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*Original Research Article*

# Assessment of heavy metals status in northern Tunisia using contamination indices: Case of the Ichkeul steams system

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**The risk of heavy metals is major environmental problem. The levels of heavy metals enrichments in the sediments sampled from the Ichkeul wetland streams system were determined using contamination indices: the contamination factor (CF), geo-accumulation index (Igeo), and pollution load index (PLI). The obtained data for the geo-accumulation index revealed that sampled sediments are unpolluted for Fe, Zn, Mn, Ni, Cu, and Cr, while the levels of Cd and Pb indicated a moderate to heavy contamination. A similar profile was given by the data of the contamination factor. The pollution load index showed low values in all studied samples, ranging between 0.45 and 1.35. The *non-metric multidimensional scaling* (NMDS) analysis highlighted three main groups suggesting that they derived from same sources.**

**Keywords:** Streams, wetland, heavy metals, contamination indexes.

## INTRODUCTION

In aquatic environments, heavy metals exist in low levels, mainly because of the soils and their associated bedrocks weathering (Sabo et al., 2013). Their levels increase due to natural or anthropogenic processes. In excess, they lead to serious problems for environment and biota, especially persistent, toxic and non biodegradable ones (Dong et al., 2011; Messaoudi et al., 2009). The sedimentary component was considered since the measurement of such pollutants in the water component is not conclusive owing to the water discharge changes as well as the low resident time (Förstner and Wittman 1983). Metallic residues in polluted ecosystems can be accumulated in aquatic organisms; they can reach the human food chain and lead to health effects (Deniseger et al., 1990; Cook et al., 1990; Yang et al., 2013). Sediment component has ecological interest since it is reservoir for various pollutants. It also maintains the trophic status of aquatic habitats (Singh et al., 1997). The geographical distribution pattern of heavy metals results in some adaptive combinations of breeding strategies, nutrition and/or space occupation, likely to be encountered in several habitats, given their environmental variables, where any disturbance of the stream mosaic will lead to alterations in structure and species richness of the biocenosis (Usseglio-Polatera 1997). The aim of the study was to assess the level of heavy metals (iron (Fe), zinc (Zn), cadmium (Cd), nickel (Ni), Manganese (Mn), chromium (Cr), lead (Pb), and copper (Cu)) in sediments from selected streams of the Ichkeul basin (Northern Tunisia), a wetland area of interest for its hydrological value (it is connected with the Mediterranean Sea *via* the Tinja Channel, so it receives salt water during the summer and flows in the sea during the winter due to the fluvial freshwater input; Bejaoui et al. (2008) and its important wildlife (Morgan and Boy 1982; Touaylia et al., 2013). This water body is under preservation (e.g. on the RAMSAR Convention List, Man And Biosphere (MAB) as a Biosphere Reserve, and the United Nations Educational, Scientific and Cultural Organisation (UNESCO) in the World Heritage List). The

