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Pollution and Ecological Risk Assessment of Heavy Metals in the Agricultural Soils Around a Gold Mine in BISSA Village, Burkina-Faso

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Abstract: Mining is considered to be one of the most important sources of environmental pollution when it comes to heavy metals. Mining causes the release of large quantities of mercury, arsenic and other elements into the environment and naturally poses a serious threat to the environment. The objective of this study is to assess heavy metal contamination and the ecological risks of agricultural soils around a gold mine, mainly in Bissa, a village in the commune of SABCÉ. Twelve (12) soils samples were collected on the surface, in depths of 0 to 15cm. Seven heavy metals (Cr, Ni, Cu, Zn, As, Hg and Pb) were analyzed by atomic absorption spectrometry. From the concentrations of these metals and on the basis of the geochemical background described by Wedepohl and Turekian (1961); the geo-accumulation index (Igeo), the degree of contamination (DC), the pollution load index (PLI), the risk factor (RF) and the potential ecological risk index (RI) were evaluated. The results revealed that the average concentrations of metals obtained were classified in descending order Cr>Zn>Cu>As>Ni>Pb>Hg with the respective values 102.3mg/kg, 58.513mg/kg, 57.133mg/kg, 49.73mg/kg, 38.873mg/kg, 17.943mg/kg and 3.83mg/kg. Mean concentrations of Cr, Cu, As and Hg exceeded their respective geochemical background values, and only arsenic was above the WHO/FAO standard. The geo-accumulation index showed that 75% of the soil samples were heavily polluted with mercury (Hg). The potential ecological risk index showed that 75% of the soil samples presented a considerable ecological risk, and 8.33% presented a very high ecological risk.

Keywords: *soil, heavy metals, pollution, ecological risk, gold mine*

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1. Introduction

Rapid urbanization, industrial progress, agricultural practices, mining activities are the source of the emission of pollutants such as heavy metals and persistent organic pollutants in the environment [1,2,3]. Heavy metals are one of the major pollutants due to these entropic activities of man [4]. Ubiquitous, persistent and non-biodegradable, heavy metals easily accumulate in soil, plants and in all living organisms [5,6]. Accumulated in the soil, through their toxicity, they modify its biological functions, poison the fauna and flora and the waters, thus constituting a potential danger to human health via the food chain [7,8,9,10].

Among the entropic activities of man, mining is one of the major sources of environmental contamination by heavy metals [11]. This is why in recent decades, around the world, several studies have focused on the assessment of heavy metals in mining soils or near mining sites. Relatively high quantities of heavy metals such as cadmium, chromium, nickel, copper, zinc, arsenic, mercury or lead have been detected in the soils of several countries in Africa and the rest of the world: Ivory Coast [12], Nigeria [13,14], Cameroon [15], South Africa [16], China [17,18], Spain [19], Iran [20].

Burkina Faso is not exempt from this mining pollution because the country has experienced a mining boom since 2009 and gold has become its first export product [21,22]. Today, the country is the fifth largest gold producer in Africa [23]. Consisting mainly of gold mining, the mining sector represents 43% of exports and globally employs 1.3 million people. This activity is distinguished by a coexistence between industrial mines and artisanal mines. The industrial sector had 26 mines, 16 of which operated

for a production of 50.3 tonnes in 2019. The artisanal sector, poorly known, had around 800 sites and produced 9.5 tonnes per year [24]. Distributed throughout the national territory, the Center-North has five (5) industrial mines, including one in Sabcé where the populations live mainly from agriculture. In view of the potential emission of heavy metals by mining activities and its corollary of associated ecological and health risk, it is therefore necessary to identify and know the level of contamination of these metals in the soils around the sites. mining. This is why our study aims to assess the spatial, quantitative and qualitative distribution of heavy metals in the agricultural areas surrounding the mine in order to assess the associated ecological risks.

2. Materials and Methods

2.1. Study Aera

SABCÉ is a department of Burkina Faso in the province of Bam in the north-central region, 100 km from the capital (Ouagadougou). It is located at $13^0$11'52'' north latitude and $1^0$31'18'' west longitude. It is also a rural commune with wan area of 373 km^2 made up of 30 villages, including BISSA.

