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RESEARCH PAPER

# The state of Metallic Contamination of Saf-Saf River Sediments (Skikda – Algeria)

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**Abstract**

The sediments of Saf-Saf river (North eastern of Algeria), were studied in order to evaluate their degree of contamination by trace metal elements. Six heavy trace metals (Cd, Cr, Cu, Fe, Mn and Ni) were researched at the surface sediments of nine study stations. Since these different metallic elements appear as tracers of anthropogenic pollution; various evaluation indices of metallic contamination were studied (Igeo, FC, DC, IPS and PEC). The results of these indices are consistent and reveal a polymetallic sediment contamination by several heavy metals essentially by Fe, Mn and Cd, with an abundance of Fe and Mn. Sediment pollution index, indicates that sediments at all stations are hazardous (IPS > 20). The environmental quality of Saf-Saf river sediments, were realized by comparing the metal contents with the values of the TEC and the PEC has showed that the metals Cd, Cu and Mn present a great danger of toxicity.

**Keywords:** Indices; Trace Metal Elements; sediments; Saf-Saf River; Algeria

## INTRODUCTION

In the hydrological cycle governing the evaluation of trace metals, sediments play an important role in the measure of wich consist vectors and reservoirs of a large number of toxic metals (Jouanneau et al., 1990). According to Förstner and Wittman (1981), a significant fraction of heavy metals in aquatic environments, is reversibly associated with surface sediments. Indeed the accumulation of heavy metals at sediments is not ultimate, under the influence of variations of the physic-chemicals properties of the place, these metals can return once more to the aqueous phase by discharge. These trace metal elements can be arisen from two sources: natural which is linked to the geological nature of the terrains in the water flow area, or anthropogenic as a result of sewage spill from neighboring human activities and more particularly industrial activity (Ramade, 2002). Also, they can be arisen from indirect flow as in the case of dry and humid discharges and agricultural runoff (Benjama et al., 2011).

Some trace metal elements are essential to life, such as copper and zinc; while others are toxic such as lead, cadmium and mercury. These elements are products of domestic, urban, industrial and agricultural usage. These metals are found in water, sediment and living organisms, drained by water or air (Belabed et al., 2013). The latter are bioaccumulated and biomagnified, in the food chain and consequently to certain levels they become dangerous. For most heavy metals, anthropogenic emissions are equal to or superior than natural emissions. On one hand, the burning of leaded petrol in cars, for example, is responsible for the widespread diffusion of lead in the world. On the other hand; for mercury, though, several reports suggest that natural

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emissions are quantitatively more important than anthropogenic inputs (Biney et al., 1991).

The elements inscribed in the list of priority substances in Europe are: cadmium, lead, mercury and nickel. Cadmium and mercury are besides classified as dangerous substances having priority. For those, the actions are put in place are aimed at stopping or removing releases, emissions and losses. The objective of the actions, being to find a representative level of the natural geochemical background.

There had not been any scientific research on heavy metals in sediments at the study area level yet. This study proposes to determine the degree of contamination by six studied heavy metal (Cd, Cr, Cu, Fe, Mn, Ni), at the surface sediments of a big part of Saf-Saf river, away from principal industrial sources. This same work is a part of a multi-disciplinary study, based on the assessment of the ecotoxicological status of Saf-Saf river, which is also carried out by the monitoring of hydrocarbon contamination and its identification in the sedimentary compartment and in the water, as well as the impacts of such pollution on the fauna and flora of this ecosystem.

## MATERIALS AND METHODS

The Saf-Saf river, is the principal tributary of Skikda Bay presented in figure 1. It is fed exclusively upstream by water supplies from the Zerdaza dam, it narrows downstream before throwing into the Mediterranean Sea. The Saf-Saf basin covers an area of 1158 $Km^2$, with an adjoining population of 460,000 inhabitants. However, this periurban stream is subject to many permanent discharges of urban and industrial origin (Hadjem, 2010).

