0	24.3
(4) nitrogen-containing substances	I a_4=IP_{TKN}	45.9	40.6
(5) Materials phosphorus	I a_5=IP_{TP}	33.2	37.9
(6) Nitrates	I a_6=IP_{NO3}	33.1	42.9
(7) Mineralization	I a_7=IP_C	50.1	50.3
(8) suspended particles	I a_8=IP_{TU}	49.5	51.6
(9) Microorganisms	I a_9=IP_{FC}	44.9	44.6
(10) MTE	Ia = Ip Cd	37.8	33.9
	Ia = IP Cr	24.9	29.1
	Ia = IP Ni	44.9	47.1
	Ia = IP Pb	26.9	29.6
	Ia = IP Zn	51.8	43.2
	Ia = IP As	29.7	29.1
overall physicochemical quality		23	24.3
overall bacteriological quality		44.9	44.6
overall quality metal		24.9	30.3

- The sharp metallic charge of the two study sites are ranked poor because of the strong presence of As, Cr, Pb and Cd, as directed diagnosis, we record a strong anthropogenic impact end to dischargesurban, industrial and craft previously untreated areas studied and are conveyed to the wadis. Chromium is mainly from tanneries, dyers, of brassware and textile industries ... The lead comes from pottery and traditional uses in cosmetic products based on Pb also use utensils to white lead. The Cd and As could come from chemical industries and para-chemistry. These results are consistent although several studies

Similar, The most recent was in 2015. This study highlighted the threat of heavy metals on the environment and on humans and confirms irrigation vegetables far by the waters of the wadis Fez charged by industrial waste and craft of the area. The vast majority of these vegetables are grown in fields located in the area Jnanates Nokbi Ain, where cultivated land is still contaminated by historical waste from the former industrial site of pottery; (Potential source of Pb (Bouftini, 2015).

Spatial distribution of the overall water quality of wadis Tghat and Zhoun 2017

Physicochemical overall quality

At the end of the previous results and parameters shown in Fig. 2, we deduce that the physicochemical overall quality of two wadis studied is poor, particularly downstream of urban areas and areas Nokbi Ain and Sidi Boujida.

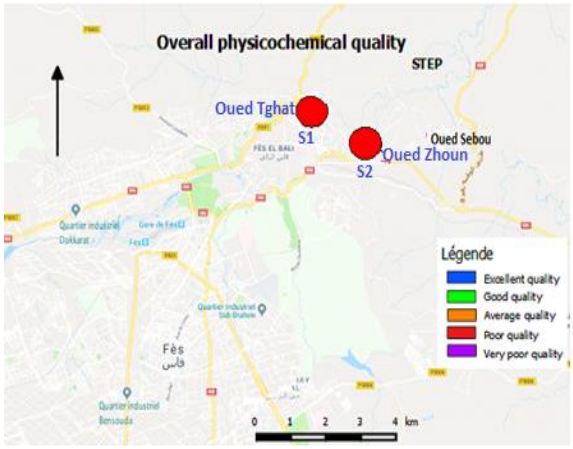


Fig. 3. Spatial distribution of the overall quality of physicochemical wadi waters Tghat and Zhoun 2017.

The type of the organic filler is at the limit of biodegradability and mineral. The organic load of nitrogen and phosphorus character. The analysis of the results reveals that the temperature alteration is for the good class (Fig. 3) the rated values meet the standards confirmed

(<30 °C) (Official Bulletin, 2016).

Overall bacteriological quality

In terms of overall quality bacteriological wadis Tghat and Zhoun and she is mean and fecal types (Fig. 4).

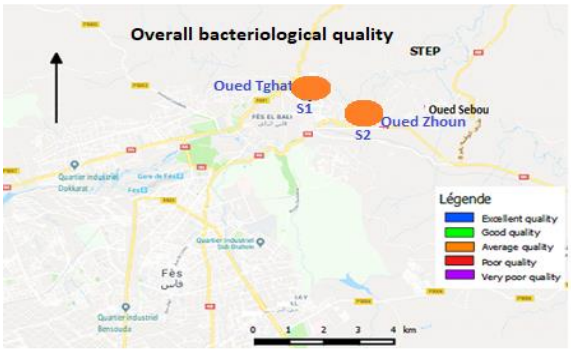


Fig. 4. Spatial distribution of the overall bacteriological quality of river waters and Tghat Zhoun 2017.

