Use of pollution indices and ecological risk in the assessment of contamination from chemical elements in soils and sediments – Practical aspects

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ABSTRACT

This paper presents a discussion involving practical aspects of applying contamination indices and ecological risk factors derived from chemical elements in the environmental assessment of soils and sediments. The single and integrated indices: Geoaccumulation index (I_{geo}), Enrichment factor (EF), Contamination factor (CF), Pollution Index (PI), Ecological risk factor (E_{ir}), Pollution Load Index (PLI), Degree of contamination (C_{deg}), Modified Contamination Factor (mC_{deg}), and potential ecological risk index (PERI) were discussed, and some applications were presented didactically. The analytical care needed to obtain reliable indices with the studied ecosystem is also evidenced. In addition, the advantages and limitations of the use of these indices are presented.

1. Introduction

The pollution and ecological risk indices are tools consolidated by geoscientists, chemists, oceanographers, and other professionals involved with environmental issues in assessing the contamination from chemical elements in soils and sediments [1,2]. They can be classified as single and integrated, corresponding to evaluating one or more than one chemical element, respectively [3,4]. Among the single indices are highlighted: Geoaccumulation index (I_{geo}) [5], Enrichment factor (EF) [6], Contamination factor (CF) [7,8], Pollution Index (PI) [7,9], and Ecological risk factor (E_r^i) [7,10]. Some of the most commonly used integrated indices are Pollution Load Index (PLI) [11], Degree of contamination (C_{deg}) [12], Modified Contamination Factor (mC_{deg}) [9], and potential ecological risk index (PERI) [7,13–15]. The results found by these indices are frequently used to define public policies, investigate environmental crimes, and other questions of great environmental importance. Thus, the analytical data that generate the indices must be obtained with maximum reliability [16].

This way, the prerequisites for obtaining pollution and ecological indices with high efficiency are:

1. Sampling is one of the main steps involved in the environmental evaluation of soils and sediments. It must be established with the utmost possible rigor to guarantee the veracity of the contents of the potentially toxic elements and, consequently, more excellent reliability of the indexes of pollution and ecological risk. Dredge-type samplers are used to collect sediment from the bed of rivers and oceans. In general, the most widespread model is the so-called Van Veen dredger. In margin sediments, cylindrical samplers are most used. The sampling project must contain recommendations for soil or sediment depth, number of stations established depending on the area studied, frequency of sample collection, number of replicates, seasonal variation, and others. The depth of the material collected is established as a function of the sedimentation rate [17,18].
2. The sample preparation procedures must be compatible with the analytical methods used to determine the chemical elements. In

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addition, the procedures for determining volatile elements must be performed in closed systems. In this context, procedures using microwave ovens are efficient, despite the limitations regarding the amount of sample mass processed and the number of samples placed in the system simultaneously [18,19]. An alternative sample preparation to determine volatile elements uses a cold finger reflux system [20]. Methods for determining mercury [21,22], arsenic [23], lead [23], cadmium [24], and selenium [22] have been established.

3. The analytical methods used to issue official reports based on pollution and ecological indices must be rigorously validated. So, the following parameters should be evaluated: the linearity of the calibration curves, limits of detection and quantification, precision, intra-day, and inter-day trials, accuracy, addition/recovery test, and robustness. The methods used must have quantification limits compatible with the contents of the elements present in the matrices studied, and the accuracy of the methods should be confirmed using certified reference materials, being from the same matrix under study [16,25,26].

4. All chemical elements potentially present in the anthropogenic source of the environmental problem should be investigated, especially the volatile ones, which in general have a greater power of contamination. Otherwise, the environmental assessment obtained may estimate a false negative. An example of this would be to carry out an environmental assessment of an area supposedly contaminated by a metallurgical plant that processes iron and copper ores. In this case, the assessment requires quantifying all metals and metalloids generally present in these ores, even at the trace level.

5. Grain size is a parameter that directly influences the content of chemical elements in sediments. The fine-grained sediments have the highest specific surface areas, which allows the accumulation of metals and metalloids due to adsorption processes. This way, many authors suggest that the determination of chemical elements in sediments should be performed in the finest granulometric fractions [27,28]. In addition, the process of reducing the particles will enable a greater homogeneity of the sample, allowing the determination of the elements with greater analytical accuracy. It is recommended that the analysis of trace elements performed on sediment samples be performed mainly on the silt and clay fractions (<0.062 mm) [29, 30].

