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Ecological Risk Assessment of Metals Contaminated Sediments from the Nile River at Beni-Suef Governorate, Egypt

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Authors' contributions

This work was carried out in collaboration between all authors. Authors HMM, HFN and ASH designed the study, performed the statistical analysis, wrote the protocol and managed the results of the manuscript. Authors FM managed the analyses of the study, wrote the first draft and managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Contamination of the Nile River water with metals and its impact on sediment quality has a high concern recently. This is the first work to assess concentration and ecological risk assessment of metals (Cu, Pb, Zn, and Cr) in sediment sampled from the Torrent drainage channel and Nile River at Beni-Suef governorate (Egypt). Ecological and human health risks index were used to evaluate the effect of the metal contaminated sediments on the ecosystem status and human health. Concentration levels of metals studies followed the order of: Zn> Cr> Cu> Pb. Geo accumulation index (Igeo) classified the surface sediment samples as uncontaminated sediments, while potential ecological risk ($R_{I)}$ showed that metals in these sediments may pose a low risk in the ecological system. Effect range median (ERMQ) and probable effect level (PELQ) quotients clarified that metal contaminated sediments could be related with 12% and 10% probability of toxicity respectively, except for some Cr concentrations where its PELQ values were related with 25.5%

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probability of toxicity. Hazard quotients (HQs), hazard indices (HIs) and cancer risk (CR) indicated that human inhabitants in the nearby area from the current sampling sites may not be exposed to carcinogenic or non-carcinogenic adverse health effects through dermal contact of their lower legs into contaminated sediments.

Keywords: Water pollution; heavy metals; sediment contamination; Nile River; risk assessment.

1. INTRODUCTION

Surface water contamination with metals becomes a main problem in many countries all over the world [1]. Sediments are described as the main sink or reservoir of pollutants including metals [2,3,4]. Metals from the contaminated water are precipitated then accumulated on the sediment surface. Afterwards, sediment releases back the accumulated metals to the water stream [1,5]. There are several factors that may affect the sediment metals accumulation from water mainly depend on the sediment particle size like Ionic strength, pH, input of organic and inorganic contaminants [6,7]. As urbanization and industrialization have increased very rapidly, particularly in the second half of the last century, causing an increase in many sources of pollution [8,9]. Different methods have been proposed for estimating the numerous adverse effects of metal contaminated sediment on ecosystems and human health consequently through measuring the pollution degree [10,11]. Geo accumulation index method was introduced by for the single metal ecological assessment [12]. The potential ecological risk index was developed by [13] to evaluate the toxic response factor for a certain metal on the studied ecosystem, moreover to relate the environmental effects with toxicology, and to estimate the investigated pollution risk through a designed equivalent index [14]. Besides, mean sediment quality guideline quotients (mSQGQs) have been developed for evaluating the potential effects of a given metal contaminants on sediments [15]. The most popular used sediments quality guidelines (SQGs) are those of U.S. National National Oceanic Atmospheric Administration (NOAA) and the Canadian council of ministers of the environment sediment guidelines (CCME) [16]. NOAA has developed sediment quality guidelines such as the effect range low (ERL) and the effect range median (ERM) guidelines for marine and estuarine sediments. These SQGs based on chemical and biological effects data base. ERL guidelines corresponds to chemical concentrations can cause adverse biological effects with 10th percentiles, and TEL guidelines to those can do it with 50 th percentiles. Threshold effect level (TEL) and probable effect level (PEL) approach, performed by CCME, are used to evaluate the ecotoxicology of sediments of fresh water sediments. They are based on the relation between measured concentrations of metals and observed biological effects on the dwelling living organisms as growth, reproduction, or mortality. TEL is the concentration below which sediment-associated contaminants are not considered to represent significant hazards to aquatic organisms, while PEL represents the lower limit of the range of concentrations associated with adverse biological effects [17,18,19].

The Torrent drainage channel and the Nile River in the eastern side of Beni-Suef governorate receive different types of pointed and non-pointed waste water discharge. Water stream in the Torrent drainage channel carry suspended contaminated sediments which reach the Nile River in this area. Where, in our previous study we assessed the concentration levels and health risk for the selected heavy metals from the same sampling points [20].