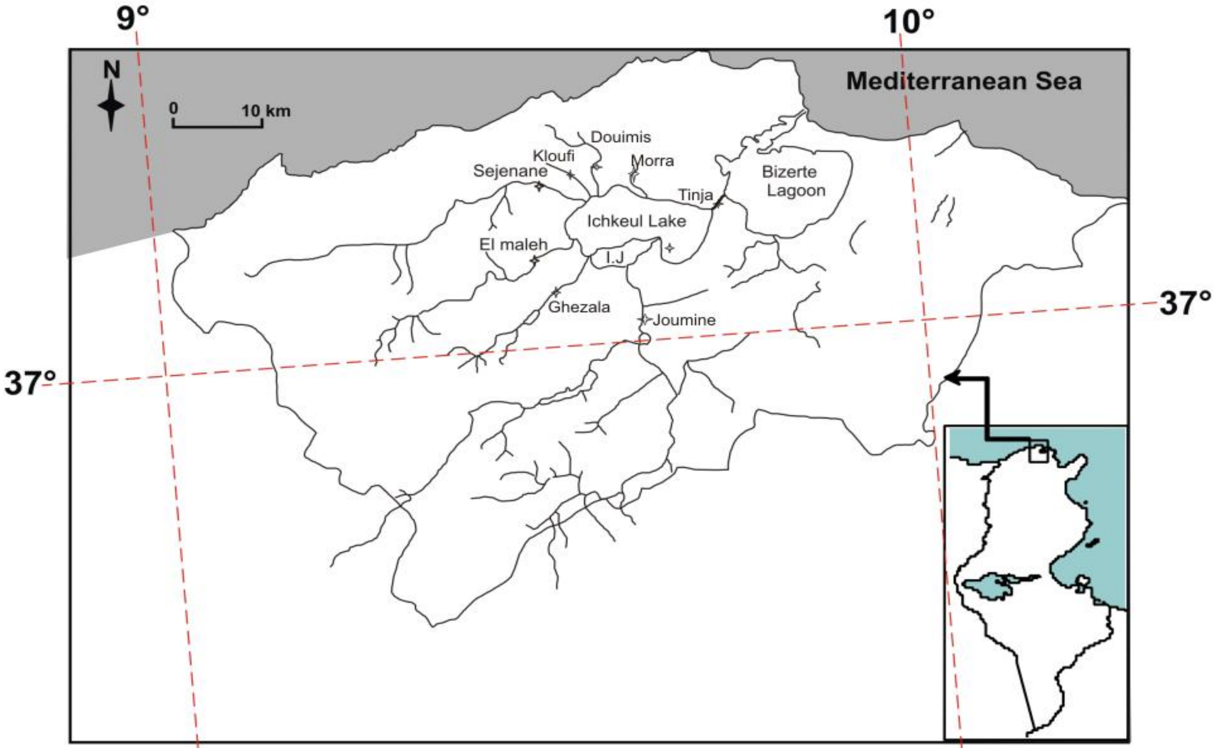

**Figure 1:** Map of the Ichkeul Lake basin showing the sampling sites with their decimal coordinates: Morra (37°14′30.41″N 09°42′42.99″E), Douimis (37°12′3.51″N 09°37′26.59″E), Kloufi (37°11′46.37″N 09°35′7.36″E), Sejenane (37°11′36.83″N 09°34′45.02″E), El maleh (37°6′22.66″N 09°32′24.93″E), Ghezela (37°09′41.98″N 9°42′39.80″E), Joumine (37°1′48.30″N 09°39′47.84″E), Tinja (37°09′37″N 9°45′51″E) and Ichkeul Lake (37°13′94.62″N 9°66′54.18″E)

explored ecosystems are of concern for their ichtyofauna and freshwater resources, part of the human food web. The objectives of the survey were (i) to assess the levels of heavy metals in the sediment component from the Ichkeul basin, (ii) to determine their origins (anthropogenic/natural) using statistical ordination, (iii) to analyse the heavy metal contamination of the streams using pollution descriptors, and (iv) to highlight their potential risk, considering the quality of sediments.

## MATERIALS AND METHODS

### Study sites and samples collection

Sediments were sampled from nine sites belonging to the main tributaries of the Ichkeul Lake basin, located in northern Tunisia (Figure 1). Investigated streams show spatial heterogeneity in their main environmental variables (water depth, water velocity, turbidity, mineralization and substrate type), they are permanent and various in their vegetation cover (Touaylia et al., 2013). The high flows were recorded from February to April, whereas the low flows occurred between August and October. The study area is under sub-humid climate (annual total rainfall about 626 mm, temperature ranging between 6.9 and 31.6°C) (NIM 2015).

Sampling was carried out in triplicates. At each sampling site, three repeated bulk samples were collected. All samples were collected at a depth of 0-20 cm. Sediments were stored in glass jars at 4°C before being air-dried at room temperature (25°C). After drying, stones, plant roots and residues were removed with plastic tweezers. Samples were sieved through a 2 mm mesh, homogenized and stored until pre-treatment. 0.2 g of sediment sample was digested using 4.5 mL 65% (m/m) nitric acid and 0.5 mL 30% (m/m) hydrogen-peroxide in a microwave digestion unit (Mile stone 1200 Mega) for 5 min at 300 W and subsequently 5 min at 600 W. Digested samples were diluted to 25 mL with deionised water (Simon et al., 2013).

### Chemical measurement

The measurement of the metal concentrations in sediments was performed using an inductively coupled plasma optical emission spectroscopy (ICP-OES, type Perkin Elmer Optima 8000, France). Blank reagents were monitored during the analysis and helped in accrediting the analytical data. To ensure quality control and accuracy of analysis, a standard reference material IAEA-SL-1 (lake sediment ) was simultaneously analyzed. The values for the reference sediment go with the certified ones (accuracy <10 %) (Ghannem et al., 2016).

## Heavy metals enrichment and data treatment

Several indexes were considered to assess the metal status for the sampled sediments: the contamination factor, the geo-accumulation index and the pollution load index.

### Contamination Factor (CF)

The sediment contamination can be assessed by the contamination factor, suggested by Hakanson (1980) as following:

$$\mathbf{CF} = \frac{\mathbf{C\ metal}}{\mathbf{C\ background}}$$

Where **C** *metal* is the metal concentration and **C** *background* represents the mean background value of the metal in sediment. The considered geochemical background values of the investigated metals (Zn = 127, Pb = 20, Ni = 50, Cd = 0.2, Mn = 720; Cu = 32, Cr = 71 and Fe = 35900) were earlier reported by Martin and Meybeck (1979). The CF value may indicate low contamination (CF < 1), moderate contamination (1 ≤ CF < 3), mean considerable contamination (3 ≤ CF ≤ 6) or very high contamination (CF > 6) (Nasr et al., 2006).

### Geo-accumulation Index (Igeo)

The Geo-accumulation Index was introduced by Muller (1969) for the assessment of the metal pollution of sediments (Praveena et al., 2007; Addo et al., 2012). It is expressed as follows:

$$\mathbf{Igeo} = \boldsymbol{log_2}\left(\frac{\mathbf{Cn}}{\mathbf{1.5\ Bn}}\right)$$

Where **C**n is the metal (n) concentration, **B**n is its geochemical background concentration (average crust), and 1.5 is the background matrix correction factor, introduced to correct eventual background value changes related to the lithogenic effect.

The Igeo range for metals allows the assessment of the sediment quality (Muller 1969): Igeo≤0 (uncontaminated: class 0); 0<Igeo≤1 (uncontaminated to moderately contaminated: class 1); 1<Igeo≤2 (moderately contaminated: class 2); 2<Igeo≤3 (moderately to heavily contaminated: class 3); 3<Igeo≤4 (heavily contaminated: class 4); 4<Igeo≤5 (heavily to extremely contaminated: class 5); and Igeo≥5 (extremely contaminated: class 6).

### Pollution load index

The pollution load index, proposed by Tomlinson et al. (1980), indicates the contamination detection through the comparison of levels between sites. It is expressed as the concentration factor of each heavy metal, considering its background value:

$$\mathbf{PLI} = \sqrt[n]{\mathbf{CF1\ x\ CF2\ x\ CF3} \ldots}$$

where CF is the contamination factor; n, number of metals. The pollution load index can indicate either no pollution (PLI≤1), moderate pollution (1<PLI≤2), heavy pollution (2<PLI≤3), or extremely heavy pollution (3>PLI) (Zarei et al., 2014).