Overall quality metal

The waters of wadis Tghat and Zhoun are of poor quality metal overall. The toxic elements having a marked presence along 2017 are Cr, As, Pb and Cd.

Fig. 5. Spatial distribution of global metal quality river waters Tghat and Zhoun 2017.

Overall quality of wadis Tghat and Zhoun

The results of the average values of the evaluation of the overall quality at wadis Tghat and Zhoun record that the overall water quality of the two wadis is poor (Fig. 6). However, the wadis Tghat is slightly lesser degree than the waters of wadis Zhoun. This shows that in the Sidi Boujida area, there is a predominance of craft activities in addition to its popular density. This poor quality was reflected in an organic load to the limit of the rich in nitrogenous materials biodegradability and phosphorus, fecal moderately and highly metallic mineral character, mainly Cr, As, Pb and Cd. This could have a negative impact on water quality of wadis Fez and therefore Sebou one hand; And on the other hand, the health of the population are mostly exploiting the presence of

heavy metals (Cr, As, Pb and Cd) considered among the endocrine disruptors. Indeed, they play an important role in the development of certain diseases such as diabetes, cancer, hypertension, They can interfere with all the major functions of living organisms: growth, reproduction, behavior, nutrition, nervous system ... They can also alter the communication process between cells or tissues and regulating the development of an organism.

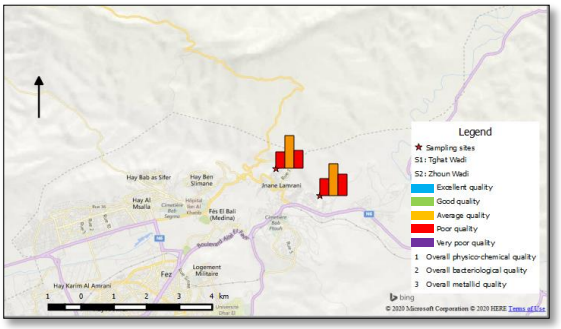


Fig. 6. Overall quality water wadis Tghat and Zhoun the city of Fez in 2017.

Overall, the physico-chemical quality of water is poor metal at the S1 and S2 sites. So these waters studied do not meet the Moroccan directives on classification of surface water (Official Bulletin, 2016). While the bacteriological quality is average in S1 and S2 (Fig. 6).

Identified surface waters statistical analysis most polluted by ANOVA

A variance analysis was conducted to analyze the results of the spatiotemporal monitoring of physical and chemical quality, biological and metal in wadis Tghat and Zhoun. For this, we studied in the first place the evolution of each parameter over time.

Secondly, we discussed the variation of these parameters depending on the sites. Table 3 summarizes the results of the analytical test varied united, fixed pattern applied to each of the 16 variables measured during the study period of 09.01.2017 to 09.12.2017.

Table 3. Analysis of variance ANOVA parameters identifying the quality of water, the sites S1 and S2 as a function of time.