The aims of the present study are (i) Continuing our previous work for measuring the concentrations of Cu, Pb, Zn and Cr in sediments during winter and summer seasons, (ii) evaluating the environmental and ecological risks of the contaminated sediments via estimating the geo-accumulation index (I_{geo}), potential ecological risk index (R_I), biological risk by using SQGs or mean ERM and mean PEL and (iii) identifying the carcinogenic and non-carcinogenic adverse health effects expected to occur via dermal exposure to the contaminated sediments using hazard quotients (HQs), hazard indices (HIs) and cancer risk (CR).

2. MATERIALS AND METHODS

2.1 The Sampling Sites Description

As seen in Fig. 1; sediments were sampled from (S_1, S_2, S_3, S_4 and S_5). Mahmoud et al. (2016)

collected water samples from the same sites for metals analysis.

S_1: is the upstream point in the Nile approximately 2.5 km before the Torrent drainage channel destination at the Nile River. It is located at GPS coordinates of N 29°03`.726`` and E 31°31`.0224``.

S_2 and S_3: two sites in the Torrent drainage channel (2.2 km length). They are located at GPS coordinates of N 29°023`.1876`` and E 31°426`.8464`` for S_2; and N 29°038`.1852`` and coordinates of E 31°359`.7564`` for S_3.

S_4: a sampling site where the drainage water mixes with the Nile River water. It is located at GPS coordinates of N 29°055`.2744`` and E 31°327`.9828``.

S_5: a sampling site that is approximately 2.1 km to the north of S_4. It is located at GPS coordinates of N 29°123`.2176`` and E 31°341`.6844``.

2.2 Samples Collection and Analysis

Sediments were collected from the five sites during winter season (December, January, and February) and summer season (June, July, and August) from 2014 to 2015. Three pooled samples (each is pooled out of ten samples) were collected in clean polyethylene vials at 5-10 cm depth. Sediments samples were mixed, air dried, grinded with petal and mortar, sieved, and kept frozen at -20ºC till their analysis. The sediments samples were dried in oven at 100°C for 12 hours, burned in a muffle furnace for 12 hours, dissolved in acids with deionized water, and filtered with 0.45 µm Whattman filter paper. Metals were measured by atomic absorption spectrophotometer (Perkin-Elmer, Model 2380) according to [21]. Certified reference material (International Atomic Energy Agency, IAEA, SD-M-2/TM) was prepared with the same method to determine the recovery rate which found to be within the range of (90 – 110 %) for all the studied metals.

2.3 Pollution Index and Risk Assessment

2.3.1 Geo-accumulation index (I_{geo})

The geo-accumulation index (I_{geo}) was introduced by [11] to evaluate sediment metal contamination by comparing the measured metal concentrations with the preindustrial concentrations in the Earth's crust. It was calculated using equation (1):

$$I_{geo} = \log_2\left(\frac{Cn}{1.5Bn}\right) \tag{1}$$

Where Cn is the measured concentration of the metal in the sediment samples, and Bn is the geochemical background value in the Earth's crust [22]. Factor 1.5 is the background matrix correction factor, and it is introduced to minimize the effect of possible variations. Seven classes of the geo-accumulation index have been distinguished to identify the degree of sediments contamination. Samples may be classified as uncontaminated ($I_{geo} \leq 0$), uncontaminated to moderately contaminated ($0 \leq I_{geo} \leq 1$), moderately contaminated ($1 \leq I_{geo} \leq 2$), moderately to heavily contaminated ($2 \leq I_{geo} \leq 3$), heavily contaminated ($3 \leq I_{geo} \leq 4$), heavily to extremely contaminated ($4 \leq I_{geo} \leq 5$), and Extremely contaminated ($I_{geo} > 5$) (Müller 1969).