### Data treatment

The data analysis follows the methods of standard community analysis described by Clarke and Goreley (2005) using "PRIMER 6" *(polysmouth routines in multivariate ecological research)*. The obtained data were transformed (logx+1) and subjected to *non-metric multidimensional scaling* (NMDS) ordination on the basis of Bray Curtis similarity to simplify its interpretation and to define the principal sources. A one-way analysis of variance (ANOVA) followed by Tukey's honest significance test was employed to examine any statistical difference between sampling sites. Correlation between the elements was tested using Pearson's coefficient with statistical significance set at $p < 0.05$, obtained by the software STATISTICA 8 (Zar 1996).

## RESULTS AND DISCUSSION

### Heavy metals levels

The metal levels in sediments are given in Table 1. The obtained metals loads are as following: Fe> Mn> Zn> Pb> Ni> Cr> Cu> Cd. The highest concentrations were recorded in five sites (Sejenane, El maleh, Ghezala, Joumine and Ichkeul Lake), receiving the most important flows and are the less vegetated habitats. This fact makes easy the transportation particles downstream. It is generally agreed that plants are important part of the wastewater treatment system *via* the uptake of considerable amount of nutrients and metals sequestered in the biomass of *Phragmites australis* (abundant species within the investigated streams) and thus, available for harvest and removal (Vymazal and Brezinová 2016). Regardless of primary producers (epiphytes), aquatic benthic and pelagic consumers (mollusks, crustaceans, and fish) accumulate metals (Mendoza-Carranza 2016). Explored habitats are heterogeneous in their biota richness and abundance, and potential actors of such process.

Site-4 (Sejenane) is located downstream of an ancient iron mine plant (actually not active) in a locality named Tamra. Waters contain released heavy metals from plant discharge into this tributary. This explains the relatively high rate of Fe in its bottom sediment. The lowest metal concentrations were observed in the sites Morra, Douimis, Kloufi and Tinja, due to low anthropogenic activities

**Table 1.** Heavy metals concentration (mg/kg dry weight) in sediments of the study sites

| Sites | Metals | Zn | Cd | Pb | Fe | Cr | Mn | Cu | Ni |
|---|---|---|---|---|---|---|---|---|---|
| Morra | Min | 165 | 1.9 | 50.4 | 1383 | 9.4 | 204.1 | 5.5 | 13.1 |
| | Max | 194.3 | 2.4 | 61.5 | 32077 | 16.6 | 252 | 13.3 | 22.5 |
| | Mean | 182.13 | 2.1 | 56.23 | 11618 | 12.33 | 222.47 | 9.67 | 17.27 |
| Douimis | Min | 163.3 | 1.2 | 21.7 | 1378 | 9.3 | 269.3 | 3.9 | 16.4 |
| | Max | 205.2 | 1.5 | 68.6 | 32144 | 22.8 | 390.9 | 16.3 | 35.5 |
| | Mean | 179.1 | 1.33 | 45.93 | 11642.33 | 15.17 | 334.4 | 9.53 | 23.53 |
| Kloufi | Min | 166.8 | 0.8 | 15.9 | 1405 | 10.5 | 213.7 | 9.9 | 12 |
| | Max | 182.5 | 1 | 29.5 | 30520 | 18.7 | 329 | 10.3 | 25.8 |
| | Mean | 168.2 | 0.9 | 24.1 | 11112 | 13.5 | 262.17 | 10.1 | 18.8 |
| Sejenene | Min | 133 | 3.4 | 37.7 | 1410 | 10.6 | 247 | 10.1 | 14.4 |
| | Max | 223.4 | 3.6 | 102.5 | 47866 | 30.3 | 672 | 17.6 | 49.5 |
| | Mean | 176.83 | 3.47 | 79.07 | 16895.67 | 17.37 | 396.43 | 14.53 | 28.5 |
| El maleh | Min | 128.3 | 3.5 | 49.5 | 1419 | 21.3 | 311.8 | 15.7 | 36.7 |
| | Max | 231.2 | 3.7 | 62.4 | 32445 | 28.5 | 469 | 24.7 | 46.1 |
| | Mean | 187.47 | 3.6 | 56.27 | 11764.33 | 24.43 | 379.13 | 19.37 | 42.27 |
| Guezala | Min | 152.9 | 3.4 | 58.1 | 1386 | 17.1 | 306.2 | 13.7 | 15.4 |
| | Max | 257.4 | 3.8 | 79.7 | 30261 | 25.5 | 399 | 22.8 | 42.6 |
| | Mean | 202.4 | 3.57 | 68.03 | 11012 | 20.27 | 338.93 | 17.27 | 29.2 |
| Joumine | Min | 174.3 | 2.1 | 36.1 | 1384 | 17 | 168 | 15.4 | 33.2 |
| | Max | 254.5 | 2.6 | 210.6 | 32109 | 18.3 | 276.8 | 29.5 | 34.9 |
| | Mean | 196.27 | 2.3 | 96.8 | 11631 | 17.53 | 236.33 | 20.73 | 34.27 |
| Tinja | Min | 311.5 | 2.8 | 38.6 | 1366 | 10.7 | 139.7 | 5.6 | 14.9 |
| | Max | 234.1 | 3 | 54.3 | 32135 | 23.2 | 309.2 | 19.9 | 44.8 |
| | Mean | 271.3 | 2.9 | 44.9 | 11628 | 15.5 | 238.3 | 12.2 | 24.93 |
| Ichkeul lake | Min | 195.2 | 1.7 | 45.1 | 1387 | 13 | 279.5 | 11 | 25.2 |
| | Max | 230.2 | 2 | 91 | 32119 | 19.9 | 292.8 | 16.6 | 30.9 |
| | Mean | 218.33 | 1.83 | 73.07 | 11636.33 | 16.5 | 284.1 | 13.4 | 28.53 |
| Crust average [a] | | 127 | 0.2 | 16 | 35900 | 71 | 720 | 32 | 50 |
| Le'an River (China)[b] | | 273.29 | 4.713 | 100.94 | - | 62.8 | - | 391.5 | 31.32 |
| Kantra River (Ras Jbel, Tunisia)[c] | | 168.08–682.31 | 0.9–4.8 | 14.2–79.28 | nd | nd | nd | 42.73–205.15 | 21.4–45.5 |

