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Identification of the quality of surface waters in the city of Fez by the SEQ-GIS approach and analysis of variance.

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Abstract

The city of Fez is experiencing dynamic industrial, artisanal and large farming with extensive use of toxic chemicals, part of which is carried by the water nearby in oueds or infiltrated by the soil into groundwater. The objective of this study is, firstly, to identify the most polluted areas near polluting industries estimated the city of Fez, and secondly, know their impact on the quality of surface waters in the city of Fez. For this, we performed a thorough diagnosis of the activities of all industrial areas of the city to determine the points of water samples to identify their quality. Next, we performed a spatiotemporal monitoring of the quality of these waters for 6 months of 2017 by the SEQ-GIS approach and statistical analysis of variance (ANOVA). The diagnostic results show that the city of Fez consists of five main business areas of variables and different activities: Ain Nokbi, Sidi Boujida, Dokkarat, Bensouda and Sidi Brahim. Oueds through the raised areas are respectively Oued Tghat, Oued Zhoun, Oued Fez upstream Oued Ain Smen and Oued Lmahraz and are characterized by strong organic fillers, mineral, metal and fecal contamination. The most polluted oueds are located in the oued downstream Fez (Tghat and Zhoun) mainly to industrial districts Ain Nokbi (S1) and Sidi Boujida (S2). The evaluation of their quality by coupling techniques Evaluation Systems Quality (SEQ) and Geographical Information (GIS) and ANOVA statistical analysis reveals that they are of very poor quality.

Keywords: Pollution; surface water; diagnosis; characterization; SEQ-GIS approach; statistical analysis.

1. Introduction

Globally, the problem of water pollution has become an environmental issue, health and major scientific alarmingly due to environmental degradation by contemporary civilization. It follows that surfaces of water are now contaminated as to be unsuitable for domestic, industrial and agricultural times [1]. As for the Moroccan state, he turned in the 1960s to control its water resources as a lever for socio-economic development. This orientation, consolidated by the promulgation of the Water Law in 1995 [2], helped establish the principles of rational watershed management, consultation in planning, integration in interventions and accountability in the funding (polluter pays principle and user-pays) capitalizing studies previous and launching additional studies tailored to untreated pollution problems. [3] One of these studies showed that the city of Fez generates various types of pollution, especially from industry, estimated at 65% of the total pollution. It comes mainly from emissions from oil mills (OMW), tanneries (chromium), brassware (Nickel), agricultural activities ... that have a direct impact on the quality of surface waters [4] This work aims to know the overall quality of surface waters in the city of Fez in applying the approach system ratings Quality (SEQ) and the Statistical analysis of ANOVA after identifying the oueds through the most polluted areas and performed a space-time monitoring of physicochemical and bacteriological parameters in terms of fecal coliforms characterizing the waters of these oueds. The results are presented as spatial maps of the Geographical Information System (GIS).

2. Methodology

The diagnosis was done by consultation Service System Network Establishment Sanitary-Fez (SRES), the Regional Direction of Sanitary and Epidemiological Fez-Standby (DREVS), Chamber of Commerce, Industry and Services -Fez (CCIS), of the Prefectural Epidemiology Unit-Fez (CPE), the High Planning Commission-Fez (HCP). It has allowed us to identify the activities of all the industrial areas of the city of Fez discharging wastewater without prior treatment in oueds through town. The method for water sampling is of composite type based on the Order defining the gate quality of surface water [2]. The monitoring of the water quality of the studied oueds held monthly during the months of study period in 2017. All samples were stored, transported and analyzed according to the AFNOR standards set by RODIER [5].In situ measured physical parameters are temperature, pH, conductivity, turbidity and dissolved oxygen. Examined chemical and biological parameters are nitrates, ammonium, total phosphorus, chemical oxygen demand (COD), biological oxygen demand (BOD5) and fecal coliforms. The parameters are analyzed metallic cadmium, chromium, nickel, lead, zinc and copper. The results of these analyzes have helped us calculate nonchalantly weathering clues in order to assess a comprehensive water quality by the SEQ according to the classification established by Moroccan directives surface water from a river (Table 1) [6].

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 [7]:

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

Or : Ii: Lower Index, Is: Higher Index ; bi: Lower limit; bs: Upper limit and pa: Parameter analyzed

The lowest index of alteration represents the overall quality of the sites. The results are plotted as spatial maps by GIS tools. The statistical treatment of parameters characterizing the water 5 oueds throughout the study period was held by applying univariate analytical tests, fixed model, each of the measured variables.

