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Evaluation and assessment of water and surficial sediments quality in Kebir-Rhumel Wadi, NE Algeria

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Abstract
This study is to investigate the physico-chemical parameters and trace metal's concentrations (Cd, Pb, Cu, and Zn) in water and surficial sediments (0-5 cm) samples in the Kebir-Rhumel Wadi, north-eastern Algeria. Trace metal concentrations was determined using flame atomic absorption spectroscopy. The mean values of the physico-chemical parameters of the Wadi water samples are consistently above than thresholds of the Algerian standard. The comprehensive pollution index (CPI) varied from 1.46 to 3.90, indicating that the Wadi water was classified from polluted to seriously polluted. The eutrophication index (EIs) were above the unity, signifying that the eutrophication is serious, except for sites S1, S7, and S8. Metals was not detected in water samples. However, the metallic concentrations in the sediment were higher than background levels. The average geo-accumulation index (Igeo) revealed an order of trace metal contamination of the Kebir-Rhumel Wadi sediments: Pb>Cd>Zn>Cu. The contamination factor (CFs) of studied metals indicated a highly contaminated nature of sediments, whereas the Cd values indicated moderate contamination, considerable contamination with Pb and low contamination with Cu and Zn. The pollution load index (PLIs) were above the unity (1), displaying an advanced decline of the sediment's quality. Potential ecological risk index of trace metals were changed as follows: Cd>Pb>Cu>Zn. Cadmium was of highly potential ecological risk to the ecological environment and prominently contribute to potential toxicity response.

Keywords: *Water, Sediments, Pollution indices, Kebir-Rhumel Wadi, Algeria.*

1. Introduction
Surface water quality is one of the most pressing environmental concerns in many parts of the world (Ferreira et al. 2010; Vural and Gundogdu, 2020), worsen by an excess of some constituents and microorganism which were harmful to the aquatic environment (Bilotta et al. 2007). Moreover, the expanding human population, industrialization, intensive agricultural practices, and discharges of massive amount of wastewater into the river lead to a deterioration of water quality (Chidya et al. 2011; Yadav et al. 2014; Chung et al. 2016; Islam 2021). The pollutants coming from anthropogenic sources influence water quality and damage aquatic habitats (Sakcali et al. 2009), especially certain trace elements in concentrations above acceptable limits (Sawidis et al. 1995; Yevseev and Krasovskaia 2001). These metals discharged into waters of rivers may rapidly bound to the surface of fine sedimentary particles (Krika and Krika 2018). The sediments are always regarded as the potential reservoir for metals and plays an important role in the adsorption of dissolved trace metals (Wang and Chen 2000).In Algeria, rivers are deteriorated by various forms of pollution, especially in the north, where most of water resources are hosted (Shali et al. 2011).Water resources have become increasingly limited, and difficult to exploit, and are exposed to significant amounts of wastewater, urban effluents, industrial and agricultural waste (Afri-Mehennaoui et al. 2004; Guettaf et al. 2017). The Kebir-Rhumel Wadi, one of the longest and most important wadis in the eastern Algeria, are affected by the indiscriminate discharge of various types of industrial effluents and domestic sewage. In this study, the variations in the physico-chemical parameters of water and metallic contamination by Cd, Pb, Cu, and Zn of surficial sediments and water of the Kebir-Rhumel Wadi, north-eastern Algeria, were investigated. Pollution indices are adopted to assess the effects on health of this aquatic ecosystem influenced by anthropogenic activities.

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2. Materials and methods
2.1. Study area
The study area is located in the Kebir-Rhumel watershed (eastern Algeria) (Fig. 1). It covers an area of 8795 km^2 and is characterized by the distinct topographic, climatic, geologic, and hydrologic settings. The study area is characterised by a various of anthropogenic activities among them: textile factories, mechanical and pharmaceutical industries, and use of fertilizers and pesticides. The Wadi vigorously crosses the numidic chain. Then, it crosses the heavily watered massifs of the small Kabylie of El Milia, before flowing into a broad valley toward the sea at Jijel (Sidi Abdelaziz). Geologically, the study area is located in a paleozoic basin, with metamorphic sedimentary rocks. The Wadi banks are characterized by recent alluvial, slightly

evolved soils (Mebarki 2009) with heterogeneous texture and structure lacking profile differentiation. The climate of this region is Mediterranean, with less humidity and considerable seasonal fluctuations in temperature. The precipitation is low (annual meaning rainfall of 699.5 mm). It is highly irregular and usually absent in July and August, therefore, the hydric balance is clearly negative during the dry season. The water of Kebir-Rhumel Wadi is used for an irrigation of the agricultural lands along both sides of the watercourse (Benfridja et al. 2021).