[a](Martin and Whitfield 1983)
[b](Chen et al. 2016)
[c](Gannem et al. 2016)

since human populations, inhabiting close area, were limited.

## Geo-accumulation index

The data of computed geoaccumulation index ($I_{geo}$) values are indicated in Table 2. This index categorises pollution status in gradual classes of extent. The $I_{geo}$ for Fe, Cr, Cu, Mn and Ni indicated unpolluted sediment quality (class 0) for all study sites. Zinc showed slight spatial variation (class 0 to 1) testifying unpolluted to moderate contamination. Cd revealed moderate to heavy contamination (class 2 to 4) whereas Pb was the most spatial heterogeneous element ranging from unpolluted to heavy contamination (class 0 to 4).

These metals (Cd and Pb) are quickly and efficiently associated with the sediment *via* adsorption onto surface particles, hydrolysis and co-precipitation. The predominant process for metals is usually adsorption since they have high affinities for iron and manganese hydroxides, particulate organic matter, and lesser extent to clay minerals. They tend to be accumulated in sediments (Rezayi et al., 2011). The observed distribution of the considered heavy metals is, in part, due to the lithologic type of neighbouring lands of these waterbodies. Sites Douimis, Morra and Kloufi are surrounded by clay dominant levels. Sites Joumine, El maleh and Sejenane are close to irrigated agricultural fields loaded by organic matter, also under impact of urbanized areas discharging wastewaters. Only the city named Mateur (near Joumine) had wastewater treatment plant, sometimes responsible for discharges not respecting guidelines. Sites Ichkeul Lake and Tinja can be seen as the last receptacle for transported materials and pollutants, as the only outlet towards the sea. A study carried out on Bortala River (China) by Zhang et al. (2016) revealed geo-accumulation index (Igeo) values for Cd, and Pb above 1, suggesting low to partial serious pollution levels Cd exhibited the highest pollution level,

**Table 2.** Geo-accumulation index for heavy metals concentrations in sediments from the Ichkeul streams system and its grading classification. I-Morra, II-Douimis, III-Kloufi, IV-Sejenane, V- El maleh, VI-Ghezela, VII-Joumine, VIII-Tinja and IX-Ichkeul Lake

| Metals | Sites | *Igeo range* | Sediments Quality | Metal | Sites | *Igeo range* | Sediments Quality |
|---|---|---|---|---|---|---|---|
| Pb | I | 1.07-1.36 | Class 2 | Ni | I | (-2.52)-(-1.74) | Class 0 |
| | II | (-0.15)-(1.52) | Class 0 to 2 | | II | (-2.19)-(-1.08) | Class 0 |
| | III | (-0.59)-(0.3) | Class 0 to 1 | | III | (-2.64)-(-1.54) | Class 0 |
| | IV | (0.65)-(2.09) | Class 1 to 3 | | IV | (-2.38)-(-0.6) | Class 0 |
| | V | (1.04)-(1.38) | Class 2 | | V | (-1.03)-(-0.7) | Class 0 |
| | VI | (1.28)-(1.73) | Class 2 | | VI | (-2.28)-(-0.82) | Class 0 |
| | VII | (0.59)-(3.13) | Class 1 to 4 | | VII | (-1.18)-(-1.1) | Class 0 |
| | VIII | (0.69)-(1.18) | Class 1 to 2 | | VIII | (-2.33)-(-0.74) | Class 0 |
| | IX | (0.91)-(1.92) | Class 1 to 2 | | IX | (-1.57)-(-1.28) | Class 0 |
| Cr | I | (-3.5)-(-2.68) | Class 0 | Zn | I | (-0.21)-(0.03) | Class 0 to 1 |
| | II | (-3.52)-(-2.22) | Class 0 | | II | (-0.22)-(0.11) | Class 0 to 1 |
| | III | (-3.34)-(-2.51) | Class 0 | | III | (-0.29)-(-0.06) | Class 0 |
| | IV | (-3.33)-(-1.81) | Class 0 | | IV | (-0.52)-(0.23) | Class 0 to 1 |
| | V | (-2.32)-(-1.9) | Class 0 | | V | (-0.57)-(0.28) | Class 0 to 1 |
| | VI | (-2.64)-(-2.06) | Class 0 | | VI | (-0.32)-(0.43) | Class 0 to 1 |
| | VII | (-2.65)-(-2.54) | Class 0 | | VII | (-0.25)-(0.42) | Class 1 |
| | VIII | (-3.32)-(-2.2) | Class 0 | | VIII | (0.3)-(0.71) | Class 1 |
| | IX | (-3.03)-(-2.42) | Class 0 | | IX | (0.04)-(0.27) | Class 1 |
| Cd | I | 2.66-3 | Class 3 | Mn | I | (-2.4)-(-2.1) | Class 0 |
| | II | (2)-(2.32) | Class 3 | | II | (-2)-(-1.47) | Class 0 |
| | III | (1.42)-(1.74) | Class 2 | | III | (-2.34)-(-1.71) | Class 0 |
| | IV | (3.5)-(3.58) | Class 4 | | IV | (-2.13)-(-0.68) | Class 0 |
| | V | (3.54)-(3.62) | Class 4 | | V | (-1.79)-(-1.2) | Class 0 |
| | VI | (3.5)-(3.66) | Class 4 | | VI | (-1.82)-(-1.44) | Class 0 |
| | VII | (2.81)-(3.12) | Class 3 to 4 | | VII | (-2.68)-(-1.96) | Class 0 |
| | VIII | (3.22)-(3.32) | Class 4 | | VIII | (-2.95)-(-1.8) | Class 0 |
| | IX | (2.5)-(2.74) | Class 3 | | IX | (-1.95)-(-1.88) | Class 0 |
| Cu | I | (-3.13)-(-1.85) | Class 0 | Fe | I | (-5.28)-(-0.75) | Class 0 |
| | II | (-3.62)-(-1.56) | Class 0 | | II | (-5.29)-(-0.74) | Class 0 |
| | III | (-2.28)-(-2.22) | Class 0 | | III | (-5.26)-(-0.82) | Class 0 |
| | IV | (-2.25)-(-1.45) | Class 0 | | IV | (-5.26)-(-0.17) | Class 0 |
| | V | (-1.61)-(-0.96) | Class 0 | | V | (-5.25)-(-0.73) | Class 0 |
| | VI | (-1.81)-(-1.07) | Class 0 | | VI | (-5.28)-(-0.83) | Class 0 |
| | VII | (-1.64)-(-0.7) | Class 0 | | VII | (-5.28)-(0.75) | Class 0 |
| | VIII | (-3.1)-(-1.27) | Class 0 | | VIII | (-5.3)-(-0.74) | Class 0 |
| | IX | (-2.13)-(-1.53) | Class 0 | | IX | (-5.28)-(-0.75) | Class 0 |