3. Results and discussion

3.1. Study zone

The diagnostic results show that the city of Fez is the third largest city in Morocco, north center of the country between the Rif and Middle, with a population of 1 112 072 inhabitants according to the census of 2014 the top Commission in plane [7]. It contains five main industrial areas: Ain Nokbi, Sidi Boujida, Dokkarat, Bensouda and Sidi Brahim that bring together several types of industries: tanneries, brassware, chemistry, chemicals, food processing, transformation and preserves, oil mills, textiles, etc [8]. These areas are crossed by oueds respectively Tghat, Zhoun, oued Fez upstream Ain Smen and Lmahraz which are shown graphically by the GIS Geographic Information System in the card the figure 1.

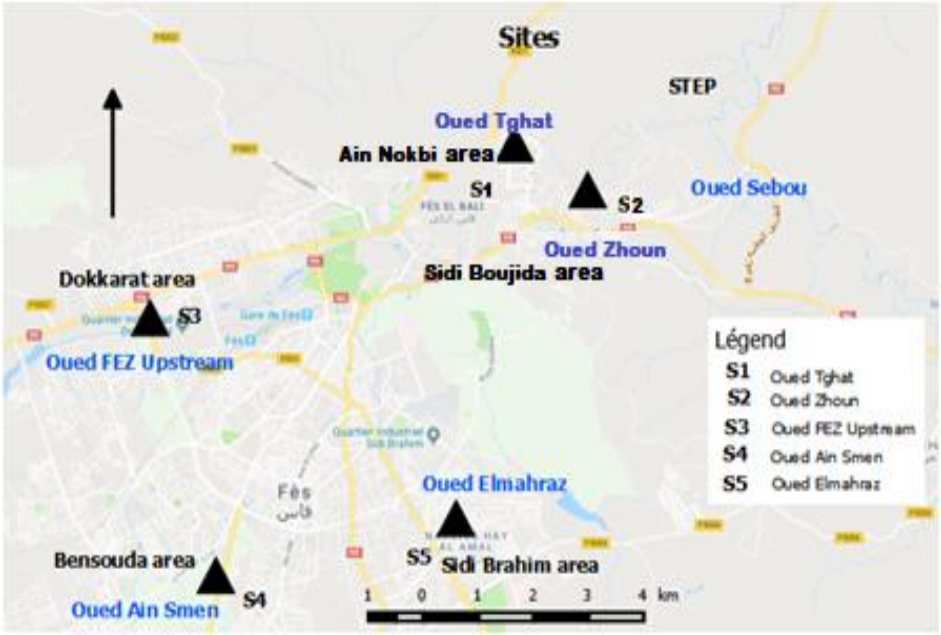

Figure 1: Spatial distribution of oueds near the industrial areas of the city of Fez GIS

3.2. Spatiotemporal assessment of the quality of surface waters Fez

The results of the spatiotemporal monitoring of parameters characterizing the water studied oueds are represented in figure2 (s).

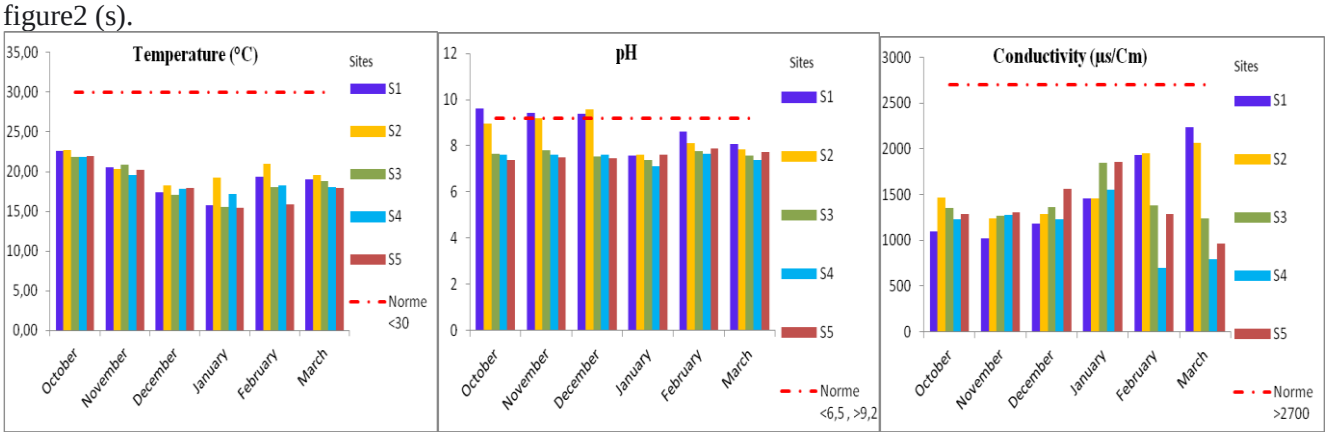

Figure 2 . Evaluation of the physicochemical and spatiotemporal fecal quality of surface Fez waters (a- l)

