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Assessment of heavy metals concentrations in tropical agroecosystem (Wakwa, Adamawa, Cameroon): An Index Analysis Approach

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Abstract

A study has been conducted to evaluate the degree of Heavy Metals (HM) contamination on farm soils of Wakwa's, using enrichment factor (EF), geo-accumulation index (Igeo), pollution load index (PLI), Ecological risk factors (E^i_r), Ecological risk indices (PER) and statistical analysis. In the current study, composite surface agricultural soil samples were collected in 4 sites and analyzed for the concentration of HMs including As, Ba, Co, Cr, Cu, Ni, Mn, Mo, Pb, Sr, V, Y, Zn and Zr. Electric conductivity (EC) and pH were also determined. The concentrations of Cr, Zr, Mo and Pb are significantly higher than average shale values in all sites. Sites WK_3 and WK_4 recorded high concentrations of Ni and V. obtained EF vary from 0.07 for Sr to 2.35 for Mo and indicate zero to moderate enrichment. Igeo vary from -3.83 for Sr to 1.26 for Mo and indicate zero to moderate contamination. PLI vary from 0.61 to 0.83 with the highest to the lowest polluted site being $WK_4 > WK_3 > WK_2 > WK_1$. All HM present low ecological concern and low potential ecological risk indices. All sites recorded acidic pH except site WK_1 which has neutral pH. WK_4 which is upstream the Lake Piu is the most polluted and present the lowest pH (5.183) and the highest EC (563.667 µs/cm) . Positive and highly significant correlations were observed for several pairs; this could indicate the same source of pollution for most HMs. This study concludes that a regular assessment is needed to estimate the risk level of toxic metal contamination in the ecosystem. The present study is valuable because it is probably the first work on heavy metal levels in Wakwa locality.

Key words*:* Heavy Metals, Herbicides,Tropical Agroecosystem, Soil Pollution, Wakwa.

1. Introduction

The population of the tropics accounts for more than three quarters of the world's population and the tropics are home to one third of the world's land (Guerra et al., 2021). Population growth is resulting in an increased demand for the exploitation of the earth's natural resources at an unconsidered rate. The afor mention situation further contributed in the exacerbation of the world's environmental problem, which range from climate change, pollution of various component of the environment such as water, air and soil. Soil is a complex and dynamic system with a direct influence on food production and, consequently, on human survival (Guerra et al., 2021). Modern agricultural practices use intensive tillage, monoculture, irrigation, application of inorganic fertilizers, and plant genome modification to maximize profit and production (Baishya and Sarma, 2014). The intensification of agricultural practices in tropical areas led to an increasing use of pesticides (Daam et al., 2019) and consequently increase soil and ecosystem pollution or contamination. In Sub-Saharan Africa countries like Cameroon, various agrochemicals (fungicides, insecticides, nematicides, molluscicides, rodenticides and herbicides) are used in agrosystems without care on despite their dangers on the environment. Among the most hazardous pesticides to ecosystem, Glyphosate-based herbicides (GBH) (main used herbicide in Cameroon) is the major pesticides of the world (Defarge et al., 2017). The target of herbicides is the destruction of unwanted plants; however, much of it ends up in the environment by various means and in various forms (Choudhury, 2019). Pesticides, fertilizers, sewage sludge, waste water and surface runoff are some of the sources of heavy metal contamination in agricultural soil (Singh et al., 2015; Mazurek et al., 2016; Saha et al., 2022).