This region is characterized by a semi-arid and hot climate, which results in two seasons: a dry season between October and May, and a rainy season from June to September. Rainfall is on average 600 mm over 10 years, but with significant fluctuations. The life of the inhabitants of SABCE is strongly impacted by the level of rainfall, as agriculture and livestock are the main sources of subsistence for the inhabitants.

2.2. Sampling, Preparation and Analysis

2.2.1 Sampling

Soil samples were taken around the mine located in Bissa. Twelve (12) soils samples were taken from depths of 0 to 15 cm. Each sampling point was identified using a GPS. For a given position, the sample is taken from two different places, then homogenized and then packed in a sterile plastic collection bag. The samples thus formed are labelled and numbered from S1 to S12 and transported to the laboratory.

2.2.2. Preparation and Analysis of Samples.

Soil samples were dried in the sun and then sieved to remove impurities. This is followed by quartering, which consists of taking sub-samples representative of the master samples. Next, the mechanical preparation which consisted of pulverizing (grinding) and then sieving the soil samples through a certified 200 mesh (75 micron) sieve. Samples of one (1) gram were made using a balance with a capacity of 200 g and an accuracy of 10^{-4} g, then digested. The mineralization which consisted in introducing the test sample into a test tube then adding 2.5 ml of nitric acid (HNO_3) and 7.5 ml of hydrochloric acid (HCl). The mixture thus obtained was placed in a water bath at 90 ± 5° C, for one hour. The solution obtained was inverted into a 100 ml volumetric flask, then topped up with pure water up to the mark, and homogenized by stirring. Finally, each solution was subjected to decantation and then sampled for analysis by atomic absorption.

2.3. Methods

To assess the ecological risks, four (4) pollution indices (the contamination factor, the degree of contamination, the pollutant load index and the geo-accumulation index) and the ecological risk and potential ecological risk indices were determined.

2.3.1. Contamination Factor, CF

The contamination factor shows the existence or absence of soil contamination by a given heavy metal. It also makes it possible to estimate the level of contamination if it exists [25,26]. CF is expressed as the ratio between the concentration of the element measured in the medium and the reference or background concentration according to [27]. Mathematically, the contamination factor is given by relation (1) [17,25,28,29,30]:

$$CF = \frac{C_n}{C_b} \quad (1)$$

C_n is the metal concentration in the sample and C_b is the geochemical background value. [27] classified contamination into four (4) levels [25,26,31]. This classification is presented in Table 1.

2.3.2. Degree of Contamination (DC)

The degree of contamination (DC) is the sum of the contamination factors (CF). It allows the estimation of the a priori polymetallic contamination for each sampling location. This degree of contamination is expressed by formula (2) [32,33,34]:

$$DC = \sum_{i}^{n} (CF)_i \quad (2)$$

$(CF)_i$ designates the contamination factor of the metal i considered.

In Table 1, the level of contamination is evaluated according to DC [27]:

Table 1. Level of contamination according to DC

CF values	DC values	Contamination intensity
$CF \leq 1$	$DC \leq 8$	Low
$1 \leq CF \leq 3$	$8 \leq DC \leq 16$	Moderate
$3 \leq CF \leq 6$	$16 \leq DC \leq 32$	Considerable
$CF \geq 6$	$DC \geq 32$	Very high

2.3.3. Pollution Load Index (PLI)

The pollution load index is a powerful tool in the assessment of heavy metals [35]. Proposed by Tomlinson (1980), it is an empirical index that comparatively evaluates the level of heavy metal pollution for each sampling site [25,29,36]. It is determined by relation (3) [36]:

$$PLI = \sqrt[n]{CF_1 \times CF_2 \times CF_3 \ldots \times CF_n} \quad (3)$$

In this expression, CF_i is the contamination factor of the considered metal i and n=7. Its value makes it possible to give the following interpretations [25,33,37,38]: PLI < 1 (unpolluted soil), PLI = 1 (level of pollution reference) and PLI > (polluted soil).