We carried out a spatiotemporal monitoring of the physicochemical and bacteriological parameters for the five sites during 6months of the year 2017, then a spatial evaluation of the overall quality of the various alterations calculated by the exploitation of the GIS. Then we carried out a monthly spatio-temporal follow-up of the two sites S1 and S2.
The results of the spatio-temporal monitoring of the parameters evaluating the quality of the five sites studied, during 3 months, have been adapted to the Moroccan standard of surface water [2] and are indicated in the figure below (1).
The analysis of the results obtained shows that the surface water temperature of the five sites is between 15.50 and 21 ° C, it complies with the Moroccan standard of surface water which is 30 ° C [2]. The pH values analyzed are almost neutral throughout the sites except for the S1 site (Ain Nokbi), which is basic at 8.6 in February, but during monitoring these values do not exceed the recommended standard [2]. The electrical conductivity is increased in March at site S1 and S2, exceeding the standard of 2700 µs.Cm-1 [2]. Turbidity TU meets the standards for all sites during the three months of monitoring, maximum values are reported for sites S1 and S2; they are respectively 39.14 NTU and 36.25 NTU.The chemical oxygen demand greatly exceeds the Moroccan standard recommended in January at site S1 and S2 (105.6 $mgO_2.L^{-1}$ and 91 $mgO_2.L^{-1}$) respectively; the rest of the studied sites, it took values varying between 14 and 81 $mgO_2.L^{-1}$ The values of BOD5 are 54 $mgO_2.L^{-1}$ and 32 $mgO_2.L^{-1}$ at the level of Oued Tghat and Oued Zhoun respectively; this may be due to the rejection of industrial and artisanal activities (tanneries), while the value tolerated by the Moroccan directives on the classification of surface water is 10 $mgO_2.L^{-1}$ [2]. Dissolved oxygen slightly meets the standards for all five sites throughout the study period. In addition, ammonium does not exceed the standard (8 $mg.L^{-1}$) in all the waters studied. However, the nitrates exceed the norms (50 $mg.L^{-1}$) in the three months of the follow-up, at the sites S1 and S2. As for the phosphorus concentration, it largely exceeds the Moroccan standard of surface water quality for sites (S1, S2, S3 and S4) with the exception of site 5 which complies with the norm authorized during the study period which has coincided with the crushing period of olives [2]. The indicator load of pollution in terms of fecal coliforms is significant in most of the 5 sites studied, this bacterial load coincides with the period of crushing olives [9]. Concerning the metallic load of the water studied, at the five sites, we observe high concentrations of Cr, As, Pb and Cd during the two studied seasons which exceed the recommended standards (BO, 2016) and which are very pronounced in oued Tghat and oued Zhoun; with the exception of S3, S4 and S5, which achieve average values that meet the standards. This high metallic load could be explained by the various industrial and craft activities that these areas experience; metallurgical industries, tanneries, textiles, potteries, dinanderies, glass industries (as paint pigment). It can also be found in coal deposits and as herbicides and in the manufacture of semiconductors (gallium arsenide, arsine, As trioxide ...).

3.3. Comprehensive quality assessment of water studied by GIS-SEQ coupling

3.3.1. Index of alteration and weighting

For the five oueds studied, the weighted index was calculated for each parameter and the index of alteration for a given alteration (Tables 2).

3.3.1.1. Physico-chemical, bacteriological and metallic quality

The Table 2 shows physico-chemical, bacteriological and metallic results weights indices and alterations. We have thus defined 10alterations: the temperature, acidification, mineralization, suspended particles, organics and oxidizable gathering dissolved oxygen, COD, BOD5 and ammonium), the phosphatic materials, nitrates, nitrogen matter, fecal coliforms and metallic trace elements.The alteration counting denotes the temperature awards good to excellent the waters of the five sites.