2.3.2 Potential ecological risk index (R_I)

The potential ecological risk index was introduced by Hakanson (1980) to assess the degree of metal pollution in sediments by calculating the potential ecological risk coefficient E_r^i of a single metal and the potential risk index R_I of a multi metals via equations (2), (3), and (4):

$$C_f^r = \frac{C_0^i}{C_n^i} \tag{2}$$

$$E_r^i = T_r^i C_f^r \tag{3}$$

$$R_I = \sum E_r^i \tag{4}$$

Where "R_I" is calculated as the sum of all risk factors for metals in sediments, E_r^i is the single potential ecological risk factor, T_r^i is the toxic response factor for a given metal, C_n^i is the contamination factor, C_0^i is the concentration of metals in the sediment and C_n^i is a reference value for metals as shown in Table 1. The following terminologies are suggested for the E_r^i and R_I values: (1) low ecological risk ($E_r^i < 40$); moderate ecological risk ($40 < E_r^i \leq 80$); appreciable ecological risk ($80 < E_r^i \leq 160$); high ecological risk (160 < E_r^i ≤ 320); and serious ecological risk (E_r^i > 320); (2) low ecological risk (R_I < 65); moderate ecological risk (65 < R_I < 130); considerable ecological risk (130 < R_I < 260); and very high ecological risk (R_I > 260).

2.3.3 Sediment quality guidelines (SQGs)

Since metals occur in sediments as complex mixtures, the mean PEL and ERM quotients (PELQ and ERMQ respectively) have been applied to determine the possible biological effects of metals using equation (5) and (6):

$$\text{ERMQ} = \frac{Ci}{ERMi} \quad \text{or} \quad \text{PELQ} = \frac{Ci}{PELi} \tag{5}$$

$$\text{mERMQ} = \frac{\left(\sum_{i=1}^{n} ERMQ\right)}{n} \text{ or mPELQ} = \frac{\left(\sum_{i=1}^{n} PELQ\right)}{n} \tag{6}$$

Where: Ci is the total content of selected metal, n is the number of selected metals, mERMQ is the effect range median quotient of multiple metal contaminations, ERMi is the ERM value of selected metal, mPELQ is the probable effect level quotient, PELi is the PEL value of a selected metal. ERMQ values of <0.1, 0.11–0.5, 0.5–1.5 and >1.5 related to 12 %, 30 %, 46 % and 74 % probability of toxicity, respectively. Similarly, PELQ values of <0.1, 0.11–1.5, 1.51–2.3 and >2.3 related with 10 %, 25.5 %, 50 % and 76 % probability of toxicity, respectively.

Fig. 1. Sampling sites in the Torrent drainage channel and the Nile River in the eastern side of Beni-Suef governorate, Egypt

Table 1. C_n^i, T_R^i, ERL, ERM, TEL, and PEL values of metals in sediment [17,22,23]

Metal	C_n^i	T_r^i	ERL	ERM	TEL	PEL
Cu	30	5	34	270	35.7	197
Pb	25	5	46.7	218	35	91.3
Zn	80	1	150	410	123	315
Cr	60	2	81	370	37.3	90

(C_n^i), Reference values; (T_r^i),toxicity coefficients; (ERL), effect range low and (ERM), effect range median; (TEL), threshold effect level; and (PEL), probable effect level values of metals in sediment

2.3.4 Human health risk assessment

In this study there is a sub human population exposes directly to the sediments through their legs during fisheries, agriculture and other activities. The estimated average daily dose absorbed by the lower legs skin area was calculated by equation (7):

$$ADD_{sed} = \frac{C_s \times CF \times SA \times AF \times ABS \times EF \times ED}{BW \times AT} \quad (7)\ [24]$$

Where, ADD is the average daily exposure to the metal contaminated sediments, Cs is the measured metal concentration in sediment (mg/kg), CF is the conversion factor (10^{-6} kg/mg), SA is the skin surface area available for contact (2370 cm^2 for lower legs), AF is the sediment to skin adherence factor (0.07 mg/cm^2), ABS is the absorption factor (0.001), EF is the exposure frequency (365 day), ED is the exposure duration (70 years), BW is the average body weight (70 kg), and AT is the averaging time (70 year x 365 day).

The risk assessment of non-carcinogenic adverse effects was estimated by calculating the hazard quotient (HQ) from the dermal exposure to contaminated sediments, and it is expressed by the ratio of ADD to the reference dose RfD of each metal by the equation (8), when HQ≥ 1 there is a non-carcinogenic risk [24].

$$HQ_{derm} = \frac{ADD_{derm}}{RfD_{derm}} \quad (8)$$

$$RfD_{\boldsymbol{derm}} = RfD_{ing} \times ABS_{Gi} \quad (9)$$

Where, RfD_{derm} is the absorbed reference dose via dermal contact (mg/kg-day), RfD_{ing} is the reference dose (mg/kg-day) via the ingestion pathway for Zn (0.3), Cu (0.04), Pb (0.0035), and Cr (0.003), and ABS_{GI} is the fraction of contaminant absorbed in gastrointestinal tract (dimension less) in the critical toxicity study [25].