2.3.4. Evaluation of Potential Ecological Risk (RI)

The Potential Ecological Risk Index is a comprehensive method relating all heavy metals to their toxicological effects. While considering geochemical background heavy metal content, it also comprehensively considers the synergy of several elements: contaminant concentrations, differences in biological toxicity of each element, ecological effects, and environmental sensitivity related to pollution. by heavy metals [39,40]. This method is widely used in the assessment of sediment pollution [41], air [42] and soil [40,43]. Indeed RI results from the sum of all the ecological risk factors (Er) linked to each heavy metal. The ecological risk factor (Er) expresses quantitatively the ecological danger associated with each metal. Corroborated by [40, 44], Er and RI are given by the formulas (4, 5 and 6) of [27]:

$$E_r = T_r.CF \quad (4)$$

$$CF = \frac{C_n}{C_b} \quad (5)$$

$$RI = \sum_{r=1}^{n} E_r \quad (6)$$

The toxicity response factors (Tr) of the trace elements studied (As, Cd, Cu, Cr, Hg, Pb, Zn and Ni) are respectively 10; 30; 5; 2; 40; 5; 1 and 5 [41,45]. The interpretations of the values of potential ecological risks according to Hakanson (1980) [27] and by many other researchers [40,41,44] are presented in table (2):

Table 2. Interpretation of ecological index and potential ecological risks

Ecological risk factor	Level of ecological risk	Index of potential ecological risk	Level of potential ecological risk
Er<40	Low	RI<150	Low
40≤Er<80	Moderate	150≤RI<300	Moderate
80≤Er<160	Considerable	300≤RI<600	Considerable
160≤Er<320	High	RI≥600	Extremely high
Er≥320	Extremely high		

2.3.5. Geoaccumulation Index

Established by [45], this index is used to determine the influence of anthropogenic factors on the levels of a heavy metal in a given topsoil sample [44,46]. According to [46,47], it is calculated by relation (7):

$$I_{geo} = \log_2 \frac{C_n}{1,5C_b} \quad (7)$$

C_n is the metal concentration, C_b is the geochemical background value of the metal [48], the constant 1.5 is the correction factor that compensates for the natural fluctuations of a given metal while minimizing anthropogenic impacts [15].

Furthermore, the numerical values of this index are associated with the seven classes presented in Table 3 [15,49,50].

Table 3. Scale of pollution associated with the values of Igeo

Values	Pollution level
$I_{geo} < 0$	Background concentration
$0 \leq I_{geo} < 1$	Unpolluted
$1 \leq I_{geo} < 2$	Unpolluted to moderately polluted
$2 \leq I_{geo} < 3$	Moderately polluted
$3 \leq I_{geo} < 4$	Moderately to highly polluted
$4 \leq I_{geo} < 5$	Highly polluted
$I_{geo} \geq 5$	Very highly polluted

3. Results and Discussion

3.1. Evaluation of Heavy Metals in Soil Samples

Seven heavy metals (Cr, Ni, Cu, Zn, As, Hg and Pb) were analyzed in the 12 soil samples taken from the study area. The mean, maximum, minimum, standard deviation and coefficient of variation of concentrations obtained are recorded in Table 4.

Chromium concentrations in agricultural soils in Sabcé ranged from 51.46 mg/kg to 222.27 mg/kg with an average of 102.30 mg/kg. The nickel concentrations were between 22.65 mg/kg and 55.23 mg/kg with an average value of 38.87 mg/kg. The average copper concentration was 57.13 mg/kg, the maximum 107.8 mg/kg and the minimum 25.04 mg/kg. Zinc concentrations ranged from 37.54 mg/kg to 92.2 mg/kg with an average of 58.51 mg/kg. Arsenic levels fluctuated between 8.98 mg/kg and 194.74 mg/kg with an average value of 49.67 mg/kg. The mean mercury concentration was 3.83 mg/kg, maximum 5.58 mg/kg and minimum 00 mg/kg. The maximum and minimum concentrations of lead were respectively 22.74 mg/kg and 12.81 mg/kg and the average value was 17.94 mg/kg. The average concentrations obtained were classified in descending order: Cr>Zn>Cu>As>Ni>Pb>Hg.