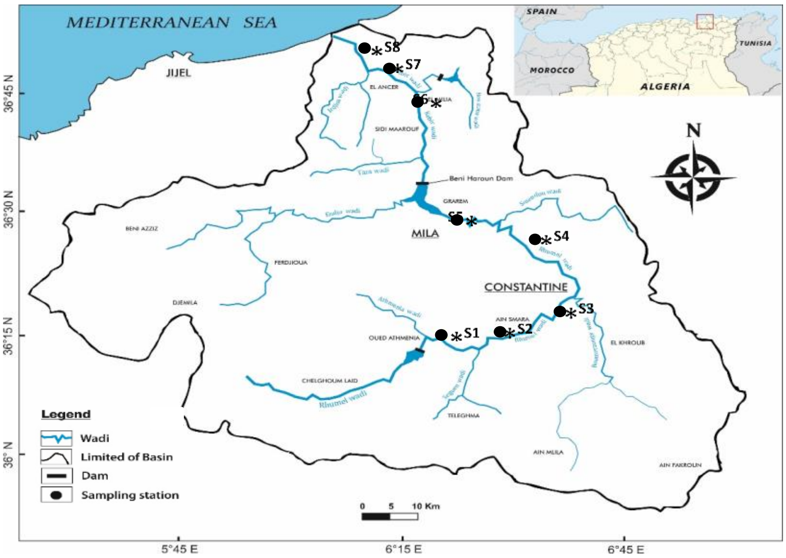

Fig 1. Location of the Kebir-Rhumel Wadi in north-eastern Algeria and its sampling sites

2.2. Sampling and data collection

Water and surficial sediment samples (0-5 cm) were collected in the Kebir-Rhumel basin from eight sites (S1 to S8). Four sub-basins were chosen: Rhumel-Seguen Wadi (sub-basin 10-04) (three sampling sites), Rhumel-Smendou Wadi (sub-basin 10-06) (two sampling sites), and Kebir maritime Wadi (sub-basin 10-07) (three sampling sites) (Fig. 1). All samples were collected between July and August 2021 in three replicates at each sampling site, in a period that coincided with the start of the dry season. In total, twenty-four water samples and twenty-four sediment samples were collected.

2.3. Kebir-Rhumel River water sampling and analytical methods

At each sampling site, water samples (for physico-chemicals analysis) were taken just below the surface into 1 L high-density polyethylene containers equipped with screw caps and labelled.

Bottles were rinsed with the objective water before sampling. The samples were then stored in an ice chest.The physico-chemical parameters, such as pH, EC, SS, NO_3, NO_2, PO_4, NH_4, BOD, and COD, were analysed according to standard methods (APHA 1998). However, pH and EC were determined in situ, unlike other parameters in laboratory.

Water samples used for trace metals measurement were pre-acidified directly (at pH = 2) by a concentrated nitric acid and filtered through a 0.45 µm Millipore membrane.nitric acid and filtered through a 0.45 µm Millipore membrane.

2.4. Water quality evaluation indices

To evaluate pollution status of the wadi, the eutrophication index (EI) and comprehensive pollution index (CPI) were calculated.

The EI is a critical eutrophication level that defines the trophic eutrophication status of water body (Jiang et al. 2019).

The EI was calculated using three parameters, i.e. COD (chemical oxygen demand), DIN (inorganic nitrogen), and DIP (dissolved inorganic phosphorus) (Sukanya and Joseph 2020). The EI is calculated through Eq (1).

$$EI = \frac{COD \times DIN \times DIP}{4500} \quad (1)$$

Where, EI>1 indicates an eutrophication, and EI<1 suggests no eutrophication (Zhang et al. 2015).

The CPI was calculated based on the assessment of a single factor index and combined effect of all factors. CPI is used for evaluating pollution degrees of the water body widely (Sukanya and Joseph 2020). The CPI was calculated according to Eq (2).

$$CPI = \frac{1}{n}\sum_{i=1}^{n} PI \quad (2)$$

Where the PI (Pollution Index) is the ratio of the measured concentration of individual parameter to the standard permissible concentration of parameter (Sukanya and Joseph 2020). And CPI<0.8 indicates qualified; 0.8-1 is basically quantified; 1-2 is polluted; and CPI>2 is seriously polluted (Zhao et al. 2012).

2.5. Sediment and water analysis

For sediment samples, triplicates of the surface sediment at each sampling site were collected using a plastic sampling spatula and then transferred to clean polyethylene bags by plastic gloves.Sediment samples were dried at 60°C during 48H. The dried sediment samples were powered using an agate mortar. The extraction of metals was completed using a conventional digestion procedure of sediments, which includes digesting aliquots of 1.0 g solid sample by the solution 3:1 of HNO3:HCl (Hoening et al. 1981). Finally, the solution was diluted to a final volume of 25 ml with deionized distilled water.The concentrations of Cd, Pb, Cu, and Zn in water and sediment samples were determined by a flame atomic absorption spectrophotometer as prescribed in standard methods (APHA et al. 2005).