Its northeastern banks, shelter the largest petrochemical platform of North Africa, with 1,200 ha of numerous oil complexes, the majority of which discharge directly their effluent into the river, especially in its part swallows (Rouidi, 2014). On its northwestern banks, it is bordered by a highway, as well as marble transformation workshops are located there. Its average width is about twenty meters with an average flow of 69 $m^3.s^{-1}$ (S.C.I., 1989). Currently the entire ecosystem is affected, hydrocarbon and trace metal contamination has been detected, both in the waters and in the sediments of its part swallows (Benyoucef and Traifi, 2009; Hadjem, 2010; Bouchalit et al., 2012; Rouidi, 2014; Boudioua and Slimani, 2016).

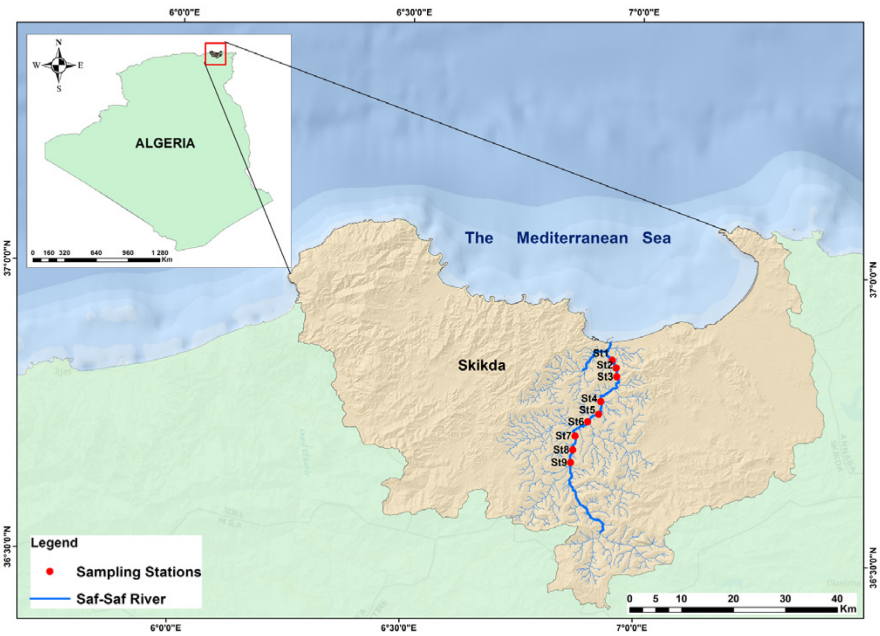


**Fig 1.** Location of sampling stations

**Table 1.** Detailed location and physicochemical properties of sampling stations

| Sites | Stations | Latitude | Longitude | Substrate | pH | $CaCO_3$ (%) | EC (µS/cm) | OM (%) |
|---|---|---|---|---|---|---|---|---|
| **Site 1** | St1 | 36°50'70''N | 6°56'13''E | Predominately Silty | 7.58 | 25.4 | 450 | 1.9 |
| | St2 | 36°50'69''N | 6°56'14''E | | 7.48 | 25.2 | 510 | 1.5 |
| | St3 | 36°50'75''N | 6°56'15''E | | 7.64 | 25.6 | 500 | 1.1 |
| **Site 2** | St4 | 36°45'33''N | 6°54'50''E | Predominately Silty-clay with coarse sand | 8.00 | 25 | 309 | 2.5 |
| | St5 | 36°45'34''N | 6°54'51''E | | 7.90 | 24.7 | 485 | 2.1 |
| | St6 | 36°45'35''N | 6°54'52''E | | 7.61 | 25.3 | 437 | 2.9 |
| **Site 3** | St7 | 36°41'93''N | 6°51'92''E | Predominately Silty-clay | 8.00 | 26.1 | 480 | 2.4 |
| | St8 | 36°41'94''N | 6°51'94''E | | 7.90 | 25.3 | 543 | 2.42 |
| | St9 | 36°42'03''N | 6°51'88''E | | 7.68 | 25.7 | 495 | 2.38 |

The coordinates of the nine (09) stations that served the sampling points which are located at the level of three (3) different sites, situated at the middle and downstream of our study area, are shown in Figure (1) and Table (1).

The surface sediments, are the first ten centimetres of depth, were taken at all stations, all located at the main bed of the Saf-Saf river. This type of sampling appears as the most appropriate whether one seeks to assess the history of contamination or to isolate the most recent sediments during monitoring actions (Charriau, 2009).