Table 2. Indices weights and alterations related to the physicochemical, biological and metallic charges

Alteration	*Sites*	*S1*	*S2*	*S3*	*S4*	*S5*
	Index / Parameters	100 80	80 60	60 40	40 20	20 0
(1) Temperature	**T°**	82,0	80,3	90,1	88,7	94,3
(2) Acidification	**pH**	40,1	48,2	69,1	71,2	67,6
(3) Organic and oxyd materials	**dissous Oxygen** ($mgO_2.L^{-1}$)	21,0	20,0	54,0	52,3	79,0
	BOD_5 ($mgO_2.L^{-1}$)	18,7	19,5	28,4	35,1	40,0
	COD ($mgO_2.L^{-1}$)	19,0	23,8	82,4	81,7	79,8
	NH_4^+ ($mgNH_4.L^{-1}$)	35,0	39,7	55,2	51,5	71,5
	Index of alteration	23,4	25,7	55,0	55,2	67,6
(4) nitrogenous matter	**NTK** ($mg.L^{-1}$)	48,7	41,4	93,3	94,2	66,5
(5) phosphorus Materials	**PT** ($mg.L^{-1}$)	27,8	36,3	44,0	55,0	68,7
(6) Nitrates	**NO_3^-** ($mg.L^{-1}$)	33,4	35,3	53,4	53,8	60,6
(7) Mineralization	**CE** 20°C (µS/cm)	49,4	48,7	57,3	70,3	61,0
(8) suspended Materials	**Turbidity** (NTU)	59,9	61,4	77,4	83,1	85,3
(9) Microorganisms	**CF**/100mL	48,7	45,2	48,8	43,3	45,5
(10) Metallic trace elements	**Cd** ($mg.L^{-1}$)	34,3	36,1	66,0	91,3	50,0
	Cr ($mg.L^{-1}$)	29,1	30,7	45,6	56,3	52,9
	Ni ($mg.L^{-1}$)	62,9	63,4	62,8	63,8	61,2
	Pb ($mg.L^{-1}$)	34,6	34,4	55,0	49,5	58,3
	Zn ($mg.L^{-1}$)	57,8	59,5	96,6	57,2	57,1
	As ($mg.L^{-1}$)	25,8	31,4	54,3	58,7	73,5
Overall physicochemical quality						
Overall bacteriological quality						
Overall metallic quality						

Acidification, mineralization and suspended particles classify these waters from good to average. Organics and oxidizable and the phosphatic materials and nitrates classify waters of Ain Nokbi and Sidi Boujida in poor quality

because of increased organic content responsible for the oxygen consumption probably from the great popular density in these areas and their high activities daily, domestic, agricultural and craft of the city of Fez [10], [11]. We also recorded that these alterations 4 classify water S3 and S4 and average quality and S5 good. About alteration fecal coliforms, it confirms the average quality of all the sites. The presence of some trace metals (SEM) even at low concentrations in surface waters could have direct impacts on the environment and human health. At five sites, indices alterations are important especially chrome, Arsenic, Cadmium and lead and very pronounced in oued Tghat and oued Zhoun ranking it in poor quality and the waters of the other sites 3, 4 and 5 are in good and middle quality. This could be explained by the urban waste and industrial areas studied and are transported to nearby oueds without prior to treatment; in addition to the solid waste that is scattered on the banks of oueds Depending on the diagnosis, zinc probably comes from burning coal for steam, pottery, painting wool or other craft. Nickel may also be in dyeing, pottery, iron and steel, brassware, cosmetics, surface treatment industries (taps, plates, decorative items,...). Chromium is mainly from tanneries, dyers, of brassware and textile industries,...

3.3.2. Evaluation of the overall quality of river water studied

The evaluation of the overall quality of Fez city of surface water at each area taking into account the physico-chemical alterations, bacteriological and metal is represented by a mapping scheme (Figures 3 to 5).