Table 4. Average concentration of heavy metals in the soils of the Bissa area

	Cr	Ni	Cu	Zn	As	Hg	Pb
Mean	102.30	38.87	57.13	58.51	49.67	3.83	17.94
Maximum	222.27	55.23	107.88	92.26	194.74	5.58	22.74
Minimum	51.46	22.65	25.04	37.54	8.98	0.00	12.81
Standard deviation	50.87	12.02	30.43	19.15	62.88	1.45	2.96
CV	49.73	30.93	53.27	32.73	126.58	37.99	16.49

The degree of human influence on metal concentrations can be estimated by the coefficient of variation [40,51,52]. The coefficient of variation is a statistical quantity which expresses the dispersion around the mean as a percentage. Depending on the scale in which its value is entered, the following interpretations are available [40]: If CV<10% then the variation is low; if 10%≤CV≤30% then the variation is moderate; if CV>30% then the variation is significant or strong.

In this study, the coefficient of variation decreases in the following order: As (126.57%) > Cu (53.27%) > Cr (49.73%) > Hg (37.99%) > Zn (32.73%) > Ni (30.93%) > Pb (16.49%). Most of heavy metal (Cu, Cr, Hg, Zn, and Ni) show strong variation. Arsenic (As) shows a very strong variation because CV (As) >75% [53] and lead which has a moderate variation. The very high variation of arsenic (As) implies a heterogeneous distribution of this metal which can be directly attributed to human activities [53,54]. A number of human activities have the potential to increase local arsenic concentrations in air, water and soil. Arsenic (As) is one of the most common pollutants in soil near gold mines with high concentrations and high variability [55]. It then happens that the agricultural soils of Bissa would have been strongly affected by the Bissa gold mine. The relatively moderate variation of Pb assumes a relatively stable spatial distribution of Pb which is moderately dependent on the human factor [56].

3.2. Comparison of Average Concentrations to Standards

The mean concentrations of heavy metals obtained in this study were compared to the standards of the FAO/WHO, and of certain countries such as Nigeria, South Africa, Holland and Canada. These standards are listed in Table 5.

Table 5. Comparison of average concentrations of heavy metals with standards

	This study	FAO/ WHO	Holland (Target Value)	Nigeria	South Africa	Canada
Cr	102.3	100	100	100	0	64
Ni	38.9	50	35	35	91	50
Cu	57.12	100	36	36	16	63
Zn	58.51	300	140	140	200	200
As	49.7	20	29	1	5.8	12
Hg	3.823	-	0.3	0.3	0.93	6.6
Pb	17.94	20	85	85	20	70
Reference		[57]	[58,59]	[60,61]	[62,63]	[64,65]

The mean concentration of chromium obtained during this study was higher than the standard of FAO/WHO, Holland, Nigeria, South Africa and Canada. The mean value of nickel concentration was only slightly above Dutch and Nigerian standards. The limit concentration recommended by the FAO/WHO and the Canadian standard for copper was higher than that the concentration obtained in this study. The concentrations of zinc and lead in the studied soils were below all standards (Table 5). It is therefore deduced that the studied agricultural soils were not contaminated by Zn and Pb. On the other hand, the mean concentration of arsenic in the analyzed samples was above all these standards, which suggests that the agricultural soils from Bissa were contaminated with arsenic. The average mercury concentration was only below the Canadian standard.

The Dutch Soil Quality Standard is considered the most appropriate guideline indicating all possible exposure pathways for the protection of humans, plants and animals [58,59]. The soil is considered unpolluted by a metal if its concentration is lower than its reference value, it is weakly to moderately polluted if the level is between the reference value and the intervention value. On the other hand, if the content of the metal is above the intervention value, the soil is considered detrimental to humans, plants and animals [59]. Considering the mean concentrations of metals (Table 5), it can be deduced that the sampling site at Bissa was classified as slightly to moderately polluted by Cr, Ni, Cu, As and Hg and not polluted by Pb, and consequently, the site of is in no way detrimental to biota and humans.