Heavy metals and metalloids are natural soil constituents and their concentration may vary depending upon the rock and geological materials present at specific sites (Lundemi et al., 2022). Metal concentrations in agroecosystems are either inherited from soil parent materials or input through human activities (Mohammed et al., 2017; Jomeil et al., 2020). HM present in soil can harm the whole biosphere and can be taken up through direct ingestion, absorbed by plants which can be hazardous both to the plant and also to the food chain (Briffa et al., 2020; Xin et al., 2023). They can alter soil's properties such as pH and natural chemistry (Navarrete et al., 2017; Li et al., 2019; Abdessamad et al., 2020). Contamination of agricultural soils by heavy metals is due to their persistence in the ecosystem (El Azhari et al., 2017). HM are non-biodegradable and therefore remain persistent in the environment for a very long time (Joimel et al., 2020) and can have negative effects on plants growth. Hussain et al. (2013) reported that the presence of Pb can reduce germination percentage and plant biomass. Chibuike and Obiora (2014) demonstrate that the presence of Cd, **Cr**, Co, Mn, and **Pb** in soil reduced the growth and protein content of maize. Co, Cu, Fe, Mn, Mo, Ni and Zn are essential elements required for normal growth and metabolism of plants, but they can easily lead to poisoning when their concentration become greater than optimal values (Rascio and Izzo, 2011). Excess amount of Zn can cause system dysfunctions that result in impairment of growth and reproduction (Singh and Kalamdhad, 2011). As, Cr, Pb, Ni and Co are among carcinogenic HMs or metalloids (Joimel et al., 2020). **As** can cause death at high-level exposure (Singh and Kalamdhad, 2011).

In Cameroon due to the apparition of the Covid – 19 pandemic, the consumption of some medicinal plants with antiviral or immunoregulatory properties, such as ginger (Zingiber officinale) (Metchum et al., 2022) has increase exponentially and this led to an increase in demand of the crop in the market. Population abandon other culture to produce ginger because it is more rentable even if it consumes lots of herbicides. With this continuous use of herbicides, it can accumulate in soil and eventually in ginger and this exposed ecosystem and population health. Several soil pollution indices have been established to evaluate soil pollution by various metals, either for a single element and for multi-element contamination; and they are agreed by national and international agencies, helpful for preliminary environmental risk assessment (Cai et al., 2015b). Many studies have been undertaken on heavy metal pollution all around the world; however, in Cameroon, there is very little work about the accumulation of heavy metals in agroecosystem. Noubissié et al (2016) demonstrate that HMs (Hg, Sn and Pb) found in fertilisers were present in the leaves of three plant species, with concentrations that in some cases exceeded the recommended limit values. In Ngaounderé, Cameroon, Adjia et al (2020) showed that vegetable plants are not suitable for human consumption due to HM accumulation. These studies focused on the presence of heavy metals in plants and left out the persistence of metals in the soil. There is almost no information available in the published literature discussing metal levels in Wakwa, Cameroon. Therefore, the present study aims to investigate the metal concentrations of As, Ba, Co, Cr, Cu, Ni, Mn, Mo, Pb, Sr, V, Y, Zn and Zr of Wakwa's tropical soil exposed to chemicals (herbicides).

2. Materials and methods

2.1 Study site

The study was conducted in the Adamawa region of Cameroon. This region, is one of the 10 regions of Cameroon and is located in the northern part of the country. It is geographically located between longitude 7'N and latitude 13'E. The study area was Wakwa, which is located geographically between longitude 7°26'N and latitude 13°56'E. Most of the agricultural land in the study area is bordered by Lake Piu. Agriculture, especially agroforestry is the main activity in the locality and of course the main source of income for different ethnic groups. The main crops grown here are ginger, maize, potato, cabbage, legumes, salad, tomato etc…. The main animals found in the study area are mainly cattle, goats, chickens and ducks. Farmers used various types of agrochemicals for crop cultivation and most importantly herbicides. All samples were collected only where herbicides are applied.

2.2 Sampling and pre-treatment

For the current study, 04 sampling sites were chosen randomly and named Wk_1 Wk_2 Wk_3 and Wk_4. 4 core soil samples were collected from randomly distributed sampling points using a stainless – steel auger. Each soil sample was collected by sampling vertically from the topsoil to a depth of about 30 cm. One of the samples (Wk_4) was taken upstream of the Lake. Core soil samples were thoroughly mixed together in the field to obtain the composite soil samples from which about 1 kg of each was brought to the laboratory packed in labelled, sealed plastic bags. Soil samples were collected from approximately the same slopes for each site. Figure 1 shows the locations of the sampling stations.