6. Natural organic matter present in sediments is generally a mixture of macromolecular substances of character that are highly complex that directly influence the solubility, toxicity, bioavailability, and distribution of the chemical elements in sediments and soils [31,32]. Transition metals are complexing by these organic substances and can decrease the toxicity of the ecosystem. The organic carbon content can contribute to the enrichment of iron, manganese, lead, chromium, zinc, and copper in sediments [33].

2. Single indexes

2.1. Geoaccumulation index (Igeo)

The Geoaccumulation index (Igeo) was proposed by Müller in 1969 [5] to assess the levels of pollution in bottom sediments [5,8,34]. Subsequently, they were also used to evaluate soil pollution. The equation used for calculations of this is:

$$I_{geo} = \log_2 \left(\frac{[X]_{sample}}{1.5 \times B_n} \right)$$

where $[X]_{sample}$ is the content of a toxic element in soil/sediment, Bn is the geochemical background content in shale. The 1.5 is the factor compensating the background content due to lithogenic effects. Geoaccumulation index (Igeo) values were interpreted as Igeo ≤ 0 – practically uncontaminated; 0 ≤ Igeo ≤ 1 – uncontaminated to moderately contaminated; 1 ≤ Igeo ≤ 2 – moderately contaminated; 2 ≤ Igeo ≤ 3 –

moderately to heavily contaminated; 3 ≤ Igeo ≤ 4 – heavily contaminated; 4 ≤ Igeo ≤ 5 – heavily to extremely contaminated; and 5 < Igeo – extremely contaminated [5,8,13–15,34,35].

2.1.1. Application

Zeghouan et al. collected thirty-six soil samples of urban and peri-urban from Setif city, eastern Algeria, and determined cadmium, chromium, copper, lead, and zinc. Igeo was calculated for all metals using the background values established by the Chinese Environmental Protection Administration (CEPA, 1995) [36] because there is no background value defined for these elements in this city. The minimum, average and maximum values found for the Igeo for chromium are (−3.08), (−1.24), and (0.13), respectively. The authors concluded that has no anthropogenic contamination by chromium in this city, considering that of the 36 samples analyzed, only 1 showed an Igeo value greater than zero (0.13) [37]. For zinc, the situation is quite different. Of the 36 samples analyzed, only 3 reported Igeo values lower than 1, being that the minimum, average and maximum values for Igeo were (−0.93), (1), and (2.08). So, the authors concluded that Setif city is moderately polluted by this metal [37]. Also, it was observed for all metals that the lowest Igeo values were recorded for the samples collected in the peri-urban area, where can be found intense agricultural activities and animal habitats and breeding. The high Igeo values found for zinc (1.96) and lead (3.30) at station 32 can be explained by the proximity of the sampled site to the city's industrial zone [37].

2.1.2. Application

Liu et al. evaluated the presence of chemical elements in the surface sediment of the Yellow River Estuary, China. Vanadium, chromium, manganese, cobalt, iron, nickel, copper, zinc, cadmium, and lead were quantified by inductively coupled plasma-mass spectrometry. The sampling step was performed with collections in summer and autumn at twelve stations along the river. Igeo index was calculated for all elements. The Igeo values for lead varied from (−3.4) to (−1.4), evidencing that this metal did not contaminate the intertidal zone of the river [38]. However, Igeo values for cadmium in autumn showed contamination, where eleven of the twelve samples collected, the Igeo values were higher than 1. The summer samples also presented contamination, but the degree was lower than in autumn [38].

2.2. Enrichment factor (EF)

The enrichment factor (EF) is a tool that makes it possible to evaluate the influence of anthropogenic sources on the environment [6,35,39, 40]. This factor determines the normalization of the concentration of an element whose contamination is evaluated against the concentration of a reference metal with low variability of occurrence in the earth's crust. The referenced metals are aluminum, calcium, iron, manganese, scandium, and titanium. However, the most employed are manganese, aluminum, and iron [6,8,13,39].

EF is calculated by the following equation:

$$EF = \frac{(C_n/C_M)_{sample}}{(C_n/C_M)_{background}}$$

Where (C_n/C_M) is the ratio between the concentration of element n (C_n) and the concentration of the reference metal (C_M) in the sediment sample. The (C_n/C_M) background is the ratio between the background concentrations of the element n and the reference metal.