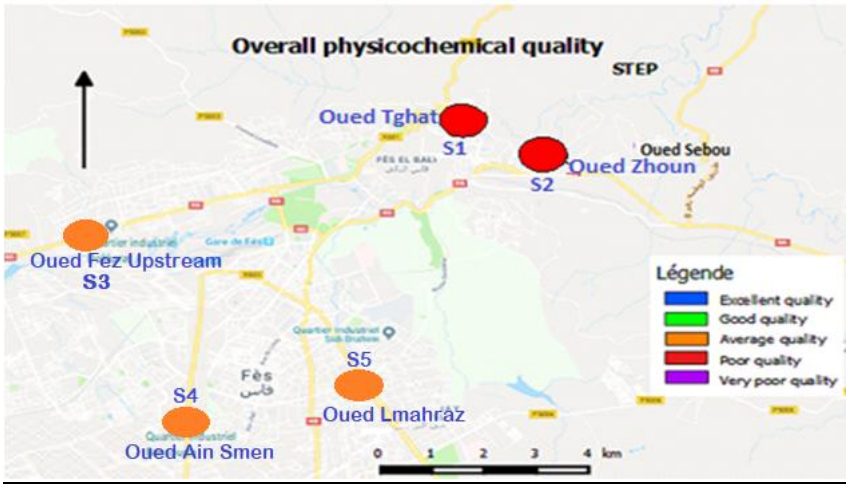

Figure 3. Overall physical and chemical quality of surface waters in the city of Fez

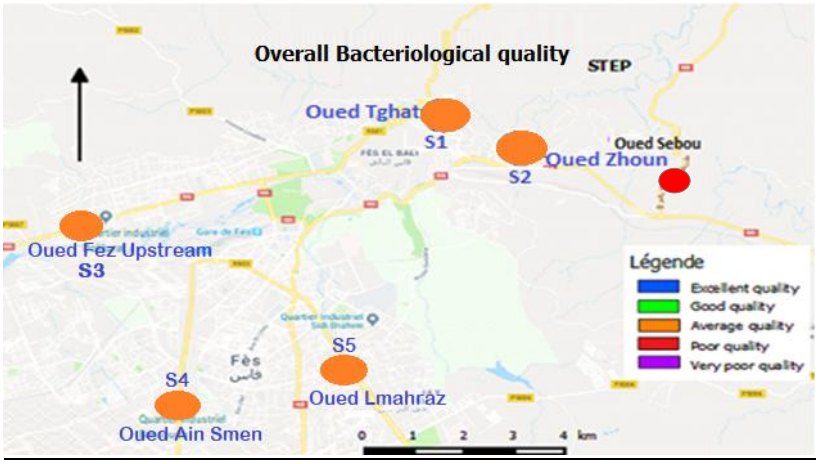

Figure 4. Overall bacteriological quality ard surface water from the city of Fez

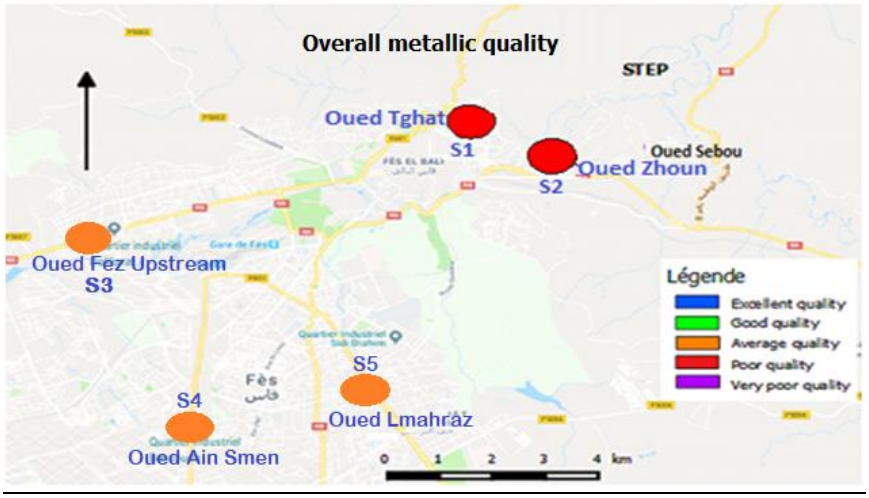

Figure 5. Overall quality of map metallic trace element surface water from the city of Fez

Analysis of mapping patterns reveals that oued Tghat and Zhoun crossing the area Ain Nokbi and Sidi Boujida is poor; all pollution alterations are outsized [6]. The oued Fez upstream, Ain Smen and Lmahrez are between good and average quality. To confirm the results obtained, we made a statistical analysis of all alterations in Fez City surface water through ANOVA.

3.4. Evaluation of the water quality of surface Fez Statistics analysis (ANOVA)

Table 3 presents the results of the analytical univariate test, fixed model applied to each of the variables made alterations characterizing the waters of the oueds through the city of Fez during a follow three months of 2017.