3.3. Comparison of the Mean Concentrations of Heavy Metals with the Values Reported by Similar Studies in other Countries

Table 6. Average concentrations of heavy metals in soils near gold mines in other countries

	This study	Marocco	South Africa	China
Cr	102.3	1.2	278.76	13.34
Ni	38.9	6.2	4.79	24.98
Cu	57.12	58.5	42.51	55.9
Zn	58.51	47.6	51.30	57.5
As	49.7	-	79.40	43.30
Hg	3.823	-	0.09	0.53
Pb	17.94	-	112.06	17.73
References		[66]	[16]	**[67]**

The data recorded in Table 6 show that the soils from Bissa were more contaminated with nickel than the soils of South Africa, Morocco and China. The mean concentration of lead (17.73) recorded in China in agricultural soils around a gold mining area in Yitong County [64], corroborates that of our study. On the other hand, that reported in South Africa [16] was well above that of this study. The mean of mercury concentration recorded in the soils from Bissa was high compared to the mean concentrations obtained in similar studies carried out in China [67] and South Africa [16]. The agricultural soil of Bissa was slightly contaminated in arsenic compared to the soil of Yitong county, in China [67] however, it was less contaminated than that of South Africa. The mean concentration of zinc obtained was higher than those obtained in South Africa [16] and Morocco [66] but in line with that recorded in China. The mean concentration of copper obtained in this study remained above those in South Africa and Morocco, however, it was close to that reported in China. As for the mean concentration of chromium obtained in this study, it turned out to be well above those obtained in Morocco and China, but too low compared to the result of South Africa.

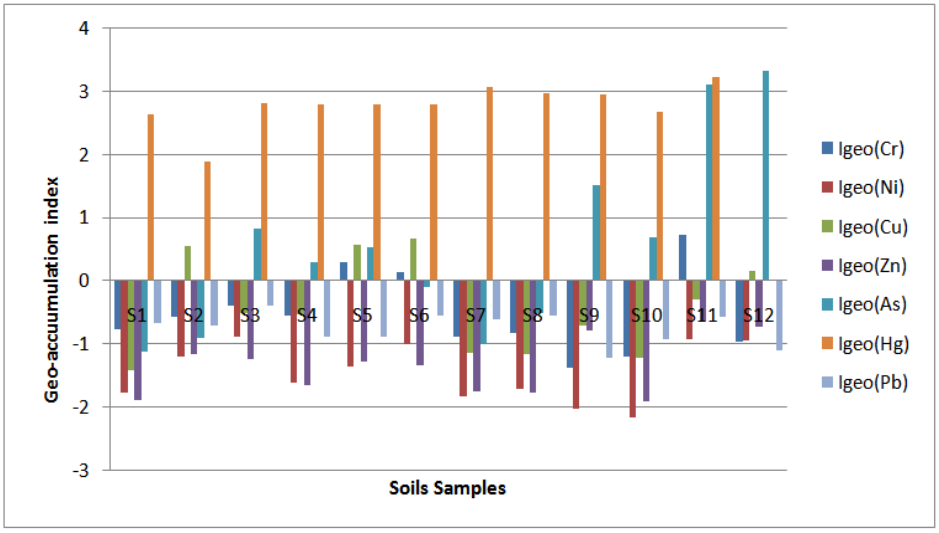

Figure 1. Geoaccumulation index in soil samples.

3.4. Ecological Risk Assessment

3.4.1. Geo-Accumulation Index

The geo-accumulation index (Igeo) of each metal in each sample is represented in Figure 1.

The geo-accumulation indices of heavy metals were in the following ranges: -1.391 to 0.719 for Cr; -2.171 to -0.885 for Ni; -1.431 to 0.676 for Cu; -1.924 to -0.627 for Zn; -1.119 to 3.320 for As; 1.874 to 3.217 for Hg and -1.228 to -0.400 for Pb. The average values of the geo-accumulation indices were arranged in the order: Hg (2.766)>As (0.553)>Cu (-0.425)>Cr (-0.537)>Pb (-1.228)>Zn (-1.352) >Ni (-1.458).