All samples were well mixed again in the laboratory and were spread on plastic trays and dried at room temperature for two weeks. Large debris, shells and visible organisms were removed prior to grinding. The operating mode respected the five steps of pre-treatment of samples: drying, grinding, sieving, separation and spraying, according to NF ISO 11464 standard (Amina et al., 2021). The air-dried samples were packed in clean and dry containers. The total concentrations of trace metals (As, Ba, Co, Cr, Cu, Ni, Mn, Mo, Pb, Sr, V, Y, Zn and Zr) in the topsoil composite samples were analyzed and determined by Inductively Coupled Plasma-Optical Emission Spectroscopy (ICP-OES; Optima 3000, Perkin Elmer) in the Laboratory of Soils, Plants, Water and

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Fertilizers Analysis in the Institute of Agricultural Research for Development (Yaoundé), accredited according to ISO 17025 standard. Standard soil reference materials (SRM 2 710 and SRM 2 711) were analysed at the same time to test the accuracy and precision of the analytical methods used.. Electric Conductivity and pH of each sample were also determined.

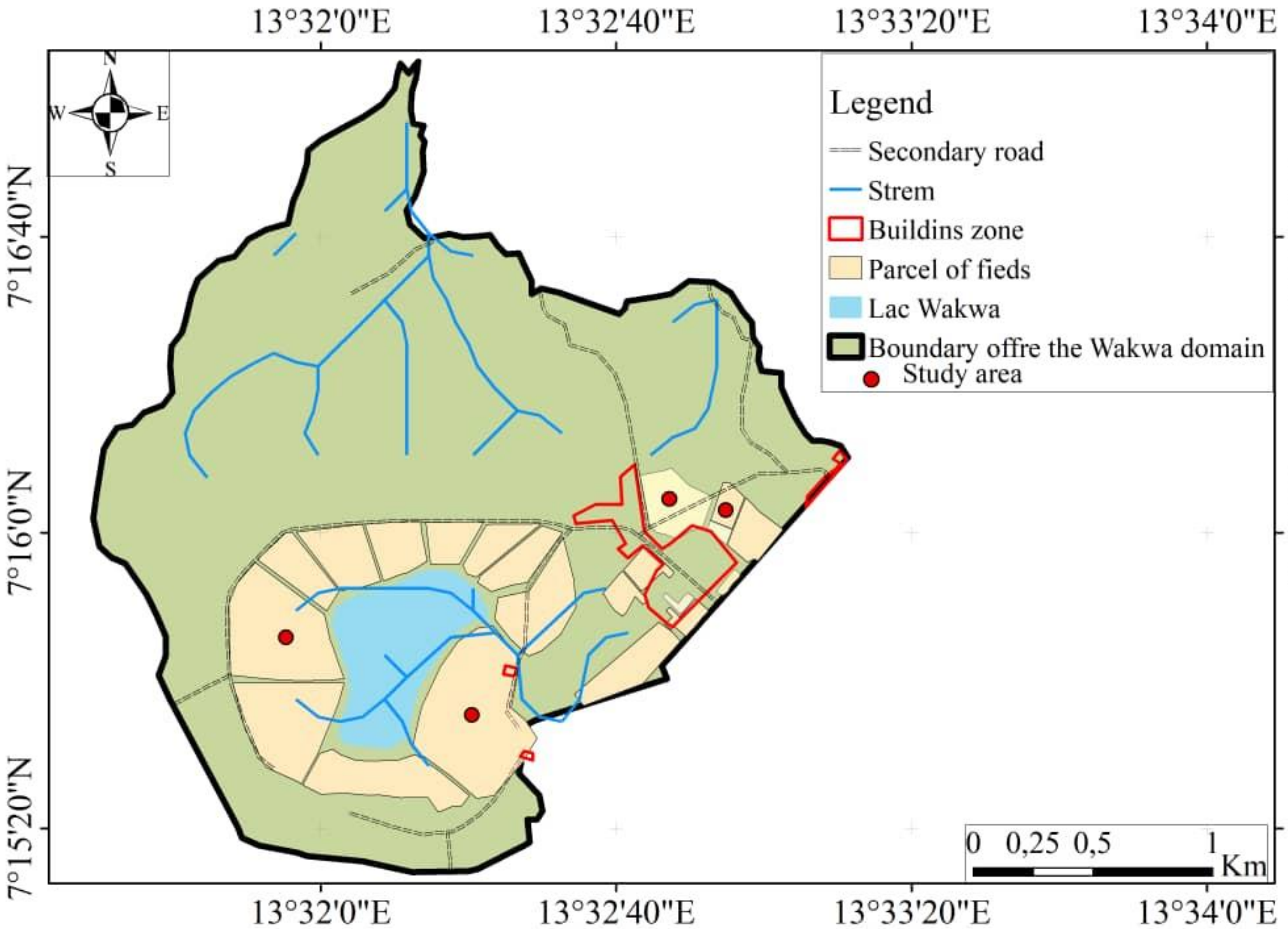

Figure 1: Study area and sampling points

2.3 Metallic Pollution Quantification

A number of calculation methods have been put forward for quantifying the degree of metal pollution in soils (Muller, 1969; Song et al., 2018; Narishma et al., 2019). In this study Enrichment Factor (EF), Contamination Factor (CF) Geoaccumulation Index (Igeo), Pollution Load Index (PLI), Ecological risk factors (E^i_r) and ecological risk indices (PER*)*, were used to assess the soil quality.

2.3.1. Enrichment Factor (EF)

Enrichment factor (EF) is used to assess the degree of contamination by individual element in soils (Lu et al., 2014). It is widely used to estimate the actual degree of contribution from anthropogenic sources of soil (Narsimha et al., 2019). EF compared each concentration value with the background or reference level, either from local or from regional average composition, considering the concentration of conservative elements such as Al, Mn or Fe ((Hakanson, 1980; Morales et al., 2020; Amina et al., 2021). The background concentrations of potentially toxic