This work done in 2016, consisting of taking samples using a shovel , three sediment samples at the most likely areas to contain permanent sediment (on the banks and where the current is weak). This type of sample permits to collect by continuous scraping, the first five centimetres of the sediment on a surface of approximately one square metre. Stored at 4°C at plastic bags while sampling campaign, the samples are conditioned as soon as they arrive at the laboratory. Then, they are oven-dried at 80°C during 48 hours, next, crushed and sifted at 63 µm, according to the method quoted by Péna and Pico (1991).

In fact, monitoring the metallic pollutants is conducted out at sediments whose fraction is less than 63 millimicron (Cosson, 1987), as in sedimentology, the metals are preferentially fixed on this fine fraction and the first centimeters of the surface layer can give us an idea, over several years of contamination (Claisse, 1995).

For heavy metals analysis, we followed the protocol described by UNEP (1995), which consists of transferring 500 mg of sample at teflon buckets of 35 mL and hot decomposed in the presence of an mixture of hydrofluoric acid (HF 48%) and aqua regia ($HNO_3$/HCl concentrated, 1:3 v/v) at a Teflon "bomb" under pressure for six hours in order to complete sediment decomposition. Once digested, the samples at the buckets have been transferred at vials of 100 mL containing 5.6 g of boric acid ($H_3BO_3$) and at least 20 mL of distilled water.

After adjusting the gauge line with distilled water, the resulting solutions were left to rest for one night before proceeding with the analysis. The solutions were analysed in triplicata with air-acetylene flame and at the required wavelengths for each metal element, by means of spectrophotometer of atomic absorption of the ICE 3000 series.

A Certified Reference Material (CRM), was treated in the same manner as the samples to assess the accuracy of the results.

This stage of the work, was performed at the laboratory of the Natural Gas Liquefaction Complex of Skikda (GL1/K).

In order to have a good idea about the physico-chemical quality of our sediments, we have determined additional parameters which are pH, electrical conductivity (EC), total limestone (CT), organic matter (MO) and particle size and which were studied at the soil physics laboratory

**Table 2.** Müller's classification (Müller, 1981)

| Class | Value | Pollution intensity |
|---|---|---|
| **0** | Igeo ≤ 0 | Unpolluted |
| **1** | 0 < Igeo < 1 | Unpolluted to moderately polluted |
| **2** | 1 < Igeo < 2 | Moderately polluted |
| **3** | 2 < Igeo < 3 | Moderately polluted to severely polluted |
| **4** | 3 < Igeo < 4 | Severely polluted |
| **5** | 4 < Igeo < 5 | Severely polluted to very severely polluted |
| **6** | 5 < Igeo | Very severely polluted |

of the University of August $20^{th}$, 1955-Skikda.

For the quantitative determination of pollution or the degree of pollution, the geoaccumulation index (Igeo), established by Müller (1981), was utilized (Table 2). This index is determined from the base level of the metal content in the sediments according to the following formula:

$$Igeo = \log2\ (Cn/1.5Bn^*) \quad (1)$$

with: Cn (Sediment concentration for element n), Bn (background or geochemical background for element n) and 1.5 (Constant taking into account natural fluctuations in the content of a given substance in an environment and low anthropogenic influences).

The background of the metal, indicates the concentration of the metal (of interest) in sediments where there was no anthropogenic input.

The contamination factor (CF) was utilized to express the level of contamination by each metal in the sediments. It is expressed as:

$$CF = \text{Metal content in the sediment/ Metal Background} \quad (2)$$

According to Hakanson (1980), the values of contamination factors were interpreted as the following:

CF< 1 indicates low contamination; 1<CF<3 indicates moderate contamination; 2<CF<6 indicates considerable contamination; CF>6 expresses very high contamination.

For the calculation of the two preceding indices, we used as geochemical background, the specific concentrations of carbonate substrates as defined by Thomas and Meybeck (1992).