while Pb displayed low to moderate pollution. Igeo values for Ni, Zn, Cr, and Cu were less than 1, indicating no pollution status.

## The contamination factor (CF) and the pollution load index (PLI)

The CF and PLI were used to assess the status of the heavy metals in sediments (Bhuiyan et al., 2010). Similar profile of sediment quality obtained by Igeo was recorded by the determination of CF and PLI. The Fe, Cu, Cr, Ni and Mn showed low contamination (respectively 0.04-1.33, 0.01-0.71, 0.13-0.43, 0.26-0.99 and 0.19-0.93) for all studied streams (Table 3). The Zn reaches moderate contamination for the whole samples. The Cd had CF values (4-19) ranging from considerable (Kloufi) to very high contamination (the other sites). The Pb is represented by CF value varying from low to very high contamination for elementary samples (0.99-13.16). The computed mean value of PLI didn't exceed the unit (PLI ≤ 1) for all sampled sites (Table 3). However, several elementary samples had PLI value indicating moderate pollution (1 < PLI ≤ 2). Aydi (2015) reported that the CF values for Cd were relatively high (3.81) in the samples from Bizerte landfill soils whereas the values of PLI were found to be low in all the studied samples and varied between 0.16 and 0.7, indicating low pollution status. Such finding can explain eventual close contamination sources. Similarly, Sabo et al. (2013) found considerable (3 ≤ CF ≤ 6) contamination for Cd in sediment of the River Delimi (Nigeria) while the other metals (Cu, Pb and Zn) showed low (CF < 1) contamination due to dumping of domestic and industrial wastes into the river.

**Table 3.** Contamination factors (CF) and pollution load index (PLI) of heavy metals in sediments from the Ichkeul streams system. I, II and III are considered replicates