elements in the average shale obtained from Turekian and Wedepohl (1961) was considered to be the background (Cai et al., 2015a). For this study Fe was chosen as a conservative tracer to differentiate natural from anthropogenic components because it is a major sorbent phase for trace elements (Amina et al., 2021) and Fe is abundant in the study area. EF was calculated using the equation 1 (Aschale et al., 2016c).

$$EF=\frac{C_n}{B_n}/\frac{C_{Fe}}{B_{Fe}} \qquad (01)$$

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Where Cn is the metal content in the soils, Bn is the geochemical background value in average shale (Turekian and Wedepohl 1961) or earth's crust (Taylor and McLennan, 1995; Wedepohl 1995), C_{Fe} is the Fe content in the soils and B_{Fe} is the background content of Fe. The upper continental crust data is supplemented by Turekian and Wedepohl (1961) due to the lack of pre-industrial data in this region (Jhénelle and Johann, 2020). The background values were used to assess the degree of contamination and to understand the distribution of elements of anthropogenic origin in the study areas. The soils can be classified as deficient to minimal enrichment (EF < 2), moderate enrichment (2 ≤ EF < 5), significant enrichment (5 ≤ EF < 20), and very high enrichment.

2.3.2. Geoaccumulation Index (Igeo)

The pollution level of heavy metals in soils were assessed by using Igeo introduced by Muller (1969). Igeo enables the assessment of soil contamination levels (Singh et al., 2015) and is computed using the equation 2 (Ji et al., 2008).

$$\mathbf{Igeo=log_2\left(\frac{Cn}{1.5Bn}\right)} \qquad \mathbf{(02)}$$

Where Cn is the concentration of a given element in the soil tested and Bn is the local natural background value of corresponding element in the earth's crust. The constant 1.5 allows to analyse natural fluctuations in the content of a given substance in the environment and to detect very small anthropogenic influences (Ji et al., 2008). According to Muller (1969), the Igeo for each metal is calculated and classified as follows: uncontaminated (Igeo ≤0), uncontaminated to moderately contaminate (0< Igeo≤2), moderately to heavily contaminate (2< Igeo≤3), heavily contaminated (3< Igeo≤5) and extremely contaminated (Igeo≥5).