According to Hakanson (1980), the degree of contamination (CD) is the sum of the CF. It allows estimating of polymetallic contamination for each sample point. It is calculated according to the following formula:

$$CD_i = \Sigma\ CF_i \quad (3)$$

This index is associated with 4 quality classes:

CD < 6 (low contamination); 6 ≤ CD < 12 (moderate contamination); 12≤ CD < 24 (considerable contamination); 24 ≤ CD (very high contamination).

Introduced by Rubio et al. (2000), the Sedimentary Pollution Index (SPI) comprises several metals: Cr, Zn, Ni, Cu, Pb and Cd. This index is defined as a linear sum of CF and takes into consideration the relative toxicity of ETMs by a weighting factor (W).

It is the weight of each metal which is a function of its relative toxicity. Its formula is as the following:

$$SPI = \Sigma(CF_x * W_x) / \Sigma W_t \quad (4)$$

where:
Wx: weight affected in the considered metal,
Wt: ΣWx

According to Singh et al. (2002), the SPI is associated with five quality classes:

0 ≤ SPI < 2 (healthy sediment); 2 ≤ SPI < 5 (weakly polluted sediment); 5 ≤ SPI < 10 (moderately polluted sediment); 10 ≤ SPI < 20 (highly polluted sediment); SPI ≤ 20 (hazardous sediment).

Sediment Environmental Quality Assessment, was done by comparing the TME concentrations in the study area to the US guide values SQGs (Sediment Quality Guidelines), developed from a database of biological and ecological effects which could produce certain concentrations of pollutants in sediments. The TEC (Threshold Effect Concentration) and the PEC (Probable Effect Concentration) established by Macdonald et al. (2000), permit to evaluate the quality of marine and fresh water sediments. The TEC identifies contaminant concentrations below where living organisms in sediments are not affected; whereas the PEC identifies contaminant concentrations above in which we observe harmful effects on living organisms in sediments (Long et al., 1995; Ingersoll et al., 1996; MacDonald, 1997; Coulibaly et al., 2014).

According to Billon et al. (2010), admitting that the effects are simply cumulative, it is thus possible to calculate a global index:

$$\Sigma\, PEC = \Sigma\, [[ME] / [Consensus - PEC]] \quad (5)$$

## RESULTS AND DISCUSSION

The entire physico-chemical results are presented by 3 different sites, each of which comprises three successive stations which are the closest geographically: Site 1 (stations 1, 2 and 3), Site 2 (stations 4, 5 and 6) and Site 3 (stations 7, 8 and 9); these stations are with very close values (Table 1).

The studied sediments texture was analyzed depending on the Pipette Particle Size Method of Robinson Khon. The obtained results are as follows (Table 1):

Stations 1, 2 and 3: texture is predominately silty;

Stations 4, 5 and 6: texture is predominately silty-clay, accompanied with a strong presence of coarse sand;

Stations 7, 8 and 9: texture is predominately silty-clay.

Our samples have neutral to slightly alkaline pH rates with values ranging from 7.48 to 8.02. These characteristics reflect well the nature of the sediments dominated by limestone and clay terrains. All these same pH conditions, the importance of physical processes is not surprising in a river whose pH near to neutrality and where the metal is predominant in its particulate form (Axtmann and Luoma, 1991).

The medium values of the calcium carbonate ($CaCO_3$) contents of the sediments of the diverse sampling stations show more or less similar CT rates (25 to 25.7%) (Table 1).

Table 1 presents the measurement of electrical conductivity (EC) showed variations between the different analyzed samples (309 to 543 µS/cm). These variations are well typical of the observed conductivity in fresh water sediments (100<EC<1000 µS/cm). Nothing that the relatively important were recorded at a few stations reflecting also a high mineralisation which can be attributed to industrial and/or urban discharges as well as the salty nature of the subbasin in question (Sahli et al., 2014).

The organic matter (OM) develops a chelating effect on metal elements. It constitutes there by a privileged support engendering an organo-metallic "complexation" at sediments (Mseddi and Ben Mammou, 2014).

The analysis of the studied sediments shows relatively lower organic contents, which vary between 1.5 and 2.5% (Table 1). Thus, the whole analysed stations did not show an important carbon pollution.

The Saf-Saf river drains in its passage the leaching waters of the river basins, where there is an important agricultural activity, as well as the polluted releases of numerous industrial units and the non-treated domestic discharges of plenty urban agglomerations (Salah Bouchaour, Ramdane Djamel and Hamadi Krouma, headquarters of our stations), which keep to develop in its surroundings.