| sites | Samples | Contamination factors (CF) | | | | | | | | PLI |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Pb | Cu | Cr | Zn | Ni | Cd | Fe | Mn | |
| Morra | I | 3.15 | 0.17 | 0.23 | 1.30 | 0.45 | 9.5 | 0.89 | 0.35 | 0.83 |
| | II | 3.84 | 0.42 | 0.15 | 1.53 | 0.32 | 12 | 0.04 | 0.29 | 0.60 |
| | III | 3.55 | 0.32 | 0.13 | 1.47 | 0.26 | 10 | 0.04 | 0.28 | 0.53 |
| Douimis | I | 1.36 | 0.51 | 0.32 | 1.33 | 0.71 | 6 | 0.90 | 0.48 | 0.92 |
| | II | 4.29 | 0.26 | 0.19 | 1.62 | 0.37 | 7.5 | 0.04 | 0.54 | 0.61 |
| | III | 2.97 | 0.12 | 0.13 | 1.29 | 0.33 | 6.5 | 0.04 | 0.37 | 0.46 |
| Kloufi | I | 0.99 | 0.31 | 0.26 | 1.31 | 0.52 | 4 | 0.85 | 0.46 | 0.74 |
| | II | 1.84 | 0.32 | 0.16 | 1.22 | 0.37 | 5 | 0.04 | 0.30 | 0.47 |
| | III | 1.68 | 0.32 | 0.15 | 1.44 | 0.24 | 4.5 | 0.04 | 0.34 | 0.45 |
| Sejnnene | I | 2.36 | 0.50 | 0.43 | 1.05 | 0.99 | 17 | 1.33 | 0.93 | 1.35 |
| | II | 6.41 | 0.55 | 0.16 | 1.76 | 0.43 | 18 | 0.04 | 0.38 | 0.76 |
| | III | 6.06 | 0.32 | 0.15 | 1.37 | 0.29 | 17 | 0.04 | 0.34 | 0.63 |
| El maleh | I | 3.56 | 0.49 | 0.40 | 1.01 | 0.92 | 17.5 | 0.90 | 0.65 | 1.27 |
| | II | 3.90 | 0.77 | 0.33 | 1.82 | 0.88 | 18.5 | 0.04 | 0.50 | 0.93 |
| | III | 3.09 | 0.55 | 0.30 | 1.60 | 0.73 | 18 | 0.04 | 0.43 | 0.81 |
| Guezala | I | 4.14 | 0.71 | 0.36 | 1.20 | 0.85 | 17 | 0.84 | 0.55 | 1.31 |
| | II | 3.63 | 0.43 | 0.26 | 2.03 | 0.31 | 19 | 0.04 | 0.43 | 0.73 |
| | III | 4.98 | 0.48 | 0.24 | 1.55 | 0.59 | 17.5 | 0.04 | 0.43 | 0.79 |
| Joumine | I | 2.26 | 0.48 | 0.26 | 1.37 | 0.66 | 10.5 | 0.89 | 0.23 | 0.93 |
| | II | 13.16 | 0.01 | 0.24 | 2.00 | 0.70 | 13 | 0.04 | 0.38 | 0.55 |
| | III | 2.73 | 0.54 | 0.24 | 1.26 | 0.69 | 11 | 0.04 | 0.37 | 0.69 |
| Tinja | I | 2.41 | 0.62 | 0.33 | 2.11 | 0.90 | 14 | 0.90 | 0.37 | 1.20 |
| | II | 2.61 | 0.35 | 0.15 | 2.45 | 0.30 | 15 | 0.04 | 0.19 | 0.57 |
| | III | 3.39 | 0.18 | 0.18 | 1.84 | 0.30 | 14.5 | 0.04 | 0.43 | 0.59 |
| Ichkeul lake | I | 2.82 | 0.34 | 0.28 | 1.54 | 0.50 | 8.5 | 0.89 | 0.39 | 0.94 |
| | II | 5.69 | 0.52 | 0.23 | 1.81 | 0.59 | 10 | 0.04 | 0.41 | 0.76 |
| | III | 5.19 | 0.39 | 0.18 | 1.81 | 0.62 | 9 | 0.04 | 0.39 | 0.70 |
| Mean | | 3.78 | 0.41 | 0.24 | 1.56 | 0.55 | 12.22 | 0.34 | 0.42 | 0.78 |

**Table 4.** Pearson's coefficient correlations for all analyzed heavy metals

| Metals | Zn | Cd | Pb | Fe | Cr | Mn | Cu |
|---|---|---|---|---|---|---|---|
| Cd | 0.2552 | | | | | | |
| Pb | 0.3379 | 0.3202 | | | | | |
| Fe | -0.4454* | -0.0519 | -0.3744 | | | | |
| Cr | -0.2787 | 0.374 | -0.1375 | 0.7277** | | | |
| Mn | -0.416* | 0.2964 | -0.0441 | 0.4925** | 0.7336** | | |
| Cu | 0.2033 | 0.4676* | 0.5006** | 0.0802 | 0.5357* | 0.2158 | |
| Ni | -0.2053 | 0.3515 | 0.0424 | 0.5747** | 0.8965** | 0.6106** | 0.6981** |

**Correlation is significant at the 0.01 level
*Correlation significant at the 0.05 level

## Correlation matrix for analyzed heavy metals

A correlation matrix was performed to highlight relationships between study metals and to define their origins. According to the obtained data for Pearson correlation (Table 4), a significant positive correlation exists between the considered elements. Fe, a natural lithogenic component, didn't show significant correlation with Cu (r= 0.0802, p>0.05), Cd (r=-0.0519, p>0.05) and Pb (r= -0.3744, p>0.05), but was significantly correlated with Zn (r=-0.4454, p<0.05), Cr (r=0.7277, p<0.01), Mn (r=0.4925, p<0.01), Ni (r=0.5747, p<0.01), indicating that they have a geogenic source. The observed significantly correlation between Cr (r=0.5357, p<0.05), Cd (r=0.4676, p<0.05), Ni (r=0.6981, p<0.01), Pb (r=0.5006, p<0.01) and Cu testified that these metals derived from domestic wastewater discharges.

The *non-metric multidimensional scaling* (NMDS) ordination, established on the basis of Bray-Curtis similarity, highlighted three main groups at 80% of