2.6. Contamination assessment on sediment

To assess the pollution of investigated heavy metals in sediments of Kebir-Rhumel Wadi, the Igeo (geo-accumulation index), CF (contamination factor), PLI (pollution load index), and RI (potential ecological risk index) were employed.Igeo is used to estimate the degree of anthropogenic influence on trace element concentrations in the sediments by comparing the current and pre-industrial elemental concentrations with that in the Earth's crust (Iqbal and Shah 2011). Igeo was calculated using Eq (3) (Müller 1981).

$$I_{geo} = Log_2 \frac{C_n}{1.5 \times B_n} \quad (3)$$

Where C_n is the measured elemental concentration in sediment samples, and B_n is the geochemical background of the Earth's crust (Loska et al. 1997). The value of 1.5 is the background matrix correction factor due to lithogenic effects.

The crustal abundance of Turekian and Wedepohl (1961), and Rudnick and Gao (2014) was used. The contamination levels were classified on a scale ranging from 1 to 6, e.g. uncontaminated ($I_{geo}<0$), uncontaminated to moderately contaminated ($0<I_{geo}<1$), moderately contaminated ($1<I_{geo}<2$), moderately to strongly contaminated ($2<I_{geo}<3$), strongly contaminated ($3<I_{geo}<4$), strongly to extremely contaminated ($4<I_{geo}<5$), and extremely contaminated ($I_{geo}>5$) (Loska et al. 2004; Iqbal and Shah 2011).

CF is the ratio of the heavy metal concentrations in the sample to its background (Eq (4)) (Hakanson 1980):

$$CF = \frac{C_{sample}}{C_{background}} \quad (4)$$

Where C_{sample} is the concentration of heavy metal in sediment samples and $C_{background}$ is the background of the heavy metal.

The contamination levels were classified on a scale of 1 to 6, i.e. low contamination (CF<1), moderate contamination (1<CF≤3), considerable contamination (3<CF≤6), and very high contamination (CF>6) (Hakanson 1980). PLI was calculated from the CF of each heavy metal to minimize the possible effect of anthropogenic input into the environment as Eq (5) by Tomlinson et al. (1980).

$$PLI = \sqrt[n]{CF_1 \times CF_2 \times CF_3 .. CF_n} \quad (5)$$

Where CF is the contamination factor, and n is the number of heavy metals. If the PLI value were less than 1, it should indicate a no detectable pollution. If the PLI value exceeded 1, the site would be considered to be polluted (Tomlinson et al. 1980; Varol and Şen 2012; Vural 2014; Rezapour Tabari and Yazdi 2014; Vural 2015; Jehangir Khan et al. 2021). The formula for potential ecological risk index (E_f^i) for a single heavy metal pollution was given in Eq (6).

$$E_f^i = C_f^i \times T_f^i \quad (6)$$

Where T_f^i is the response coefficient for the toxicity of each trace metal. This index reveals hazards of trace metals on the human and aquatic ecosystem, and reflects the level of heavy metal toxicity and ecological sensitivity to heavy metal pollution (Guo et al. 2010). The standardized response coefficient for the toxicity of heavy metals, made by Hakanson (1980), was adopted as the evaluation criterion. The corresponding coefficients for Cd, Cu, Pb, and Zn are 30, 5, 5, and 1, respectively (Zhao et al. 2005).RI (potential toxicity response index) is a method to assess the ecological risk of heavy metals in soil or sediments (Hakanson 1980), which was widely used (Zhu et al. 2012; GhasemShirazi et al. 2014; Yang et al. 2020). The RI of all heavy metals was calculated as Eq (7).

$$RI = \sum E_f^i = \sum C_f^i \times T_f^i \quad (7)$$

Where C is the contamination factor, i is the number of heavy metals and T is toxic-responsefactor of heavy metals for a given substance. Grading standards of the potential ecological risk of heavy metals were given in Table 1.

2.7. Statistical analysis

Statistical analyses were conducted using Statistica 8.0 software. Minimum, maximum, mean and standard deviation were calculated for water physico-chemical parameters, and trace metal in sediments. Spatial variations of sediment trace metal concentrations and physico-chemical properties of water were tested by analysis of variance was conducted to show the significant differences among the sites for water and sediment samples at 5% level of significance (Zar 2000). The level of significance was set at *p* value (5%).