For the multiple risk assessment of metals in sediments, the hazard index is calculated by equation (9), when HI≥ 1 the human population exposed to contaminated sediments may be experienced adverse health effects.

$$HI = \sum_{i-0}^{n} HQ \quad (10)$$

Cancer risk (CR) was evaluated by using equation (10), when CR> 10^{-6} there is a carcinogenic risk [23,25]:

$$CR_{derm} = \frac{ADD_{derm}}{SF_{derm}} \quad (11)$$

$$SF_{derm} = \frac{SF_{ing}}{ABS_{GI}} \quad (12)$$

Where, CR_{derm} is the estimated cancer risk via the dermal contact exposure, SF_{derm} is the cancer slope factor (mg/kg-day), SF_{ing} is (0.0085) and Cr is (0.5) [25,26].

2.4 Statistical Analysis

Statistical package version 22 of IBM SPSS was used in the performance of all the statistical tests. Metal results were analyzed using one way analysis of variances (ANOVA) and Tukey post hoc test to determine the spatial variations and differences between the five sampling sites. The seasonal variations were determined by using Student t-test. Pearson correlation analysis was used to evaluate the relationships between metals in sediments for the two studied seasons. The metals values were expressed as mean (M) ± standard error of mean (SEM). The accepted significance level was at *p=0.05*.

3. RESULTS AND DISCUSSION

The concentration levels of Cu, Pb, Zn, and Cr in water samples collected from the Torrent drainage channel (S_2 and S_3) and from the Nile River (S_1, S_4 and S_5) during winter and summer seasons from (2014 – 2015) reported by [20]. Sediments samples are collected from the same sampling sites during winter and summer seasons, and Cu, Pb, Zn, and Cr concentration levels are investigated in the present study for the sampled sediments and are shown in Table 2. Correlation coefficients between different metals are recorded in Table 3. Pollution indices and risk assessment are calculated and manifested in Figs. 2, 3, 4 and Tables 4, 5.

3.1 Metals Concentrations and Correlations

The detected metal concentrations in sediment samples collected from the five sampling sites (S_1 - S_5) followed the pattern of Zn> Cr> Cu> Pb during winter and summer seasons as shown in Table 2. Among the four selected metals studied (Cu, Pb, Zn, and Cr) higher concentrations are observed for Zn and Cr, whereas lower concentrations are observed for Cu and Pb at the five sampling sites during winter and summer seasons. The average Cu values are ranged from 0.992 to 4.021 mg/kg, and the highest concentration value for Cu (4.021 ± 0.162 mg/kg) is recorded at S_2 during summer season. Cu shows a significant spatial increase at $P< 0.05$ in S_2 during summer season, while it shows a significant increase at $P< 0.05$ in S_4 during winter season. Cu range in the current sampling sites is within the average range (3.61 – 4.46 mg/kg) reported by [27] along the course of the Nile River in Cairo city; it is higher than Cu range (0.030 – 0.054 mg/kg) reported by [28] along the whole course of the Nile River in Egypt from Aswan to Damietta and Rosetta branches; and it is less than Cu range (27.55 – 100.10 mg/kg) reported by [18] in sediments at the upper reach of Yangtze River in China.

The average Pb values are ranged from 0.927 to 1.919 mg/kg at the five sampling sites during winter and summer seasons. The highest concentration for Pb (1.919 ± 0.395 mg/kg) is recorded at S_1 during winter season. No spatial or seasonal significant differences are noticed for Pb in the current study. The detected concentration level range of Pb in the current study is lower than that (21.98–73.42 mg/kg) reported by [1] in Karnaphuli River at Bangladesh and lower than Pb range (21.3 – 58.2 mg/kg) reported by [29] at the Nile river sediments in Assuit governorate.