All these tributaries, brought to the Saf-Saf river pollutants of various natures, in notable quantities and which end up inevitably in the Mediterranean Sea.

Analysis of trace metal elements in the sediments of the Saf-Saf wadi revealed the presence of Cd, Cr, Cu, Fe, Mn and Ni in all samples.

Metal contents at Saf-Saf river sediments, the crustal metal concentrations (Rudnick and Gao, 2003) and geochemical background noise (Thomas and Meybeck, 1992), were presented in Table 3.

Generally, the sediments of the nine stations present strong concentrations of TMEs, which vary from one station to another. With the exception of Cr, the maximum studied metal contents are higher than the UCC (Upper Continental Crust) values quoted by Coulibaly et al.,(2014) thus showing the existence of pollution by Cd, Cu and Ni.

The comparison of the minimum TME contents at the different stations with those of background noise shows contamination by Cd, Fe and Mn.

The most abundant element at the sediments of the Saf-Saf wadi is the Fe. Its concentrations ranged from 18723.89 to 23428.12 µg/g. According to Welken and Weiller (1987) the high Fe content may be linked to the structure of silicates that are a part of the major sediment constituents.

In second position, we have the Mn whose values ranged from 3379.76 to 4780.84 µg/g. The remarkable enrichment at this major element, reflects an existence of a metal contribution linked with human activities at the level of the watershed.

In turn the Ni oscillates from 57.24 to 80.12 µg/g ; with concentrations higher than those of the UCC, but very close to those of the geological background.

Concerning copper and cadmium, they also have significant levels in the sediments of Saf-Saf river, with a margin of 32.46 to 72.81 µg/g for Cu and 7.34 to 16.7 µg/g for Cd. These levels reflect obvious sediment contamination, as they exceed considered values as natural (Background).

The least abundant element is chromium. It varies from 4.48 to 17.28 µg/g at all the stations, with concentrations below reference levels. Its presence in the sediments of the different stations, is therefore totally natural.

On average, the order of enrichment of the various metal elements at the sediments of the study stations is: Fe >Mn> Ni> Cu> Cd> Cr.

However, the levels of determined metals correspond to adsorbed TMEs to the particles and reflect the level of contamination and not the total content (Afri-Mehennaoui et al., 2009).

Trace metal levels in the sediments at the Saf-Saf river were compared with those of other sites in order to assess the contamination degree of these sediments at the national and Maghrebian scale (Table 4). The comparison shows that the contamination of the studied TMEs at our sediments is much lower than those other comparison regions with the exception of iron. This same comparison proves that, the sediments of the Nile river (Egypt) quoted by Fawzy et al. (2017), have significantly lower concentrations than at other studied sites.

The determination of the level of anthropogenic pollution by trace metal elements (TMEs) at the sediments of the Saf-Saf river, with the aid of the geoaccumulation index (Müller, 1981);

**Table 3.** The average levels of TME at the nine study stations (µg/g)

| Stations | Cd | Cr | Cu | Fe | Mn | Ni |
|---|---|---|---|---|---|---|
| **St 1** | 12.08 | 10.79 | 36.36 | 19949.50 | 4024.21 | 62.66 |
| **St 2** | 14.96 | 13.52 | 32.46 | 19634.34 | 4442.60 | 68.00 |
| **St 3** | 16.70 | 10.89 | 34.13 | 19994.54 | 4780.84 | 69.84 |
| **St 4** | 15.72 | 04.85 | 36.39 | 18723.89 | 3392.30 | 80.12 |
| **St 5** | 12.20 | 04.84 | 47.42 | 21003.49 | 3476.42 | 73.63 |
| **St 6** | 12.85 | 04.48 | 39.98 | 23428.12 | 3379.76 | 64.54 |
| **St 7** | 07.34 | 13.54 | 72.81 | 22089.98 | 3518.43 | 59.74 |
| **St 8** | 08.90 | 15.17 | 55.72 | 22553.35 | 4151.92 | 61.66 |
| **St 9** | 09.48 | 17.28 | 58.03 | 22227.47 | 4217.02 | 57.24 |
| **Min** | 7.34 | 4.48 | 32.46 | 18723.89 | 3379.76 | 57.24 |
| **Max** | 16.7 | 17.28 | 72.81 | 23428.12 | 4780.84 | 80.12 |
| **Mean** | 12.25 | 10.60 | 45.92 | 21067.19 | 3931.50 | 66.38 |
| **SD**[a] | 3.03 | 4.55 | 12.93 | 1495.29 | 482.38 | 6.86 |
| **UCC**[b] | 0.1 | 35 | 14 | - | - | 19 |
| **Background**[c] | 0.3 | 120 | 50 | 51.8 | 1 | 80 |
| **SQG – TEC**[d] | 0.99 | 43.4 | 31.6 | 20000 | 22.7 | 460 |
| **SQG – PEC**[d] | 4.98 | 111 | 149 | 40000 | 48.6 | 1100 |