3. Results and discussion

3.1. Physico-chemical parameters of water

The distribution of water parameters is shown in Figure 2, and basic results of statistical analysis are given in Table 2. Results show that all investigated parameters were above the limits specified by relevant regulation, except for pH, EC, and NO_3. There are significant variations in physicochemical parameters of water among sampling sites (Fig. 2). The results of analysis of variance (ANOVA), carried out to study the spatial variations of the physico-chemical parameters of the water, showed that at the significance level of 5%, there are significant variations in parameters of water among the different sites (F=309.7 ; p<0.001

Table 1. Relationship among RI, E_f^i, and pollution levels (Guo et al. 2010).

Scope of potential ecological risk index (E_f^i)	Ecological risk level of single-factor pollution	Scope of potential toxicity index (*RI*)	General level of potential ecological risk
$E_f^i < 40$	Low	RI<150	Low
$40 \leq E_f^i < 80$	Moderate	150≤RI<300	Moderate
$80 \leq E_f^i < 160$	Higher	300≤RI<600	Severe
$160 \leq E_f^i < 320$	High	600≤RI	Serious
$320 \leq E_f^i$	Serious		

The pH of water varies between 8.08 and 8.71 (meaning 8.40), indicating a slightly basic water, which is due to the calcareous nature of Kebir-Rhumei basin (Mebarki 2009) and to the variable inputs from industrial effluents (Santhiya et al. 2011). According to Tsytsarin (1988), this situation characterized waters where life develops optimally.

Table 2. Statistics of water chemistry parameters and permissible limits of Algerian standards

	Parameter	Mean	SD	Max	Min	Algerian permesible limits (AOJ 2011)
Water	T (°C)	26.11	1.04	27.6	23.7	25
	pH	8.40	0.16	8.71	8.08	6.5-9
	EC(mS/cm)	1.38	0.35	1.97	0.85	2.8
	SS (mg/L)	45.50	23.10	101.0	19.80	25
	NO_3 (mg/L)	15.24	9.02	34.62	6.45	50
	NO_2(mg/L)	1.16	0.64	2.73	0.53	0.1
	PO_4 (mg/L)	14.15	1.70	7.97	2.11	10
	NH_4(mg/L)	5.86	4.88	15.31	1.11	04
	COD(mg/L)	79.82	21.16	115.3	52.60	30
	BOD_5(mg/L)	9.61	6.65	25.4	3.04	07

Water samples' temperatures range from 23.70°C to 27.60 °C (meaning 26.11°C). The variability in temperature values at the study locations may have resulted from the weather condition at the time of study. The increased water temperature might reduce the solubility of oxygen and amplify the odour due to an aerobic reaction (Akan et al. 2008).The EC of the water in Kebir-Rhumel Wadi ranged from 0.85 to 1.97 mS/cm (meaning of 1.38 mS/cm). Some samples, close to the Mediterranean Sea (S7 and S8), generally show higher values of EC. However, the EC values, observed in sites S2 and S4, can be attributed to the presence of salt soils (Sahli et al. 2011) and can be ascribed also to domestic sewage, introducing large amounts of salts into the river system.The SS content in the water samples of Kebir-Rhumel Wadi varied between 19.80 to 101 mg/L (meaning 45.50 mg/L).

The highest value was recorded at site S3, which could be attributed to industrial and urban discharges and run-off from grounds neighbouring wadi. Dalmacija and Tumbas-Ivančev (2004) reported that SS are closely linked to a variety of factors such as: transport of nutrients (especially phosphorus), metals, industrial wastes and agricultural practices.Nitrogen species in surface water are usually related to excessive use of fertilizers, thus, linked to agricultural activities (Ogwueleka 2015). (NO_3) was ranged from 34.62 to 6.45 mg/L (meaning 15.24 mg/L). The lowest value was observed at site S2, while highest value was observed at site S5. According to Pradhan et al. (2009), this variation may be due to the nitrate released from fertilizers, not absorbed by the soil but washed off from the land during flows.The (NO_2) content varied from 0.53 to 2.73 mg/L (meaning 1.16 mg/L). Concentrations of nitrites presented some fluctuations among the sampling sites, owing to the location of anthropogenic activities. The highest concentration of NO_2 in water appeared at site S4 while the lowest mean concentrations belonged to site S1. The increase in nitrate levels in the waters of Kebir-Rhumel Wadi at site S4 is synonymous with the leaching of fertilizers (Van Cleemput and Samater 1995 ; Burns et al. 1995) used in agricultural lands located on the banks of the river and its vicinity.The ammonium values ranged from 1.11 to 15.31 mg/L (meaning 5.86 mg/L). Major sources of the NH_4 pollution are fertilizer runoff and municipal wastewater (Sun et al. 2015).