The average Zn values are ranged from 6.767 to 16.881 mg/kg in the five sampling sites during winter and summer seasons. The highest detected concentration for Zn (16.881 ± 3.643 mg/kg) is recorded at S_2 during summer season. Zn shows a seasonal significant increase $P < 0.05$ at both S_1 and S_4 during winter season, while during summer season it shows a significant increase $P <0.005$ at S_2. Zn range in the current study is within the average range (17.82 – 20.90 mg/kg) reported by [27] along the Nile River in Cairo, Egypt and lower than Zn range (37.1 – 942 mg/kg) reported by [15] in surface sediments from the Yanghe River at China.

The investigated Cr average concentrations are ranged from 6.774 to 15.151 mg/kg in the five sampling sites during winter and summer seasons. The highest concentration for Cr (15.151 ± 5.712 mg/kg) is detected at S_5 during winter season. While, there is no spatial or seasonal significant differences are noticed for Cr. In the current study, Cr range is within the range (8.7 – 17.6 mg/kg) reported by [28] along the whole course of the Nile River in Egypt from Aswan to Damietta and Rosetta branches and less than Cr range (40.4 – 96.39 mg/kg) reported by [30] in surface sediments collected from the Jialo River in China.

The correlation coefficients for both seasons are recorded in Table 3, where Cu and Zn showed a positive correlation values of ($r= 0.679$, $P< 0.05$) and ($r = 0.849$, $P< 0.01$) for winter and summer seasons respectively. That means, those metals tend to accumulate together and derived from similar sources [10]. Also, metals accumulation from water to sediments show different patterns in the five sampling sites, this may be due to the difference in sediment particles where the Torrent drainage channel sites (S_2 and S_3) passes through a desert area which mainly composes of sand, while the Nile River sites (S_1, S_4 and S_5) sediment mainly composes of clay. In addition to the ionic strength which affects the metals accumulation in sediment particles due to high levels of salinity in the Torrent drainage channel water reported by [20].

Table 2. Mean values ± standard error (m±SE) of Cr, Cu, Pb and Zn in sampling sites during winter and summer seasons

	S1	S2	S3	S4	S5
Cu					
W	2.419 ± 0.854	2.713 ± 0.562	2.323 ± 0.831	3.134 ± 0.212	1.859 ± 0.481
S	1.467± 0.132	4.021 ± 0.162	2.553± 1.109	1.176 ± 0.153	0.992 ± 0.165
Pb					
W	1.919± 0.395	0.927 ± 0.634	1.118 ± 0.195	1.358 ± 0.186	1.768 ± 0.39
S	1.534± 0.113	1.015 ± 0.038	1.206 ± 0.229	1.134 ± 0.068	1.331 ± 0.092
Zn					
W	12.021 ± 0.837	13.276 ± 0.177	12.665 ± 4.886	14.397 ± 1.498	9.549 ± 0.704
S	10.361 ± 0.929	16.881 ± 3.643	15.672 ± 4.16	9.921 ± 0.394	6.767 ± 0.841
Cr					
W	14.512 ± 4.131	8.846 ± 1.327	13.721 ± 7.791	12.756 ± 2.538	15.151 ± 5.712
S	10.261 ± 0.765	8.929 ± 2.303	8.506 ± 1.879	6.774 ± 0.465	12.142 ± 6.853

** S, summer; W, winter*

Table 3. Correlation analysis between the four investigated metals

	Cu	Pb	Zn	Cr
Cu	1	-0.257	0.849^{**}	0.014
Pb	-0.168	1	-0.143	0.483
Zn	0.679^{*}	-0.300	1	0.059
Cr	0.079	0.365	0.400	1

**. Correlation is significant at the 0.05 level (2-tailed).*
***. Correlation is significant at the 0.01 level (2-tailed)*

3.2 Ecological and Human Risk Assessment

3.2.1 Geo-accumulation index (I_{geo})

The mean I_{geo} index values of sediment samples during winter and summer seasons are shown in Fig. 2; the calculated I_{geo} values are less than zero, where the I_{geo} ranges from (-5.503 to -3.484) for Cu, (-5.338 to -4.288) for Pb, (-3.652 to -2.829) for Zn, and (-3.732 to -2.571) for Cr. Thus, the I_{geo} shows that the surface sediments can be classified as uncontaminated samples according to Müller classes.