The EF has 5 classes: EF ≤ 2, Minimal mineral enrichment deficiency; 2 < EF ≤ 5, Moderate enrichment; 5 < EF ≤ 20, Significant enrichment; 20 < EF ≤ 40, Very high enrichment; EF > 40, Extremely high enrichment. Soil and sediment contamination can also be expressed as the percent enrichment factor (%EF).

2.2.1. Application

Cerda et al. determined aluminum, chromium, copper, iron, manganese, nickel, lead, tin, and zinc in marine sediments from Palma de Mallorca Bay, Spain. Samples were collected in ten sites from different regions of the bay. The contamination was evaluated employing the Enrichment Factor. The mean EF values for copper, manganese, nickel, and tin are 3, 5, 3, and 2, respectively, demonstrating moderate contamination from anthropogenic sources. For lead, the EF values between stations 1–7 (ship traffic and mooring) ranged from 14.7 to 56.4, with an average of 39, showing substantial contamination. In the tourist area, the EF values were 4.5, 4.5, and 5.5, indicating moderate contamination [41].

2.2.2. Application

Arisekar et al. collected sediment samples in five sites from the Thamirabarani River located in the Western Ghats of South India. Cadmium, arsenic, lead, cobalt, zinc, nickel, chromium, and manganese were determined by ICP-MS. The EF values for all elements were less than 0.07, except for cadmium, which ranged from 0.0671 to 0.3343. These results showed that the concentrations of the chemical elements in this river were not affected by anthropogenic sources, considering that EF values lower than 2 indicate that the levels of the elements are derived from natural sources [42].

2.3. Contamination factor (CF)

The contamination factor (FC) is quantified by the ratio between the concentration of a chemical element whose contamination is being evaluated and its preindustrial concentration in the region under study [7]. This index is calculated by the equation:

$$CF = \frac{[X]_{sample}}{[X]_{preindustrial\ concentration}}$$

Where $[X]_{sample}$ is the concentration of the element in the soil or sediment samples, $[X]_{preindustrial\ concentration}$ is the preindustrial concentration of the element studied. Preferably, the $[X]_{sample}$ should be an average value of at least five sampling sites [8]. The EF values show the level of contamination with the following coding: low contamination (CF < 1), moderate contamination ($1 \leq$ CF ≤ 3), considerable contamination ($3 \leq$ CF ≤ 6) and very high contamination (CF ≥ 6) [7,8,13].

2.3.1. Application

Monte et al. [43] investigated the contamination by heavy metals in estuarine sediments from Iguaçu and Meriti Rivers, Rio de Janeiro, Brazil. Cadmium, chromium, copper, iron, manganese, nickel, lead, and zinc were determined by employing ICP OES. The contamination factor was one of the indexes employed to evaluate the contamination of these rivers. The results demonstrated that zinc shows high contamination for both rivers (CF > 6), being that the contamination for the Meriti River is higher than for the Iguaçu River. All the results of the CF for cadmium are lower than three, which demonstrates that this metal presents moderate contamination for the two rivers. In the Iguaçu River, the CF values for lead are (< 6), demonstrating considerable contamination. However, in the Meriti River, CF varied from 10.04 to 16.02, evidencing high contamination of this ecosystem by lead. The CF values for nickel are lower than 1 for the Iguaçu River, which means the absence of contamination, varying from 2.65 to 3.03, presents moderate contamination by this metal in the Meriti River [43].

2.3.2. . Application

Usese et al. used the geo-accumulation (*IGeo*), enrichment, and contamination factors (CF) to evaluate the arsenic contamination in sediment samples collected from a Tropical Open Lagoon in Southwest Nigeria. The sample project involved 15 stations. The *IGeo* values varied from − 5.10 to − 1.86, which means that the investigated lagoon is

practically uncontaminated. By another hand, the contamination factor varied from 0.04 to 0.34. These values evidenced that this ecosystem has low contamination [44].

2.4. Pollution index (PI)

PI is an index single that evaluates the pollution of soils and sediments. Its equation of calculation is defined by:

$$PI = \frac{[X]_{sample}}{CB}$$

Since [x] is the element concentration, CB is the element's background in the region studied. The coding established to estimate pollution is: unpolluted, low level of pollution (PI < 1), moderate polluted ($1 \leq$ PI ≤ 3), strong polluted (PI ≥ 3). In addition to the background concentration, PI also uses other reference values: preindustrial level, average crust level, baseline level, values of national criteria, or threshold pollution values [13].