In the study area, ammonium was detected at all sampling sites. The highest value of NH_4 was observed at site S4, and the lowest value of NH_4 was detected at site S8. In general, concentration of NH_4 in the study area is disturbing, especially at site S4 where it is home to remarkable agricultural activities these past years and wastewater discharges loaded with organic matter received at this site would be responsible of these high levels.

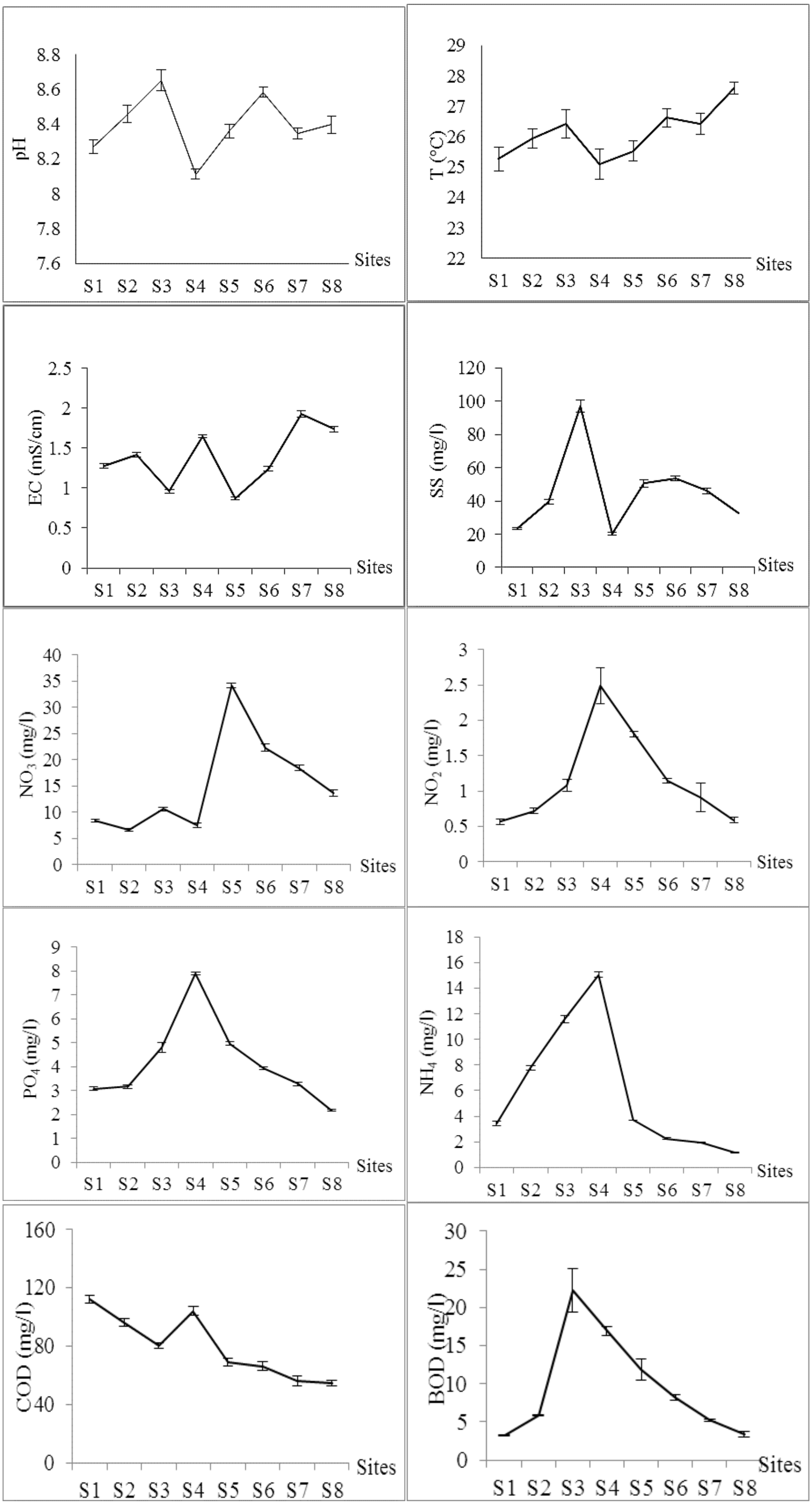

Fig. 2. Physico-chemical parameters and nutrient variables in water at different locations of the Kebir-Rhumel Wadi.

Phosphate was mainly from tertiary industries, food and beverage industries, domestic sewage from residential areas, and the phosphate fertilizer used in farms (Huang et al. 2010; Tanjung et al. 2019).

The lowest average value in (PO4) is recorded at site S8, while the highest average value is recorded at site S4. This is due to the significant discharges of domestic wastewater heavily loaded with phosphate (Cerqueira et al. 2005).