[a] SD: Standard Deviation

[b] UCC : Upper Continental Crust (Coulibaly et al., 2014).

[c] Background (Thomas and Meybeck, 1992).

[d] Sediment quality guideline (MacDonald et al., 2000) ; TEC and PEC values of Fe and Mn (Copaja and Muñoz, 2018).

**Table 4.** Trace metal elements concentrations at sediments of different rivers (µg/g)

| Area | Cd | Cr | Cu | Fe | Mn | Ni | References |
|---|---|---|---|---|---|---|---|
| **Saf-Saf river (Skikda, Algeria)** | 12.25 ±3.03 | 10.60 ±4.55 | 45.92 ±12.93 | 21067.19 ±1495.29 | 3931.50 ±482.38 | 66.38 ±6.86 | Current study |
| **Djendjen river (North Eastern Algeria)** | 1.10 ±0.07 | - | 121.56 ±4.50 | - | - | 140.68 ±2.52 | Krika and Krika (2018) |
| **Nil river (North Eastern Algeria)** | 2.34 ±0.22 | - | 38.83 ±2.47 | - | - | - | Krika and Krika (2017) |
| **Bassin Boumerzoug (North Eastern Algeria)** | 1.19 ±0.68 | 46.82 ±17.54 | 31.18 ±79.15 | - | - | 24.19 ±5.02 | Sahli et al. (2014) |
| **Seybouse river (Annaba, Algeria)** | - | 9.50 ±3.2 | 145.15 ±35.2 | 2460.20 ±74.8 | 3.60 ±1.2 | 16.80 ±2.6 | Louhi et al. (2012) |
| **Seybouse river (Guelma, Annaba -Algeria)** | 0.219-4.158 | - | 7.09 - 45.41 | 18 685 - 37 990 | - | 8.58 - 41.13 | Talbi and Kachi, (2019) |
| **Rémir river (Tunisia)** | 64.2 | 41.95 | 44.6 | 27163 | 1204.1 | - | Mseddi and Ben Mammou (2014) |
| **Siliana river (Tunisia)** | 0.4 | 47.1 | 17.88 | 15276.88 | 189.08 | - | |
| **Hassar river (Marroco)** | 0,752-2,105 | 3,85-115,97 | 8,47-5969,17 | 3,08-207,69 | - | - | Nahli et al. (2016) |
| **The Nile (Aswan, Egypt)** | 0.1 | 2 | 0.75 | 672 | 10.9 | 0.82 | Fawzy et al. (2017) |

showed by means of the obtained averages (Table 5) that the sediments of stations 1, 5, 6, 7, 8 and 9 are strongly polluted by Cd. In parallel, stations 2, 3 and 4 are extremely polluted by the same element.

Conserning Cr, Cu and Ni, whose presence is at all sediments results in negative Igeo values, was not reflecting also any pollution.

The calculation of the Igeo du Fe and Mn, gave for the whole stations only averages > 5, translating an extreme pollution by these elements.

The calculation results of the contamination factors of the diverse studied TMEs are presented in Table 6.

According to the Hakanson scale (Hakanson, 1980), the CF of Cd, Fe and Mn at the sediments of all stations in the Saf-Saf river reflect very high contamination (CF >6).