3.2.2 Potential ecological risk index (R_I)

The calculated toxicity coefficients show a low ecological risk index for each single metal (E_r^i) and for the sum of metals (R_I) according to [13] classification. The E_r^i values range from (0.1653 to 0.0.6702) for Cu, (0.1854 to 0.3838) for Pb, (0.0846 to 0.211) for Zn, and (0.2258 to 0.505) for Cr. The R_I values for the surface sediments in the current sampling sites range from (0.7726 to 1.421) and follow the orders of $S_1 > S_4 > S_5 > S_3 > S_2$ and $S_2 > S_3 > S_1 > S_5 > S_4$ during winter and seasons respectively, (Fig. 3). Therefore, the selected metals in the surface sediments pose a low ecological risk for the aquatic organisms.

3.2.3 Sediment quality guidelines (SQGs)

In the current study, the effect range median quotient (ERMQ) values range from (0.0037 to 0.0149) for Cu, (0.0043 to 0.0088) for Pb, (0.0165 to 0.0412) for Zn, and (0.0183 to 0.0409) for Cr. While, the mean-ERMQ (mERMQ) values for the four metals range from (0.013 to 0.0219), and they follow the orders of S4> S1> S3> S5> S2 and S2> S3> S1> S5> S4 during winter and summer seasons respectively. The ERMQ and

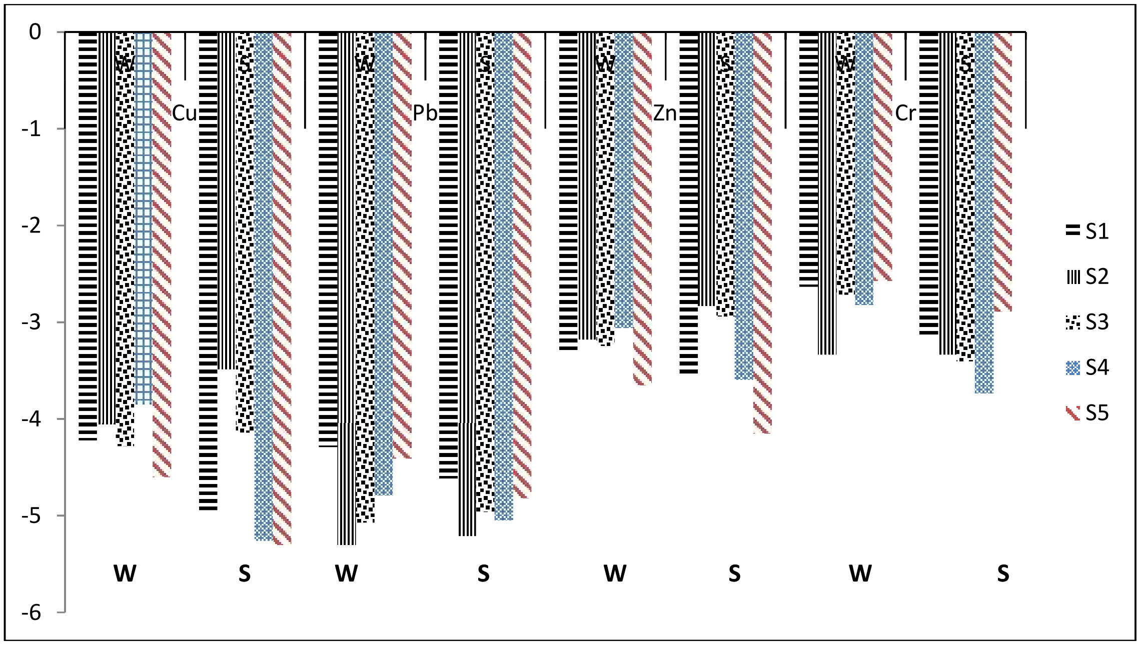

Fig. 2. I_{geo} values for the five sampling sites (S_1:S_5) for Cu, Pb, Zn, and Cr during winter (W) and summer (S) seasons

the mERMQ values in the current study are related to 12% probability of toxicity. Moreover, the probable effect level quotient (PELQ) values range from (0.005 to 0.0204) for Cu, (0.0102 to 0.021) for Pb, (0.0215 to 0.01683) for Zn, and (0.0753 to 0.1683) for Cr. The mPELQ values for the four metals range from (0.0315 to 0.0581), they follow the order S_1> S_5> S_4> S_3> S_2 during winter season and S_2> S_5> S_1> S_3> S_4 during summer season. The calculated PELQ values and the mPELQ values in the present study are related to 10% probability of toxicity except for the PELQ values of Cr in S_1, S_3, S_4 and S_5 during winter season and for S_1 and S_5 during summer season which are related with 25.5% probability of toxicity (Fig. 4).