However, excess concentration of phosphate in water results in overgrowth aquatic plants and algae that rapidly consume and decrease the dissolved oxygen levels in water and kill aquatic life finally (Nas and Berktay 2006; Nartey et al. 2012; Khan et al. 2016).

BOD and COD are water quality parameters that represent biodegradable and total organic content of surface water, respectively, and indicators of organic pollution from industrial and domestic discharges (Kazi et al. 2009).

The concentrations of COD and BOD in Kebir-Rhumel Wadi samples were ranged from 52.60 to 115.30 mg/L (meaning 79.80 mg/L) and 3.04 to 25.40 mg/L (meaning 9.61mg/L), respectively.

The increase in COD and BOD (cases of S4 and S3) may be were attributed to the increase of organic matter due to agriculture, urbanisation (wastewater) and industrial effluents.

3.2. Water quality indices

Results of eutrophication index (EI) and comprehensive pollution index (CPI) of the Kebir-Rhumel Wadi water are shown in Table 3.

Table 3. Pollution indices of the Kebir-Rhumel Wadi water

Sites	EI	Status	CPI	Status
S1	0.95	No eutrophication	1.46	Polluted
S2	1.02	Eutrophication	1.77	Polluted
S3	1.97	Eutrophication	2.31	Seriously polluted
S4	4.60	Eutrophication	3.90	Seriously polluted
S5	3.01	Eutrophication	2.84	Seriously polluted
S6	1.48	Eutrophication	2.10	Seriously polluted
S7	0.87	No eutrophication	1.69	Polluted
S8	0.40	No eutrophication	1.74	Polluted

There is fluctuation of EI in the values at studying stations. The highest value (4.60) was recorded at site S4, while the lowest value (0.40) was observed at site S8. The Kebir-Rhumel Wadi water coincides with the eutrophication water class category, except for S1, S7 and S8 waters.

The calculated CPIs ranged from 1.46 at site S1 to 3.90 recorded at site S4. The Kebir-Rhumel Wadi waters belong to the seriously polluted water class category for the sites of S3, S4 S5 and S6 and the polluted water class category for the others sites (S1, S2, S7 and S8).

3.3. Trace metals in water

The trace metals are undetectable in the water samples. There might have been complete retention of trace metals by the suspended solids of sediments in different forms, such as exchangeable ions, carbonates, oxides/hydroxides, or complexed with organic matter. Sediments act as sinks and sources of trace metal contaminants in aquatic ecosystems (Sahli et al. 2011).

3.4. Trace metals in sediment

Heavy metals in sediment provide information about the water system pollution and critical sites. Metal concentrations in sediment samples are presented in Figure 3, which include mean concentrations with standard deviation values. The metal concentrations at different sampling sites varied significantly, indicating that the metal contamination is not uniform in the wadi. These results were confirmed by the analysis of variance (ANOVA), which showed that at the 5% level of significance, there are significant spatial variations of metal concentrations in sediment samples (F=137.86 ; p<0.001).

The highest concentration for Cd was registered at site S5, while the highest concentration of Cu was observed at site S6. Zn showed high concentration in the site S2, however the highest concentration of Pb was registered at site S4. Infact , the high levels of concentration of the metals studied in these sites were originating primarily from anthropogenic activities (Afri-Mehennaoui et al. 2004) such as the discharge of industrial water (textile factories, mechanical industries, pharmaceutical industries), agricultural practices (use of fertilizers and pesticides in the areas located upstream, in the middle and downstream of the wadi) and domestic water wastage in untreated form in rural and semi-urban areas.

The concentrations of Cd, Pb, Zn and Cu in Wadi sediments greatly exceed the background levels (Table 4). According to Thomas and Meybeck (1992), sediments are considered contaminated if metal concentration values exceed the background level. The metal distribution in sediment follows the order: Zn > Pb > Cu > Cd.

To better understand the status of heavy metals in the study area, these metals' concentrations were compared with those reported in other rivers around the world (Table 4).

Sediment Quality Guidelines*:* A general assessment of metal pollution was conducted by comparing the determined metal contents with (SQGs) of the US EPA. Two consensus-based values were reported for each potential contaminant: (1) the threshold effect concentration (TEC), which is the concentration below which harmful effects are unlikely to be observed; and (2) the probable effects concentration (PEC), or the concentration above which harmful effects are likely to appear (MacDonald et al. 2000).

The TEC and PEC reference values for the sediments were listed in Table 04. In terms of PEC, the concentration of trace metals was lower than the reference values in all sampling sites, suggesting that the concentrations of these metals did not causes any harmful effects on the benthic fauna.