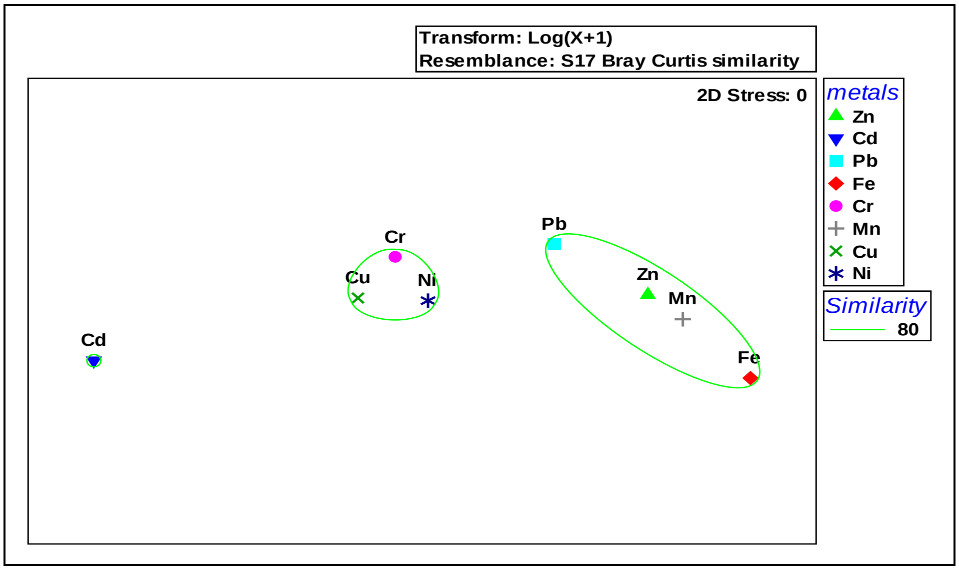

**Figure 2:** *Non-metric multidimensional scaling* NMDS showing affinity between heavy metals

similarity (Figure 2). The first group articulates around Cd illustrating to have anthropogenic source, the second group includes three elements (Cr, Cu, and Ni) demonstrated a geogenic source with no evidence of anthropogenic impacts, while the third group gathers the other investigated heavy metals (Fe, Zn, Pb, and Mn). The presence of Zn and Pb in this group would suggest possible sources of industrial contamination (Ennouri et al., 2010). This finding could mean that these metals have a common anthropogenic source and have similar properties (Calace et al., 2005). The elevated values identified for Pb and Cd might be related to human activities (wastewater discharges) (Zarei et al., 2014). A similar profile of heavy metals contamination was reported by Ghannem et al. (2016) for Kantra River (Ras Jbel, Tunisia) under three jeans fading industries: Lee Cooper, Denim authority and CRJ.

## CONCLUSION

The rate at which natural and anthropogenic (domestic) wastes are released into streams of the Ichkeul wetland has been of great concern. The study attempted to assess the status of several heavy metals (Fe, Ni, Zn, Pb, Cu, Cd, Cr and Mn) in the bottom sediments of the streams. High levels were found due to wastewater discharged from an iron mine plant located upstream (Sejenane) or domestic wastewaters (Joumine, Kloufi, Ghezala and Ichkeul Lake). The study showed that the total heavy metals concentrations in the sediment samples in the streams followed the order: Fe > Mn > Zn > Pb > Ni > Cr > Cu > Cd. Useful indexes (I*geo*, CF and PLI) were used to assess the sediment quality in the Ichkeul stream system. These descriptors highlighted similar profile about heavy metals status (unpolluted sediment for Zn, Fe, Cu, Cr, and Mn whereas Pb and Cd exceeded standard levels). Multivariate analysis was performed and classified heavy metals in the streams into three main groups of similarity. The first group had a single element (Cd), a second group (Cr, Cu, and Ni) and a third group (Fe, Zn, Pb, and Mn) including metals probably derived from similar sources. The recorded values for Pb, Zn and Cd are likely to be harmful to organisms that live in the sediments (Varol 2011), thus, it is strongly recommended in depth study should be performed on the impact of heavy metals on the biota of the streams and their distribution within such vulnerable freshwater ecosystems. Sustainable development of the Ichkeul Park requires monitoring (physico-chemical and biological) and preservation of their components (forest, tributaries and lake, subject of our survey) in order to save its biodiversity and resources for human communities.

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### Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of the paper

## REFERENCES

Addo MA, Affum HA, Botwe BO, Gbadago JK, Acquah SA, Senu JK, Adom T, Coleman A, Adu PS, Mumuni II (2012). Assessment of water quality and heavy metal levels in water and bottom sediment samples from Mokwe Lagoon, Accra, Ghana. Res. J. Environ. Earth Sci. 4(2):119-130.

Aydi A (2015). Assessment of heavy metal contamination risk in soils of landfill of Bizerte (Tunisia) with a focus on application of pollution indicators. Environ. Earth Sci. 74:3019-3027.Crossref

Bejaoui B, Harzallah A, Moussa M, Chapelle A, Solidoro C (2008). Analysis of hydrobiological pattern in the Bizerte lagoon (Tunisia). Est. Coast. Shelf Sci. 80:121-129.Crossref

Bhuiyan MAH, Parvez L, Islam MA, Dampare SB, Suzuki S (2010). Heavy metal pollution of coal mine-affected agricultural soils in the northern part of Bangladesh. J. Hazard. Mat. 173:384-392.Crossref

Calace N, Ciardullo S, Petronio BM, Pietrantonio M, Abbondanzi F, Campisi T, Cardellicchio N (2005). Influence of chemical parameters (heavy metals, organic matter, sulphur and nitrogen) on toxicity of sediments from the Mar Piccolo (Taranto, Ionian Sea, Italy). Microchem. J. 79(1-2):243-248.Crossref

Chen H, Teng Y, Li J, Wu J, Wang J (2016). Source apportionment of trace metals in river sediments: A comparison of three methods. Environ. Pollut. 211:28-37.Crossref

Clarke KR, Goreley RN (2005). Change in Marine Communities: an approach to statistical analysis and interpretation. Plymouth Routines *In* Multivariate Ecological Research: PRIMER-E.

Cook JA, Andrew SM, Johnson MS, (1990). Lead, zinc, cadmium and fluoride in small mammals from contaminated grass-land established on fluorspar tailings, Water Air Soil Pollut. 51:43-54.Croosref

Deniseger J, Erickson J, Austin A, Roch M, Clark MJR (1990). The effects of decreasing heavy metal concentrations on the biota of Buttle Lake. Water Res. 24:403-416.Crossref

Dong JH, Yu M, Bian ZF, Wang Y, Di CL (2011). Geostatistical analyses of heavy metal distribution in reclaimed mine land in Xuzhou. China. Environ. Earth Sci. 62(1):127-137.Crossref

Ennouri R, Chouba L, Magni P, Kraiem MM (2010). Spatial distribution of trace metals (Cd, Pb, Hg, Cu, Zn, Fe and Mn) and oligo-elements (Mg, Ca, Na and K) in surface sediments of the Gulf of Tunis (Northern Tunisia). Environ. Monit. Assess. 163:229-239.Crossref

Förstner U, Wittman GTW (1983). Metal Pollution in Aquatic Environment, Springer-Verlag, New York.