Table 3: Analysis of variance ANOVA physicochemical and bacteriological parameters of the water five oueds a function of time

p> a = 0.05 (ns) no significant differences of 5 with an error of 5% w <a = 0.05 (*) differences just significatives p <a

Parameter	**Sites**				**Time**			
	MS	F	P value summary	significant	MS	F	P value summary	significant
(1) Temperature	126.907	1,378	0.248 ns	No	2219.721	2219.721	P <0.0001 ***	Yes
(2) pH	2316.628	11.022	, 0002 ***	Yes	338.252	338.252	0001 ***	No
(3) organic and oxidizable materials	13261.250	317.363	P <0.0001 ***	Yes	334.577	334.577	0.240 ns	No
(4) nitrogenous matter	0,029	0,058	0,811 ns	No	1.930	47,379	P<0.0001***	yes
(5) Total phosphorus	5951.250	330.363	0.000 ***	Yes	1,429	1,429	0.626 ns	No
(6) Nitrate	4205.000	228.463	0.00 *	Yes	100.820	100.820	0.895 ns	No
(7) Conductivity	3808.800	290.017	0.00 **	Yes	242	242	0.892 ns	No
(8) Particulate materials	3808.800	395.017	P <0.0001 ***	Yes	7,220	7,220	0.951 ns	No
(9) Fecal coliforms	64808.800	228.463	0.000 ***	Yes	2349.825	2349.825	0.932 ns	No
(10) metallic trace elements:								
Arsenic	0,174	0,219	0,0042 **	Yes	1,649	3,0195	0,465 ns	No
Chromium	5,596	0,132	0 ,0178 ***	Yes	176,521	368,638	0.741 ns	No
Lead	100,929	2,721	0,0107 ***	Yes	139,697	17,592	0.917 ns	No
Cadmium	0,009	1,221	0.0275***	Yes	0.015	2,874	0,639 ns	No

= 0.01 (**) differences highly significatives p < a = 0.001 (***) very highly significant differences mean 100% true F: F value of Fisher; MS: RMS

The calculation of the quadratic averages, Fisher's tests and the p value of the different alterations characterizing the surface water of the city of Fez shows that most of the alterations vary considerably with the sampling sites and the time because they do not the same origins or the same anthropic activities. The analysis of the results shows that the site factor of all the alterations is greater than the time factor except that of the temperature. The difference is very highly significant (P <0.0001) for the five sampling sites almost for all the alterations. Their variation is between highly significant and just significant. However, for temperature, we can accept the null hypothesis (value P = 0.24), because the variance characterizing the error due to a model error is much lower than the experimental error. So this parameter varies in a non-significant way with the sampling sites. On the other hand, it varies in a very highly significant way over time (P <0.0001). Thus, we note that the acquired results corroborate those identified by the SEQ-GIS approach.

4. Conclusion

This work aimed to evaluate the quality of the surface water of the city of Fez by the SEQ-GIS coupling approach and analysis of the ANOVA variance after having made a diagnosis on oued crossing the city and the activities of the neighboring population. . The results of the diagnosis show that the city of Fez is divided into 5 zones Ain Nokbi, Sidi Boujida, Dokkarat, Bensouda and Sidi Brahim. The oueds crossing these zones are respectively Oued Tghat, Oued Zhoun, Oued Fez upstream, Oued Ain Smen and Oued Lmahraz. Spatiotemporal monitoring of the parameters characterizing the waters of 5 oueds shows that these waters carry high organic and bacterial loads and are rich in zinc and to a lesser degree in chromium, nickel and copper. The most polluted waters are those of Oued Tghat and oued Zhoun crossing the Ain Nokbi and Sidi Boujida zones respectively. The study of the overall quality of surface water in the city of Fez using the SEQ-GIS approach allowed us to define eight alterations combining the physicochemical parameters and fecal coliforms and an alteration specific to their metallic charge. It records that these waters are loaded with organic pollutants and microbial micro-organisms and constitute a real threat to the environment and the health of the consuming population, especially those of oued Tghat which is of a very poor quality. The ANOVA variance analysis of the various alterations asserts the results obtained by the SEQ-SIG technique and indicates that the site factor has more influence on each of the alterations than the time factor except for the temperature and that the surface waters from the city of Fez are highly polluted in descending order: oued Tghat, oued Zhoun, oued Fez upstream, Oued Ain Smen and oued Lmahrez.

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