2.3.3. Pollution Load Index (PLI)

The PLI is another effective tool to evaluate the severity of contamination in the environment (Tomilson et al., 1980; Jhénelle and Johann, 2020). PLI for a single site is calculated as the root of n number of contamination factor (CF) values, multiplied together. The CF for a particular metal is that metal's concentration as a proportion (or quotient) of the background concentration of the same metal, as indicated in the equation 3

$$\mathbf{CF={}^{C_n}/_{C_b}} \quad \mathbf{(03)}$$

Where C_n is metal concentration and C_b is background concentration for the same metal

$$\mathbf{PLI= (CF_1 \times CF_2 \times CF_3 \times .... \times CF_n)^{1/n}} \qquad \mathbf{(04)}$$

When PLI > 1 the soil is polluted and it is not when PLI < 1

2.3.4 Potential ecological risk load index

Potential ecological risk load index (PER) is used to assess the degree of metal contamination in soils (Lu et al., 2015). The equations for PER calculation were proposed by Hakanson (1980) and are as follows

$$CF=\frac{C_n}{C_b}, \qquad E^i_r=T_r \times CF \qquad PER=\sum_{i=1}^{m} E^i_r$$

Where CF represents the contamination factor of an element, C_n is the concentration of the element in sampled soil, and C_b denotes the corresponding background value. E^i_r stands for the potential ecological risk index and T_r symbolizes the toxic response coefficient of a heavy metal (Mn = Zn = 1=Cu=Ba < V = Cr = 2 < Ni = Co = Pb = 5 < As = 10) (Hakanson, 1980; Guo et al., 2010; Xu et al., 2016; Ali Akber et al., 2019). PER is the comprehensive potential ecological risk index and is computed as the sum of all E^r_i.

The single potential risk index (E^r_i) is calculated and classified as follow: low pollution (E^r_i< 40), moderate pollution (40 ≤ E^r_i <80), high (80≤ E^r_i < 160), higher pollution (160≤ E^r_i <320) and serious pollution (E^r_i ≥320). PER is calculated and classified as follow: low risk (PER < 65), moderate risk (65≤ PER <130), considerable risk (130≤ PER < 260), very high risk (PER ≥2600).

2.4 Statistical Analysis

Data collected were registered in a Microsoft excel spreadsheet and were subjected to descriptive analysis (mean, minimum and SD). Correlation using the Pearsons correlation coefficient at a threshold probability of p value < 0.05 analysis was performed to segregate the most significant correlations between all variables (Acosta, 2011). As the coefficient approaches 1, the positive relationship between the correlated variables is significant and the correlated variables move in the same direction. For negative correlation, correlated variables move in opposite directions. CE and pH can affect metals in the soils (Abdessamad et al., 2020), for this reason, relationship between HMs and those physical parameters were established. The correlation matrix was used to evaluate the relationships between heavy metals and physicochemical soil parameters. Then, a principal component analysis (PCA) was conducted to identify the main correlations between variables and determine the sources of the heavy metal pollutants. The statistical analysis were performed using the XLSTAT language programming.

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3. Results and Discussions

3.1 Results

Concentrations of potentially toxic elements in soil samples and some background values of elements are reported in table 1 ; all values are in (mg/kg). The ranges of potentially toxic elements in soil samples were 6.33-9.67 mg/kg for As, 142.66-191 mg/kg for Ba, 9-18.33 mg/kg for Co, 109.67- 161 mg/kg for Cr, 22.33- 31 mg/kg for Cu, 47-83.33 mg/kg for Ni, 461-765.66 mg/kg for Mn, 3.33-9.33 mg/kg for Mo, 22.33-38 mg/kg for Pb, 37-61 mg/kg for Sr, 107.33-180.66 mg/kg for V, 19-20.67 mg/kg for Y, 42-64.33 mg/kg for Zn and 165.33-232.66 mg/kg for Zr. Figure 2 present mean concentrations of all studued HMs. Results obtained from the current study showed the presence of all the studied HMs (**As, Ba, Co, Cr, Cu, Ni, Mn, Mo, Pb, Sr, V, Y, Zn and Zr**) in various concentrations. Some lower than the average shale reference values (**As, Ba, Cu, Mn, Sr, Y and Zn**) in all sites. While others (**Cr, Mo Pb, and Zr,)** are above the average shale reference values in all sites. We also noticed that for sites WK_3 and WK_4 the **Ni** and **V** concentrations are higher than the average shale reference values. Figure 2 present the mean concentration of HM in sites.