On the other hand, Cr has an absent to a low contamination in all sediments, with a values of CF < 1.

The Cu and Ni CF calculation also shows an absent to low contamination at most stations, with the exception of stations 7, 8 and 9 for Cu and station 4 for Ni, which 1 ≤ CF ≤3, indicates a moderate contamination at these stations.

Table 6 exposes as well as results at the level of polymetallic contamination of all workstations, expressed by the degree of contamination (DC). These data show the presence of a very high contamination by all treated TMEs, at the level of the whole analyzed sediments, with the

**Table 5.** Averages of the geoaccumulation index (Igeo)

| Stations | Igeo | | | | | |
|---|---|---|---|---|---|---|
| | Cd | Cr | Cu | Fe | Mn | Ni |
| **St 1** | 4,75 | -4,06 | -1,04 | 8,00 | 11,39 | -0,94 |
| **St 2** | 5,06 | -3,73 | -1,21 | 7,98 | 11,53 | -0,82 |
| **St 3** | 5,21 | -4,05 | -1,14 | 8,01 | 11,64 | -0,78 |
| **St 4** | 5,13 | -5,21 | -1,04 | 7,91 | 11,14 | -0,58 |
| **St 5** | 4,76 | -5,22 | -0,66 | 8,08 | 11,18 | -0,70 |
| **St 6** | 4,84 | -5,33 | -0,91 | 8,24 | 11,14 | -0,89 |
| **St 7** | 4,03 | -3,73 | -0,04 | 8,15 | 11,20 | -1,01 |
| **St 8** | 4,31 | -3,57 | -0,43 | 8,18 | 11,43 | -0,96 |
| **St 9** | 4,40 | -3,38 | -0,37 | 8,16 | 11,46 | -1,07 |

**Table 6.** Averages of the contamination factor (FC) and the degree of contamination (DC)

| Stations | CF | | | | | | CD |
|---|---|---|---|---|---|---|---|
| | Cd | Cr | Cu | Fe | Mn | Ni | |
| **St 1** | 40,27 | 0,09 | 0,73 | 385,13 | 4024,21 | 0,78 | 4451,20 |
| **St 2** | 49,87 | 0,11 | 0,65 | 379,04 | 4442,6 | 0,85 | 4873,12 |
| **St 3** | 55,67 | 0,09 | 0,68 | 385,99 | 4780,84 | 0,87 | 5224,15 |
| **St 4** | 52,40 | 0,04 | 0,73 | 361,47 | 3392,3 | 1,00 | 3807,93 |
| **St 5** | 40,67 | 0,04 | 0,95 | 405,47 | 3476,42 | 0,92 | 3924,47 |
| **St 6** | 42,83 | 0,04 | 0,80 | 452,28 | 3379,76 | 0,81 | 3876,52 |
| **St 7** | 24,47 | 0,11 | 1,46 | 426,45 | 3518,43 | 0,75 | 3971,66 |
| **St 8** | 29,67 | 0,13 | 1,11 | 435,39 | 4151,92 | 0,77 | 4618,99 |
| **St 9** | 31,6 | 0,14 | 1,16 | 429,10 | 4217,02 | 0,72 | 4679,74 |

**Table 7.** Averages of SPI and ΣPEC of Saf-Saf river sediments

| Stations | SPI | ΣPEC |
|---|---|---|
| **St 1** | 39,62 | 4,06 |
| **St 2** | 49,06 | 4,74 |
| **St 3** | 54,76 | 5,12 |
| **St 4** | 51,55 | 5,09 |
| **St 5** | 40,01 | 4,33 |
| **St 6** | 42,14 | 4,22 |
| **St 7** | 24,08 | 3,31 |
| **St 8** | 29,19 | 3,57 |
| **St 9** | 31,09 | 3,63 |

**Table 8.** Sediment quality of the Saf-Saf river

| | Cd | Cr | Cu | Fe | Mn | Ni |
|---|---|---|---|---|---|---|
| **< TEC : Non-toxic** | - | 1 – 9 | - | 1 - 4 | - | 1 – 9 |
| **TEC < x < PEC : Toxic** | - | - | 1 – 9 | 5 - 9 | - | - |
| **> PEC : Highly toxic** | 1 – 9 | - | - | - | 1 – 9 | - |

values of DC > 24 at each station. These rates are mainly due to manganese and iron, whose presence is notable. According to the DC values, the order of classification of the different stations in terms of contamination is as follows: St 3 > St 2 > St 9 > St 8 > St 1 > St 7 > St 5 > St 6 > St 4.