2.4.1. Application

Ayoko et al. collected sediment samples in twenty-two different sampling sites from Brisbane River, Australia. Then, the chemical elements were determined: silver, arsenic, calcium, cadmium, copper, cobalt, mercury, manganese, nickel, lead, and zinc. Afterward, the pollution index (PI) was applied to the contents found of the elements investigated. Three of the twenty-two sampling stations had PI values lower than 1, attributing to these sites a low pollution level. The PI values for the other nineteen stations varied from 1.1 to 2.7, denoting a pollution level moderate. This way, it was concluded that the Brisbane River has moderate pollution [45].

3. Integrated indices

3.1. Pollution load index (PLI)

A pollution load index is a tool that has been used to evaluate the quality of water, soil, and sediment [11,35,46,47], is calculated by the nth root of the multiplication of the contamination factors of the investigated chemical elements, as the following expression:

$$PLI = (CF_1 \times CF_2 \times \ldots \times CF_n)^{1/n}$$

Where, CF_1, CF_2, and CF_n are the contamination factors of the elements 1, 2, and n. This index classifies the soil or water into three categories, which are: Polluted (PLI > 1), Baseline levels of pollution (PLI = 1) and, Not polluted (PLI < 1).

3.1.1. Application

Jahan and Strezov collected sediment samples of six seaports from Australia and quantified the following chemical elements arsenic, copper, nickel, lead, zinc, cadmium, chromium, and manganese. Afterward, the pollution was evaluated by employing the Pollution load index (PLI). The results obtained were: Port Jackson (PLI = 1.02), Port Yamba (PLI = 0.01), Port Botany (PLI = 27.99), Port Kembla (PLI = 2.91.1013), Port Newcastle (PLI = 6.09.1011), and Port Eden (PLI = 1.21.1019). The PLI values found demonstrated that the studied ports are heavily polluted (PLI > 1), except Port Jackson (PLI = 1.02) pollution at baseline level and Port Yamba (PLI = 0.01) not polluted [48].

3.2. Degree of contamination (C_{deg})

The degree of contamination is an evaluation tool of contamination in soil and sediment. It is a complex index, which is calculated by the following equation:

$$C_{deg} = \sum_{i=1}^{n} CF_i$$

where CF_i is the contamination factor for each element (i) investigated. This index classifies the soil into four categories of contamination that are: Low degree of contamination ($C_{deg} < 8$), Moderate degree of contamination ($8 \leq C_{deg} \leq 16$), Considerable degree of contamination ($16 \leq C_{deg} \leq 32$), Very high degree of contamination ($32 \leq C_{deg}$) [7,12].

3.3. Modified contamination factor (mC_{deg})

Modified Contamination Factor is a multielement index used to assess soil and sediment contamination [9]. This classifies the soil on a seven-order scale of contamination, which is: very low contamination ($mC_{deg} \leq 1.5$), Low contamination ($1.5 \leq mC_{deg} \leq 2$), Moderate contamination ($2 \leq mC_{deg} \leq 4$), High contamination ($4 \leq mC_{deg} \leq 8$), Very high contamination ($8 \leq mC_{deg} \leq 16$), Extremely high contamination ($16 \leq mC_{deg} \leq 32$), Ultra-high contamination ($32 \leq mC_{deg}$).

This index is calculated using the following equation:

$$mC_{deg} = \frac{1}{n} \sum_{i=1}^{n} CF_i$$

where n is the number of elements evaluated and CF is the contamination factor for each element (i) individually [9,49,50].

3.3.1. Application

Surface sediment samples from the Gulf of Mexico were collected, and the chemical elements arsenic, copper, zinc, cobalt, chromium, and vanadium were quantified. Then, contamination factors (CF) were calculated for the investigated elements. The CF values obtained for the Antigua River were 0.99 for vanadium, 1.02 for chromium, 1.05 for cobalt, 0.64 for nickel, 1.57 for copper, 1.32 for zinc, and 6.59 for arsenic, 0.95 for cadmium and 0.95 for lead [49].

Degree of contamination = (0.99 + 1.02 + 1.05 + 0.64 + 1.57 + 1.32 + 6.59 + 0.95 + 0.95) = 15.08.

A value of 15.08 for the degree of contamination demonstrates that the evaluated ecosystem has a moderate degree of contamination according to the classification established by this index. A moderate degree of contamination ($8 \leq C_{deg} \leq 16$) [49].

$$\text{Modified Contamination Factor} (mCdeg) = \frac{15.08}{9} = 1.67$$

The Modified Contamination Factor evidenced that the Antigua River has low contamination by the studied elements considering the terminology (Low contamination $1.5 \leq mC_{deg} \leq 2$) [49].