The fluctuations of the geo-accumulation index of heavy metals from the different sampling points are shown in Figure 1. The values of geo-accumulation indices of Ni, Zn and Pb were all negative, suggesting that no sample from the study area was not polluted by Ni, Zn and Pb.

Two (2) samples (S5 and S11) out of twelve (12) had their Igeo in Cr between 0 and 1, and the ten (10) samples had their Igeo negative. So all the soil samples from Bissa were unpolluted in Cr.

In accordance with the values of the Igeo of As, five (5) samples (S1, S2, S6, S7 and S8) out of twelve (12) were classified as background concentration, four samples (S3, S4, S5 and S10) were classified as unpolluted, only one sample (S9) was unpolluted to moderately polluted and the last two (S11 and S12) were moderately to highly polluted.

As for mercury (Hg), the pollution was effective in all the samples but to different degrees: S2 was classified as unpolluted to moderately polluted; S1, S3, S4, S5, S6, S8, S9 and S10 were in the moderately polluted class; S7 and S11 were moderately to highly polluted. This parameter showed that mercury was the most polluting metal in soils from Bissa.

3.4.2. Contamination Factor and Degree of Contamination

The values of the contamination factor (CF), degree of contamination and pollution load index are recorded in Table 7.

The contamination factor values vary from 0.572 to 2.470 for Cr; from 0.33 to 0.812 for Ni; from 0.556 to 2.397 for Cu; 0.395 to 0.971 for Zn; from 0.691 to 14.98 for Ace; from 0 to 13.95 for Hg and from 0.6405 to 1.137 for Pb.

Its mean contamination factor values decrease in the order: Hg (9.569) > As (3.821) > Cu (1.269) Cr (1.137) > Pb (0.8972) > Zn (0.616) > Ni (0.572).

Maximum values of the Zn and Ni contamination factors were less than one (1), and suggest that all the samples from Bissa were low contaminated.

The chromium contamination factors for samples S2, S3, S4, S5, S6 and S11 were between one (1) and three (3), implying that they were moderately contaminated. Soil samples S2, S3, S4, S5, S6, S11 and S12 have copper contamination factors greater than one (1) and less than three (3), suggesting moderate contamination.

The S11 and S12 samples had a very high contaminated in arsenic because they have contamination factors greater than six (6). The samples S3, S4, S5, S6, S8, S10 had a moderate arsenic contamination and contamination intensity of sample S9 was considerable.

All the studied soils were very highly contaminated with mercury, except for the soil sample S2 which had a so-called considerable contamination level.

The lead contamination factors of samples S3, S6, S8 and S11 were between one (1) and three (3), therefore these soils were moderately contaminated.

The values of the degrees of contamination of the soils studied are recorded in Table 7, and vary from 11.729 to 33.209, with an average of 17.88. In accordance with the interpretations (Table 1), the samples S2 and S11 were respectively classified as moderately contaminated and very highly contaminated and the eight (8) other samples were in the considerably contaminated class.

3.4.3. Pollution Load Index

The pollution load index varies from 0.910 to 2.364 with an average of 1.347 (Table 7). An analysis of Figure 2 shows that apart from the three (3) samples (S1, S7 and S10) which were unpolluted, the nine (9) other samples were polluted. Among the polluted samples, S11 was considered highly polluted because the PLI value was between two (2) and three (3). The samples S2, S3, S4, S5, S6, S8, S9 and S12 were moderately polluted because the PLI were between one (1) and two (2) [68,69].