The calculation of the sedimentary pollution index relating to the study stations gave only 20 values, indicating that sediments at all stations are hazardous (Table 7). The problem of the use of this index is the weight of cadmium on the SPI result. Indeed, the coefficient 300 appears to overestimate the toxicity of cadmium. Hence, SPI is often correlated with Cd (Billon et al., 2010), this metal is considered as extremely toxic for benthic fauna (Lesven, 2008).

The sediment quality evaluation of the Saf-Saf river was based on the results of Table 7, by comparing the TME levels at the nine stations with the CET and PEC values (MacDonald, 2000). This analysis revealed three levels of toxicity (Table 8).

The Cr and Ni in the sediments of stations 1 to 9 and Fe in stations 1 to 4 are not toxic. Nevertheless, the rest of the studied TMEs, as well as for Fe at stations 5 to 9, constitute a (toxic or very toxic) danger for the environment of the Saf-Saf river.

In contrast, the PEC calculation of four TMEs in the sediments of the workstations (Cd, Cr, Cu and Ni), using the formula proposed by Billon et al.(2010) allowed for obtaining results presented in Table 5. These results are thus all superior than 1, suggesting that it is possible at overall stations to observe the toxic effects related to metals, according to Billon et al.(2010).

## CONCLUSIONS

At the end of this work, which consists of applying an assessment of the sediments contamination of the Saf-Saf river, by employing various indices. We found that most of these sediments are composed of silt, with some clay and/or coarse sand in some samples. The monitoring of the evolution of the six metal trace elements (Cd, Cr, Cu, Fe, Mn, and Ni) at the sediments of Saf-Saf river, mentions that their contents undergo an irregular evolution according to this order : Fe> Mn> Ni> Cu> Cd> Cr.

The contents of all these TME show a polymetallic contamination of the sediments by several metals essentially by Fe, Mn and Cd. Otherwise, this sediment contamination remains inferior than the concentrations found by other authors at river sediments.

The calculation of the Geoaccumulation Index montioned that Cd present a high and variable pollution: high contamination (stations 1, 5, 6, 7, 8 and 9) to extreme contamination (stations 2, 3 and 4). While the Fe and Mn, translate an extreme pollution at all stations.

The contamination factors of Cd, Fe and Mn which are at present in the sediments of all the stations of Saf-Saf river, reflect a very high contamination (CF > 6), confirming the results of the Igeo. Whereas, the CF of Cu (stations 7, 8 and 9) and Ni (station 4) indicate moderate contamination.

The degree of contamination index shows a very high polymetallic contamination at overall workstations, whose main cause is the abundance of iron and manganese.

The Sedimentary Pollution Index at the study stations points out that the sediments of all stations are hazardous (SPI > 20), because their SPI is often correlated with Cd.

The environmental quality of the Saf-Saf river sediments, was realized by comparing our results with the values of the TEC and the PEC, belonging to the American guide standards SQGs (Sediment Quality Guidelines), mentioned that the metals Cd, Cu and Mn present a great danger of toxicity at the nine workstations. The danger of toxicity is likewise caused by the presence of Fe at stations (5 to 9). The considerable enrichment by certain metallic elements (Cd, Fe and Mn), could also be of agricultural origin linked to soil leaching and the spreading of fertilizers at the level of the two banks of the Saf-Saf river. Without excluding industrial, urban and road traffic, which contribute to this enrichment.

The potential causes and threats of pollution at Saf-Saf river sediments are multiple and closely related with intense human activity. Apart from, the use of these different indices does not allow us to recognize precisely intervening pollution resources in this contamination.

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## CONFLICT OF INTEREST

The authors declare that there is not any conflict of interests regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/ or falsification, double publication and/or submission, and redundancy has been completely observed by the authors.

## LIFE SCIENCE REPORTING

No life science threat was practiced in this research.

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