3.3.2. Application

Swarnalatha et al. evaluate the contamination of sediment samples collected from a shallow lake in southern India. Lead, zinc, chromium, cobalt, nickel, and copper were determined in 10 sampling stations. The contamination factor values in the Stations 4 and 5 are shown in Table 1 [51].

Pollution Load Index (PLI).
PLI – Station 4 = $(0.68 \times 0.21 \times 0.62 \times 0.64 \times 0.30 \times 1.11)^{1/6}$ = 0.52.
PLI – Station 5 = $(1.61 \times 0.84 \times 4.16 \times 4.18 \times 1.37 \times 4.00)^{1/6}$ = 2.25.

PLI with a value of 0.52 denotes that Station 4 has a condition of not polluted. However, the PLI value of 2.25 means that Station 5 has a pollution level.

Degree of contamination.
Station 4 = (0.68 + 0.21 + 0.62 + 0.64 + 0.30 + 1.11) = 3.56 ($C_{deg} < 8$).
Station 5 = (1.61 + 0.84 + 4.16 + 4.18 + 1.37 + 4.00) = 16.16 ($8 \leq C_{deg} \leq 16$).

The C_{deg} value for the station 4 evidenced that this region ok lake has low degree of contamination. However, the Station 5 has a moderate degree of contamination.

Modified Contamination Factor.
Station 4

$$Cdeg = \frac{(0.68 + 0.21 + 0.62 + 0.64 + 0.30 + 1.11)}{6}$$
$$= 0.59$$

Station 5

$$Cdeg = \frac{(1.61 + 0.84 + 4.16 + 4.18 + 1.37 + 4.00)}{6}$$
$$= 2.69$$

Station 4 showed a mC_{deg} value of 0.59, which also evidences a condition of very low contamination for this sampling point. Despite this, the mC_{deg} value for the Station 5 was 2.69 denoting moderate contamination in this region.

4. Ecological risk

4.1. Ecological risk factor (E_r^i)

This index numerically presents the ecological risk of a chemical element on soil or sediment studied. Hakanson proposed it in 1980 [7] and the equation used for the calculation is:

$$E_r^i = T_r^i x CF^i$$

Where, T_r^i is the toxic-response factor of a contaminant chemical element and CF^i is the contamination factor of this element. The toxic-response factor values as Hakanson [7] are shown in Table 2. This index classifies the chemical element in five categories: low ecological risk ($E_r^i < 40$), moderate ecological risk ($40 \leq E_r^i < 80$), considerable ecological risk ($80 \leq E_r^i < 160$), high ecological risk ($160 \leq E_r^i < 320$), serious ecological risk ($E_r^i \geq 320$) [7,10,13].

4.1.1. Application

The single ecological risk indices are compatible with the contamination factor results found by Monte et al. [43], discussed in item 3.2.1. The E_r^i values for the nickel varied from 2.80 to 29.64, evidencing a low ecological risk from this metal for both rivers because of $E_r^i < 40$. For the cadmium, there are two situations: In the Iguaçu River, E_r^i varied from 16.73 to 48.93, denoting a low ecological risk. By another hand, in the Meriti River, the E_r^i values were 67.76–95.30, which means moderate to considerable ecological risk. The results for lead in the two rivers are also consistent with the conclusions relative to the contamination factor. All the E_r^i values for the Iguaçu River are lower than 40, representing a low ecological risk, but in the Meriti River, the E_r^i values were in the range of 50.20 and 76.17, showing a greater ecological risk for this ecosystem relative to the lead, considering that moderate ecological risk

Table 1
The contamination factor values in stations.

Station	Chromium	Nickel	Copper	Zinc	Cobalt	Lead
4	0.68	0.21	0.62	0.64	0.30	1.11
5	1.61	0.84	4.16	4.18	1.37	4.00

Table 2
Pre-industrial reference level (µg g^{-1}) and toxic-response factor [7,10].

Elements	Hg	Cd	As	Cu	Pb	Cr	Zn
Pre-industrial reference level	0.25	1.0	15	50	70	90	175
Toxic-response factor	40	30	10	5	5	2	1

$(40 \leq E_r^i < 80)$.