Table 7. Contamination factor, degree of contamination and pollution load index

Soils	Contamination factor							CD	PLI
	Cr	Ni	Cu	Zn	As	Hg	Pb		
S1	0.878	0.437	0.556	0.403	0.691	9.225	0.941	13.130	0.910
S2	1.012	0.646	2.187	0.666	0.798	5.500	0.920	11.729	1.212
S3	1.139	0.812	1.048	0.630	2.665	10.425	1.137	17.856	1.526
S4	1.015	0.487	1.036	0.475	1.838	10.275	0.814	15.940	1.207
S5	1.848	0.584	2.224	0.620	2.179	10.250	0.808	18.512	1.600
S6	1.636	0.749	2.397	0.587	1.407	10.250	1.019	18.046	1.587
S7	0.806	0.420	0.674	0.443	0.749	12.400	0.985	16.476	0.989
S8	0.844	0.459	0.672	0.439	1.055	11.625	1.018	16.111	1.052
S9	0.572	0.367	0.922	0.862	4.264	11.450	0.641	19.077	1.266
S10	0.655	0.333	0.638	0.395	2.416	9.475	0.783	14.694	0.998
S11	2.470	0.791	1.214	0.971	12.811	13.950	1.003	33.209	2.364
S12	0.764	0.773	1.668	0.901	14.980	0.000	0.701	19.787	1.451
Mean	**1.137**	**0.572**	**1.269**	**0.616**	**3.821**	**9.569**	**0.897**	**17.881**	**1.347**
Minimum	**0.572**	**0.333**	**0.556**	**0.395**	**0.691**	**0.000**	**0.641**	**11.729**	**0.910**
Maximum	**2.470**	**0.812**	**2.397**	**0.971**	**14.980**	**13.950**	**1.137**	**33.209**	**2.364**