3.2.4 Human health risk assessment

The hazard quotient (HQs) and hazard index (HIs) via dermal contact of the lower legs with the contaminated surface sediments in the present study are recorded in Table 4. The HQ values range from (6.6E-8 to 2.4E-5) for Cu, (2.5E-5 to 5.1E-5) for Pb, (5.3E-8 to 1.3E-7) for Zn, and (9.2E-8 to 4.1E-4) for Cr. Since, the HQ values are less than 1.0, so there are no expected carcinogenic adverse effects on inhabitants may occur via dermal contact of the lower legs with the surface sediments. Also, the HI values are less than 1.0, where they range from (4.4E-4 to 9.7E-4) and follow the order of S_5> S_1> S_3> S_4> S_2 during winter season and S_5> S_1> S_2> S_3> S_4 during summer season. So, the inhabitants' health may not be affected by the dermal contact with the surface sediments during their lifetime. The cancer risk (CR) values are recorded in Table 5, where all the values are less than unity of 1.0E-6; so there are no expected carcinogenic adverse effects on inhabitants' health may occur via dermal contact with the surface sediments during their lifetime.

Table 4. The hazard quotient (HQ) and hazard index (HI) values of the dermal contact of lower legs with the surface sediments at the sampling sites (S_1 to S_5) during winter and summer seasons

HQ	**S_1**	**S_2**	**S_3**	**S_4**	**S_5**
Cu					
W	1.4E-7	1.6E-7	1.4E-7	1.9E-7	1.1E-7
S	8.5E-8	2.4E-7	1.5E-7	7.0E-8	6.0E-8
Pb					
W	5.1E-5	2.5E-5	2.9E-5	3.7E-5	4.8E-5
S	4.1E-5	2.7E-5	3.3E-5	3.1E-5	3.7E-5
Zn					
W	9.3E-8	1.0E-7	1.0E-7	1.1E-7	7.7E-8
S	8.3E-8	1.3E-7	1.2E-7	8.0E-8	5.3E-8
Cr					
W	8.7E-4	5.4E-4	8.5E-4	7.7E-4	9.2E-4
S	6.4E-4	5.4E-4	5.1E-4	4.1E-4	7.4E-4
HI					
W	9.2E-4	5.7E-4	8.8E-4	8.1E-4	9.7E-4
S	6.8E-4	5.7E-4	5.4E-4	4.4E-4	7.8E-4

Table 5. Cancer risk (CR) values of the dermal contact with Pb and Cr contaminated sediments from the sampling sites (S_1 to S_5) during winter (W) and summer (S) seasons

	S_1	**S_2**	**S_3**	**S_4**	**S_5**
Pb					
W	1.3E-8	9.5E-9	7.6E-9	9.4E-9	1.2E-8
S	1.1E-8	7.1E-9	8.5E-9	7.9E-9	9.4E-9
Cr					
W	8.8E-10	5.5E-10	8.6E-10	7.8E-10	9.4E-10
S	6.5E-10	5.5E-10	5.2E-10	4.2E-10	7.5E-10