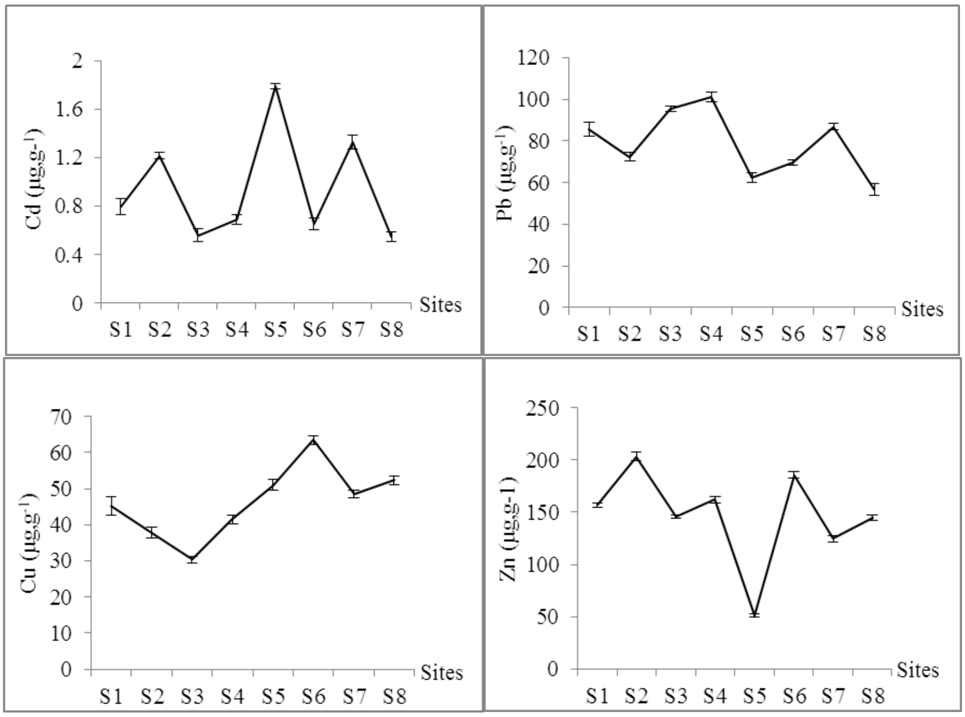

Fig. 3. Heavy metal concentrations in the Kebir-Rhumel Wadi sediment

Table 4. Concentration (µg/g) of trace metals in the Kebir-Rhumel Wadi and selected rivers around the world

	Cd	Pb	Zn	Cu	References
Mean	0.94	78.8	146.8	46.2	This study
Background	0.3	20	95	45	Turekian and Wedepohl (1961)
SQGs					
TEC	0.99	35.8	121	31.6	MacDonald et al. (2000)
PEC	4.98	128	459	149	
Boriganga River	5.3	476.5	835.5	231.5	Mohiuddin et al. (2011)
Almandes River	2.50	93	262	158	Olivares-Rieumont et al. (2005)
Old Brahmaputra Rive	0.48	7.60	52.7	6.20	Bhuyan et al. (2019)
Karnofuly River	0.24	4.96	16.30	1.22	Islam et al. (2013)

3.5. Pollution of the sediment

Geo-accumulation index (Igeo)

Based on Müller (1969) classification and mean I_{geo} values (Table 5), sediments of Kébir-Rhumel are uncontaminated with respect to Cu, and Zn, uncontaminated to moderately contaminated with Cd, and moderately contaminated with Pb. Based on average values of I_{geo}, the ranking of intensity of trace metal pollution of the Kebir-Rhumel Wadi sediments is as follows: Pb>Cd>Zn>Cu. The elevated values identified for Pb and Cd are probably as a result of anthropogenic activities in the study area such as brickyards and dyeworks**.**

Contamination Factor (CF)

According to the classification of Hakanson (1980**)** and the results of Table 5, all sites along the Kebir-Rhumel wadi indicated a moderate Cd contamination, a considerable Pb contamination, and a low Cu and Zn contamination. Moreover, level of Pb was higher than other heavy metals in sediments, and the mean CF values for the metals in the studied area followed the sequence: $CF_{Pb} > CF_{Cd} > CF_{Zn} > CF_{Cu}$.

Pollution Load Index (PLI)

The values of PLI obtained are summarized in Table 5. They ranged from 1.27 to 2.26 indicating that the heavy metal concentration levels in all investigated sites were higher than one (>1), indicative of a heavy pollution, with respect to total of the metals studied. Sekabira et al. (2010) reported that a PLI greater than one (>1) mainly results from anthropogenic inputs. Compared to these values, the Kebir-Rhumel Wadi sediments are having serious anthropogenic pollution (mechanical engineering industries, building material units and others) (Sahli 2011).