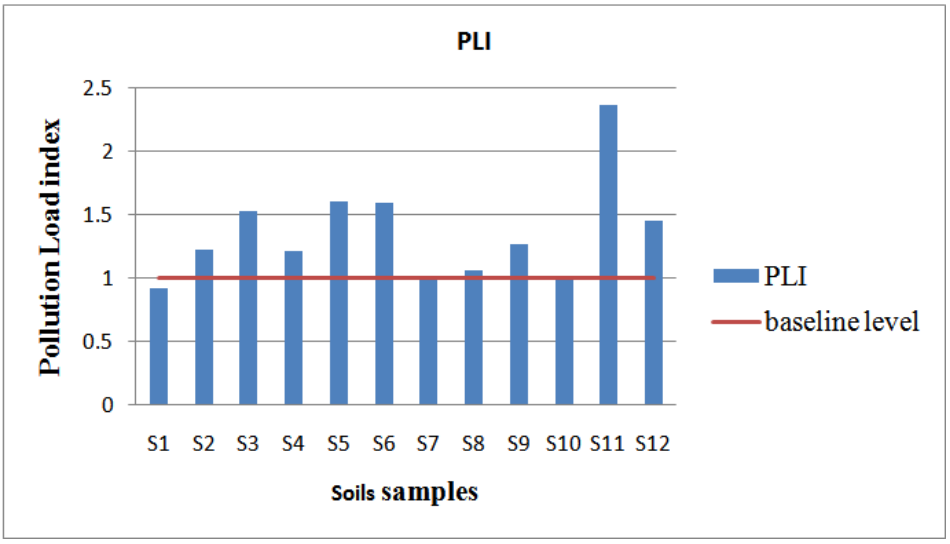

Figure 2. Histogram of the pollution load index

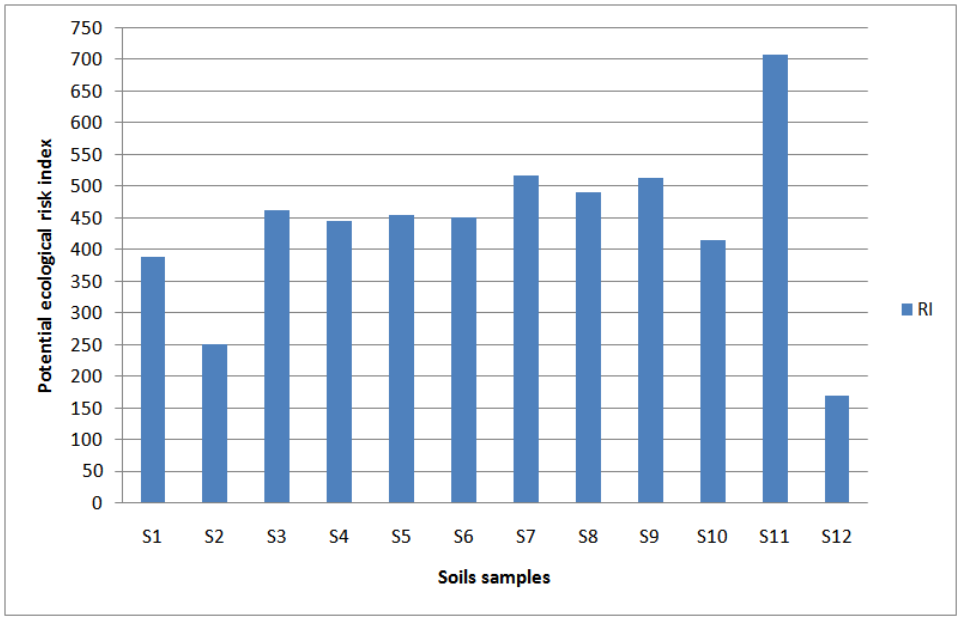

Figure 3. Variation of RI according to the samples

Table 8. Ecological risk factor and potential ecological risk

	Ecological risk factor							RI
	Cr	Ni	Cu	Zn	As	Hg	Pb	
Mean	**2.273**	**2.858**	**6.347**	**0.616**	**38.211**	**382.750**	**4.486**	**437.541**
Minimum	**1.144**	**1.665**	**2.782**	**0.395**	**6.908**	**0.000**	**3.203**	**167.935**
Maximum	**4.939**	**4.061**	**11.987**	**0.971**	**149.800**	**558.000**	**5.685**	**707.056**

Precautions to be taken are associated with the value of PLI [36,70,71]. Thus, they suggest that a more detailed study is needed to monitor S1 and S11 because $0.5 \leq PLI < 1$, and that immediate intervention is needed to improve the pollution status of the other samples because their $PLI \geq 1$.

3.4.4. Potential Ecological Risk

The ecological sensitivity of heavy metals has been comprehensively assessed using the ecological risk factor (E_r) and the potential ecological risk index (RI). The variations of the ecological risk factor are shown in Figure 4 and Table 8.

Mean values of ecological risk factors were ranked in the order: Hg (382.750) > As (38.211) > Cu (6.347) > Pb (4.486) > Ni (2.858) > Cr (2.273) > Zn (0.616).

The evaluation of ecological risk factors values showed that mercury was the main contaminant in the area because it presents a very high ecological risk with an average Er greater than 320 [54]. The mean ecological risk factors value of the other metals (As, Cu, Pb, Cr, Zn and Ni) were all below 40, indicating that these metals had a relatively low level of ecological risk.

The fluctuations of the potential ecological risk index (RI) are shown in Figure 3.

The RI values ranged from 167.935 to 707.056, indicating a level of ecological risk ranging from moderate to extremally high in the sampling area.

Soil samples S1, S3, S4, S5, S6, S7, S8, S9, and S10 had RI values between 300 and 600, indicating that the level of ecological risk of these samples was considerable. The highest value (707.056) of RI was observed in sample S11, which made it a sample at extremely high ecological risk because the RI was greater than 600. The samples S2 and S12 indicated a moderate level of ecological risk because the RI was between 150 and 300.

The ecological risk was proven in the soils studied around the mine in the village of Bissa, therefore, corrective measures are urgently needed to mitigate the pollution [72]. Depollution of its soils could be an alternative to avoid harmful effects on the health of populations.

4. Conclusion

The objective of this study was to assess the concentrations of heavy metals and ecological risks in agricultural soils around the gold mine in the Bissa village of the commune of SABCÉ. It shows that the average concentrations of chromium, arsenic and mercury in the agricultural soils from Bissa around the mine were higher than the FAO/WHO standard and other standards in Africa. In view of these results, the contamination factors were calculated. On the one hand, the contamination factor, the geo-accumulation index and the ecological risk index show that mercury and arsenic were the main contaminants in the study area. On the other hand, the evaluation of the ecological impact from the pollution load index and the potential ecological risk index showed that the ecological risk was proven in the soils studied around the mine in the village of Bissa, therefore, remedial measures are urgently needed to mitigate the pollution.

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