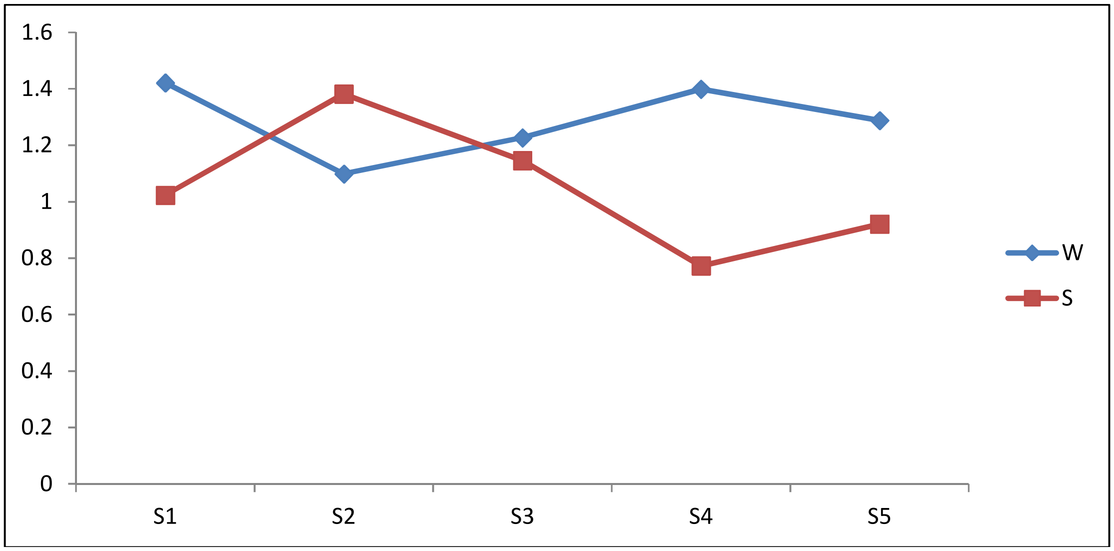

Fig. 3. Potential risk index (R_I) for the five sampling sites (S_1:S_5) during winter (W) and summer (S) seasons

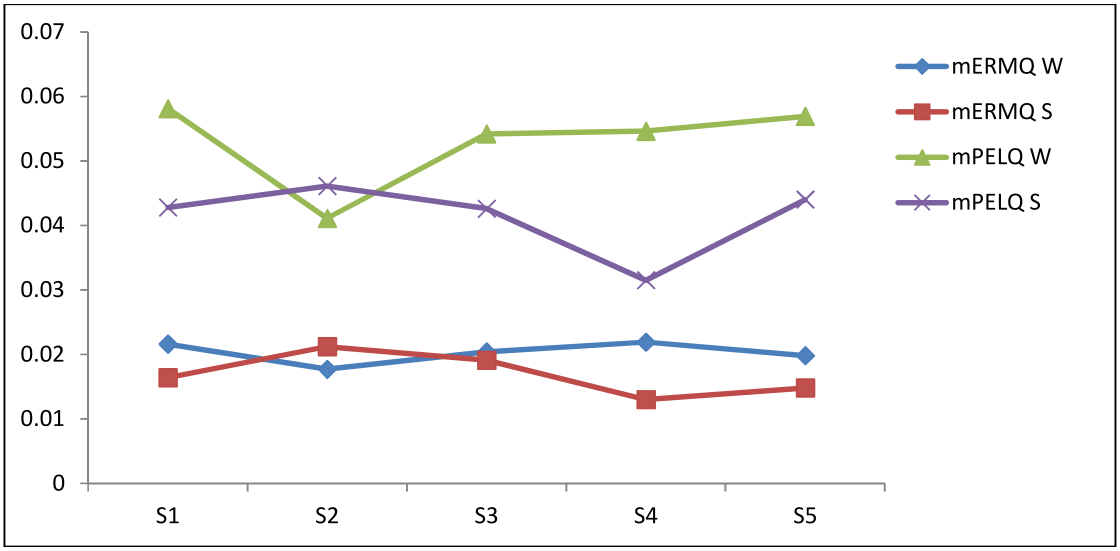

Fig. 4. mERMQ and mPELQ for the five sampling sites (S_1:S_5) during winter (W) and summer (S) seasons

4. CONCLUSION

The investigated metals were Cu, Pb, Zn and Cr in five sampling sites at the Torrent drainage channel (S_2 and S_3) and the Nile River (S_1, S_4, and S_5). Results obtained in this study showed that metals studies pose a low risk in the ecological system and aquatic living organisms. That is the same case for living the nearby area these water bodies, who may not be exposed to carcinogenic or non-carcinogenic adverse health effects via the dermal contact of their lower legs to the contaminated sediments through their lifetime. Further studies are needed to monitor other chemical contaminants in sediments of the recent sampling sites.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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