Table 5. Geoaccumulation indexes (Igeo), contamination factors (CF), pollution load indices (PLI) and potential ecological risk index (RI) of the studied metals in sediments of the Kebir-Rhumel Wadi.

Sites	I_{geo}				PLI	CF			
	Cd	Pb	Cu	Zn		Cd	Pb	Cu	Zn
S1	0.88	1.51	-0.58	0.13	2.10	2.76	7.26	1.01	1.65
S2	1.42	1.26	-0.83	0.51	2.26	4.03	3.62	0.84	2.04
S3	0.61	1.67	-0.34	0.16	2.16	2.26	4.76	1.20	1.68
S4	0.69	1.75	-0.71	0.15	2.08	2.43	5.06	0.92	1.67
S5	1.96	1.04	-0.39	-0.60	2.11	5.70	3.11	1.13	0.99
S6	0.43	1.21	-1.73	-0.88	1.27	2.03	3.49	0.45	0.82
S7	1.56	1.15	-0.47	-0.20	2.13	4.43	3.34	1.07	1.31
S8	0.20	0.91	-0.38	0.02	1.71	1.73	2.84	1.16	1.52
Mean	**0.96**	**1.31**	**-0.67**	**-0.08**	**1.97**	**2.79**	**4.18**	**0.97**	**1.46**

Table 6. Potential ecological risk index and potential toxicity response index of trace metals

Sites	Potential ecological risk indices for single heavy metal (E_f^i)				Potential toxicity response index for heavy metals (*RI*)
	Cd	Pb	Cu	Zn	
S1	82.8	36.3	5.05	1.65	125.8
S2	120.9	18.1	4.20	2.24	145.2
S3	67.8	23.8	6.0	1.68	99.3
S4	72.9	25.3	4.6	1.67	104.5
S5	171.0	15.60	5.15	0.99	192.7
S6	60.9	17.45	2.25	0.82	81.4
S7	132.9	16.7	5.35	1.31	156.3
S8	50.9	14.2	5.8	1.52	73.4
Average	94.7	20.9	4.8	1.48	122.3

Potential ecological risk index and potential toxicity response index

Potential ecological risk index and potential toxicity response index of heavy metals in the sediments of Kebir-Rhumel Wadi were listed in Table 6. In this Table, the potential ecological risk index of Pb, Cu and Zn in all sites were lower than 40, which indicated slight potential ecological risk of all three metals in all sites. The main element causing ecological hazards was Cd, and its average E_f^i was 94.7. There were 4 sites (S3, S4, S6 and S8) with moderate ecological hazards and 3 sites (S1, S2 and S7) with higher ecological hazards. E_f^i in site S5 was 171, which had high risk. These results reflect a potential ecological risk at sites where most agglomerations, industries and agricultural lands are located.

The maximum *RI* of all sites was 192.7 in site S5, and the minimum *RI* of all sites was 73.4 in site S8. The average *RI* of all sites was 122.3. According to the evaluating standard, sites S5 and S7 have moderate ecological risk level (150 ≤ RI < 300) and the other six stations had low potential ecological risk levels with *RI* < 150 (Table 6).

4. Conclusions

To determine physico-chemical parameters, trace element levels and their spatial variations along the Kebir-Rhumel Wadi (Algeria). 8 sampling sites were collected for Water and surficial sediments. In water, the mean values of the studied parameters are consistently above than the limits, certified by the Algerian standard (except for pH, EC and NO_3). The results of The CPI parameter revealing a polluted and/or seriously polluted class of the studied Wadi water. The (EI) values were above the unity (>1) indicating that the eutrophication is much more serious in all sampling sites, except for sites S1, S7 and S8. Water findings showed undetectable contents in term of metals. However, in sediment samples, metals presents significant spatial variations and they were greatly exceeded background levels. various indices were used to assess the magnitude of the trace metals in sediments namelu: geo-accumulation index (I_{geo}), contamination factor (CF), pollution load index (PLI) and potential ecological risk index (RI). Igeo and CF indices revealed that the pollution followed the sequence: Pb>Cd>Zn>Cu. The PLI, ranging from 1.27 to 2.26, indicated a heavy pollution of river sediments. The RI values confirmed an eventual possibility of an ecological risk, in particular at S1, S2, S4, S7 and S5 sites.

The potential ecological risk index (E_f^i) indicates a slight potential ecological risk in all sites except for Cd.

Studies of the physico-chemical parameters of water and heavy metal concentrations of sediment enables prediction of the pollution level and framing of suitable strategies for restoration and remediation measures. The present study is suggests constant monitoring of water quality along of Kebir-Rhumel Wadi since anthropogenic activities contributing to the current environmental state of this aquatic ecosystem are expected to increase.

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