Settings	Sites				Month			
	MS	F	P value	Significant	MS	F	P value	Significant
Temperature	0.082	0.006	0.941 ns	No	58.602	73.433	P <0.0001 ***	Yes
pH	0,002	0,003	0.958 ns	No	2,404	27.396	P <0.0001 ***	Yes
Dissolved O_2	0.168	0,181	0.672 ns	No	3,758	81.490	P <0.0001 ***	Yes
Conductivity	2128.091	0,003	0.955 ns	No	2,750,009.455	354.528	P <0.0001 ***	Yes
COD	1654.610	7.957	0.007 ***	Yes	785.103	10,211	P <0.0001 ***	Yes
BOD_5	511.364	1,311	0.259 ns	No	1586.564	50.684	P <0.0001 ***	Yes
KTN	0,029	0.058	0.811 ns	No	1930	47.379	P <0.0001 ***	Yes
Nitrate	421.762	6,443	0.015 **	Yes	133.072	2,386	0,029*	Yes
Ammonium	20.783	4,205	0,047 *	Yes	16.840	9,269	P <0.0001 ***	Yes
Total phosphorus	2,472	9,993	0.003 **	Yes	0.877	7,077	P <0.0001 ***	Yes
PES (Turbidity)	144.221	0.463	0.500 ns	No	1147.542	21.653	P <0.0001 ***	Yes
Arsenic	0.174	0.219	0.642 ns	No	1,649	3.0195	0006***	Yes
Chromium	5,596	0.132	0, 718 ns	No	176.521	368.638	P <0.0001 ***	Yes
Lead	100.929	2,721	0.107 ns	No	139.697	17,592	P <0.0001 ***	Yes
Cadmium	0009	1,221	0.275 ns	No	0015	2,874	0.011 ***	Yes
fecal coliforms	930,909.091	0.111	0.740 ns	No	10818909.091	1,467	0.196 ns	No

The analysis of the ANOVA is to compare between sampling sites and equality of means for each parameter measured during the study period. In fact, this test has allowed us to identify differences between study sites and sampling campaigns.

p> a = 0.05 (ns) differences not significative
p <a = 0.05 (*) differences just significatives
p <a = 0.01 (**) differences highly significatives
p <a = 0.001 (***) differences very highly significatives
F: value of Fisher;
MS: RMS

It should be noted that the value of P is the probability of the test Fisher; This is a ratio of two variances inter and intra-group, the null hypothesis is true when P <0.05% (Xiao *et al.*, 2012) The values figured in the table present therms corresponding to

the study of monthly changes in physico-chemical parameters, bacteriological and metal. The counting results assign that all of the parameters (T °, pH, DO, χ, COD, BOD5, NH4 +, NTK, TU, Pt, As, Cr, Pb and Cd) vary approximately in a manner very highly significant with the succession of months (P <0.0001). Cadmium is highly significant (P =0.011) with the months. Nitrate is just significant (P =0.029) with the months. As for fecal coliforms, we can accept the null hypothesis (P value> 0.05), as this parameter varies from nonsignificant with the months.

Following the results achieved, we find that

- The month factor has a significant influence on most of the studied parameters. except the parameter of faecal coliforms that do not vary significantly with the month.
- The site has less influence factor on each of the parameters analyzed the month factor; as the root mean square of all parameters of each site is lower than that of the month.

Indeed, surface water sampling sites both have the same sources of pollution, and almost the same human activities (industrial, agricultural ...). In addition, distinguished significant differences are related to the nature of activities affecting the water quality of the two wadis Tghat and Zhoun.

Conclusion

This work aimed to realize a space-time monitoring of parameters assessing the overall water quality of wadis Tghat and Zhoun in the city of Fez, while 2017 by the SEQ-SIG approach and by the statistical analysis of variance (ANOVA).

The study of the overall quality of surface waters of both sites S1 and S2 most polluted identified Fez by the SEQ-GIS approach has allowed us to define ten alterations involving physicochemical parameters and faecal coliforms and clean alteration to their metallic charge. She recorded that these waters are loaded with organic pollutants and trace metals in endocrine effect and constitute a real threat to the environment and health of consumers. The emphasis of these metal contents shows that the polluted particles come from neighboring industries in those areas; mainly tanneries and brassware.

The analysis of variance ANOVA results of the spatiotemporal assessment of the water quality of wadis Tghat and Zhoun says the results of SEQ GIS-based technique alterations definition and calculation of weighted indices, and denotes factor that the site has less influence on each of the parameters analyzed the month factor and the fecal coliforms parameters does not vary significantly with the month.

Acknowledgments

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Declaration of interests

The authors confirm that this article content has no conflict of interest.

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