4.2. Potential ecological risk index (PERI)

This index assesses the ecological risk related to all chemical elements present in the studied region, determined by the sum of the individual ecological risks of these elements, as the following equation [13,52].

$$PERI = \sum E_r$$

PERI classifies soils and sediments into four categories, namely: low ecological risk (PERI < 150), moderate ecological risk (150 < PERI < 300), high potential ecological risk (300 < PERI < 600), significantly high ecological risk (PERI $\geq$ 600).

4.2.1. Application

Monte's work [43] also assessed integrated ecological risk (PERI). In the Iguaçu River, this index ranged from 54.73 to 144.44, and in the Meriti River, from 240.73 to 336.89, meaning that the Iguaçu River has a low ecological risk (PERI < 150). On the other hand, the Meriti River presents a moderate ecological risk (150 < PERI < 300). This PERI index denotes the degree of risk but does not determine which heavy metal most influences the environmental problem.

4.2.2. Application

Silva Junior et al. collected sediment samples from Joanes River, Bahia State, Brazil. The sampling involved ten stations in the dry and rainy periods. Cadmium, copper, chromium, nickel, lead, and zinc were determined by employing ICP OES. The ecological risk of this river was evaluated using the potential ecological risk index. The results showed that the environment analyzed has low ecological risk (PERI < 150). In addition, the ecological risk in the dry season is lower than the ecological risk in the rainy period, except for a station [53].

4.2.3. Application

The Contamination factor values found by Swarnalatha in Stations 4 and 5 were employed to evaluate the ecological risk of the lake as the single index for the metals (copper, lead, zinc, and chromium) the integrated index (PERI). Table 3 shows the calculations of these indexes.

5. Speciation analysis and the toxicity of the chemical elements

Most the contamination and ecological risk assessment works estimate the indices using the values of the total concentrations of the chemical elements. However, in some cases, the conclusions can generate false negatives. This concern appears mainly for chemical elements whose toxicity varies with the oxidation number. A classic example is the chromium metal, whose oxidation state of species (VI) is considerably more toxic than species (III) [54]. Mercury also constitutes a typical case. Organic mercury species are considerably more toxic than inorganic species [55,56]. Antimony is present in oxidation states (III) and (V). Many authors have stated that antimony(III) species is ten times more toxic than antimony(V) [57]. Arsenic has similar behavior to antimony. Arsenic(III) is more toxic than arsenic(V), which is more toxic than organic species mono-methanearsonate (MSMA) and dimethylarsinic (DMA) [58]. In these cases, the most advisable thing would be to determine the indices from the concentrations of the most critical species in terms of contamination. If this is not possible, one should at least investigate the chemical forms of the elements that prevail in the analyzed samples. This way, some authors have used sequential extraction procedures and speciation analysis to determine these indices [59–62].

Table 3

Integrated ecological risk calculations [7,51].

STATION 4	Chromium	Copper	Zinc	Lead	PERI
Contamination Factor	0.68	0.62	0.64	1.11	
Toxic-response factor	2	5	1	5	
Ecological risk factor	1.36	1.24	0.64	5.55	**8.79**
STATION 5	Chromium	Copper	Zinc	Lead	**PERI**
Contamination Factor	1.61	4.16	4.18	4.00	
Toxic-response factor	2	5	1	5	
Ecological risk factor	3.22	20.80	4.18	20.00	**48.20**

The PERI values of 8.79 and 48.20 for Stations 4 and 5 mean that these lake regions have low ecological risks, considering both indexes are lower than 150.

6. Conclusions

The efficiency of the results obtained while applying these indices depends on the quality of the data obtained during the determinations of the chemical elements in the matrix studied.

The assessment of contamination and ecological risk of an ecosystem can be done using the single and integrated indices of pollution, but fundamentally taking into account other issues such as industrial and agricultural development, climatic conditions, sanitary sewers, land traffic, and river traffic from region studied.

Despite the importance and wide use, in some situations, the use of these indices is difficulted to the followings questions: (i) the calculations of the Geoaccumulation Index and Enrichment factor for the metal in soil or sediment require the background value of this metal from the region studied. However, this parameter is not always known for the region under study. When this occurs, the background value of the earth's crust is used, which can establish a conclusion with a false negative. (II) The Contamination factor and the Pollution load index are tools employed to estimate the degree of contamination by one or several chemical elements present in a studied environmental region. These indices are calculated as a function of the background value of the respective chemical elements in the area investigated. The difficulty occurs because sometimes the background value is unknown for this region. So, the background value of the earth's crust is used for the calculations.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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