Ghannem S, Khazri A, Sellami B, Boumaiza M (2016). Assessment of heavy metal contamination in soil and *Chlaenius (Chlaeniellus) olivieri* (Coleoptera, Carabidae) in the vicinity of a textile factory near Ras Jbel (Bizerte, Tunisia). Environ. Earth Sci. 75:442. Crossref

Hakanson L (1980). An ecological risk index for aquatic pollution control. A sedimentological approach. Water Res. 14(8):975–1001.Crossref

Martin JM, Meybeck M (1979). Elemental mass balance of materials carried by major world rivers. Mar. Chem. 7:173-206.Crossref

Martin JM, Whitfield M (1983). The significance of the river input of chemical elements to the ocean. In: Wong CS, Boyle E, Brul KW, Burton JD, Goldberg ED (eds). Trace metals in sea water. Plenum Press, New York, pp 265-296.Crossref

Mendoza-Carranza M, Sepúlveda-Lozada A, Dias-Ferreira C, Geissen V (2016). Distribution and bioconcentration of heavy metals in a tropical aquatic food web: A case study of a tropical estuarine lagoon in SE Mexico. Environ. Pollut. 210:155-165.Crossref

Messaoudi I, Deli T, Kessabi K, Barhoumi S, Kerkeni A, Saïd K (2009). Association of spinal deformities with heavy metal bioaccumulation in natural populations of grass goby, *Zosterisessor ophiocephalus* Pallas, 1811 from the Gulf of Gabès (Tunisia). Environ. Monit. Assess. 156:551-560. Crossref

Morgan NC, Boy V (1982). An ecological survey of standing waters in North West Africa: I. Rapid survey and classification. Biolog. Conserv. 24:5-44.Crossref

Muller G (1969). Index of geoaccumulation in sediments of the Rhine River. Geo. J. 2:108-118.

Nasr SM, Okbah, MA, Kasem SM (2006). Environmental assessment of heavy metal pollution in bottom sediment of Aden port, Yemen. Int. J. oceanogr. 1(1):99-109.

NIM (2015). Mean monthly values of temperature and rainfall in Bizerte, in 2015, National Institute of Meteorology.

Praveena SM, Ahmed A, Radojevic AM, Abdullah MH, Aris AZ (2007). Factor cluster analysis and enrichment study of mangrove sediments-an example from Mengkabong, Sabah. Malays. J. Anal. Sci. 11(2):421-430.

Rezayi M, Ahmadzadeh S, Kassim A, Heng LY (2011). Thermodynamic studies of complex formation between Co (SALEN) ionophore with chromate (II) ions in AN-$H_2O$ binary solutions by the conductometric method. Int. J. Electrochem. Sci. 6:6350-6359.

Sabo A, Gani AM, Ibrahim AQ (2013). Pollution status of heavy metals in water and bottom sediment of river Delimi in Jos, Nigeria. Amer. J. Environ. Protect. 1(3):47-53.Crossref

Simon E, Vidic A, Braun M, Fábián I, Tóthmérész B (2013). Trace element concentrations in soils along urbanization gradients in the city of Wien, Austria. Environ. Sci. Pollut. Res. 20:917-924.Crossref

Singh M, Ansari AA, Muller G, Singh IB (1997). Heavy metals in freshly deposited sediments of Gomti river (a tributary of the Ganga river): effects of human activities. Environ. Geol. 29:246-252.Crossref

Tomlinson DL, Wilson JG, Harris CR, Jeffrey DW (1980). Problems in the assessment of heavy metal levels in estuaries and the formation of a pollution index. Helgol. Meeresunter. 33(1-4):566-575.Crossref

Touaylia S, Garrido J, Boumaiza M (2013). Abundance and diversity of the aquatic beetles in a Mediterranean stream system (Northern Tunisia). Annal. Soc. Entomol. Fr. (N.S.): Internat. J. Entomol. 49(2):172-180.

Usseglio-Polatera Ph (1997). Caractéristiques biologiques, stratégies géologiques et évolution environnementale d'un hydrosystème : l'exemple des Trichoptères du Rhône à Lyon (France). Geobios. 21:151-158.Crossref

Varol M (2011). Assessment of heavy metal contamination in sediments of the Tigris River (Turkey) using pollution indices and multivariate statistical techniques. J. Hazard. Mat. 195:355-364.Crossref

Vymazal J, Brezinová T (2016). Accumulation of heavy metals in aboveground biomass of Phragmites australis in horizontal flow constructed wetlands for wastewater treatment: A review. Chem. Engin. J. 290:232-242. Crossref

Yang H, Huo X, Yekeen TA., Zheng Q, Zheng M, Xu X (2013). Effects of lead and cadmium exposure from electronic waste on child physical growth. Environ. Sci. Pollut. Res. Int. 20:4441-4447.Crossref

Zar IH (1996). Biostatistical analysis. Prentice Hall, NJ.

Zarei I, Pourkhabbaz A, Khuzestani RB (2014). An assessment of metal contamination risk in sediments of Hara Biosphere Reserve, southern Iran with a focus on application of pollution indicators. Environ. Monit. Assess. 186(10):6047-6060 Crossref

Zhang Z, Juying L, Mamat Z, QingFu Y (2016). Sources identification and pollution evaluation of heavy metals in the surface sediments of Bortala River, Northwest China. Ecotox. Environ. Saf. 126:94-101.Crossref