For Pb concentrations in decreasing order are $WK_3 > WK_2 > WK_4 > WK_1$. For Cr concentrations in decreasing order are $WK_3 > WK_4 > WK_1 > WK_2$. For Mo $WK_4 > WK_2 > WK_3 > WK_1$.For concentrations in decreasing order are Zr $WK_4 > WK_3 > WK_2 > WK_1$. For V concentrations in decreasing order are $WK_3 >$ WK4. For Ni concentrations in decreasing order are $WK_4 > WK_3$. Electrical conductivity and pH are also presented in tale 1, all studied sites present acidic pH except site Wk_1 which recorded neutral pH. The lower the pH the higher the electrical conductivity in this study (Wk_4).

Table 1 : Concentrations of elements (mean ± standard deviation, dry weight, mg/kg) of heavy metals, some standards values and physical parameters

Elements	Wk1	Wk2	Wk3	Wk4	Average shale	Average values MPA	MPC	World wide average soil
As	(7.333±0.645) ^{a,b}	(9.667± 0.645) ^{a}	(8.000±0.645) ^{a,b}	(6.333±0.645)^{b}	13	4.5	-	
Ba	(165.33±1.99)^{b}	(191.00±1.99)^{a}	(142.67±1.99)^{c}	(163,00±1.99)^{b}	580	9	-	
Co	(9.000±1.19)^{b}	(12.667±1.19)^{b}	(13.333±1.19)^{a,b}	(18.333±1.19)^{a}	19	24	5	11.3
Cr	(119.00±1.39)^{c}	109.667±1.39)^{d}	(161.000±1.39)^{a}	(149.000±1.39)^{b}	90	3.8	6	59.5
Cu	(22.333±1)^{b}	(28.333±1)^{a,b}	(31.000±1)^{a}	(29.333±1)^{a}	45	3.5	3	
Ni	(47.000±1.22)^{d}	(57.667±1.22)^{c}	(69.333±1.22)^{b}	(83.333±1.22)^{a}	68	2.6	4	29
Mn	(461.333±17.567)^{b}	(540.000±17.567)^{b}	(459.667±17.567)^{b}	(765.667±17.567)^{a}	850			488
Mo	(3.333±0.707)^{b}	(5.333±0.707)^{a,b}	(4.000±0.707)^{b}	(9.333±0.707)^{b}	2.6	253	-	
Pb	(22.333±1.291)^{c}	(32.667±1.291)^{a,b}	(38.000±1.291)^{a}	(29.333±1.291)^{b,c}	20	55		27
Sr	(53.667±1.130)^{b}	(61.000±1.130)^{a}	(43.000±1.130)^{c}	(37.000±1.130)^{c}	350			
V	(107.333±1.443)^{d}	(121.667±1.443)^{c}	(180.667±1.443)^{a}	(159.000±1.443)^{b}	130	1.1		
Y	(16.333±1.247)^{a}	(20.667±1.247)^{a}	(19.000±1.247)^{a}	(21±1.247)^{a}	26			
Zn	(42.000±1.190)^{c}	(64.333±1.190)^{a}	(50.667±1.190)^{b}	(46.667±1.190)^{b,c}	95	16	23	70
Zr	(165.333±1.748)^{c}	(180.000±1.748)^{b}	(227.000±1.748)^{a}	(232.667±1.748)^{a}	160			
pH	7.203	6.353	5.567	5.183				
EC (µs/cm)	140.333	242.000	321.333	563.667				

Enrichment factor

Table 2 present the average values of EF.

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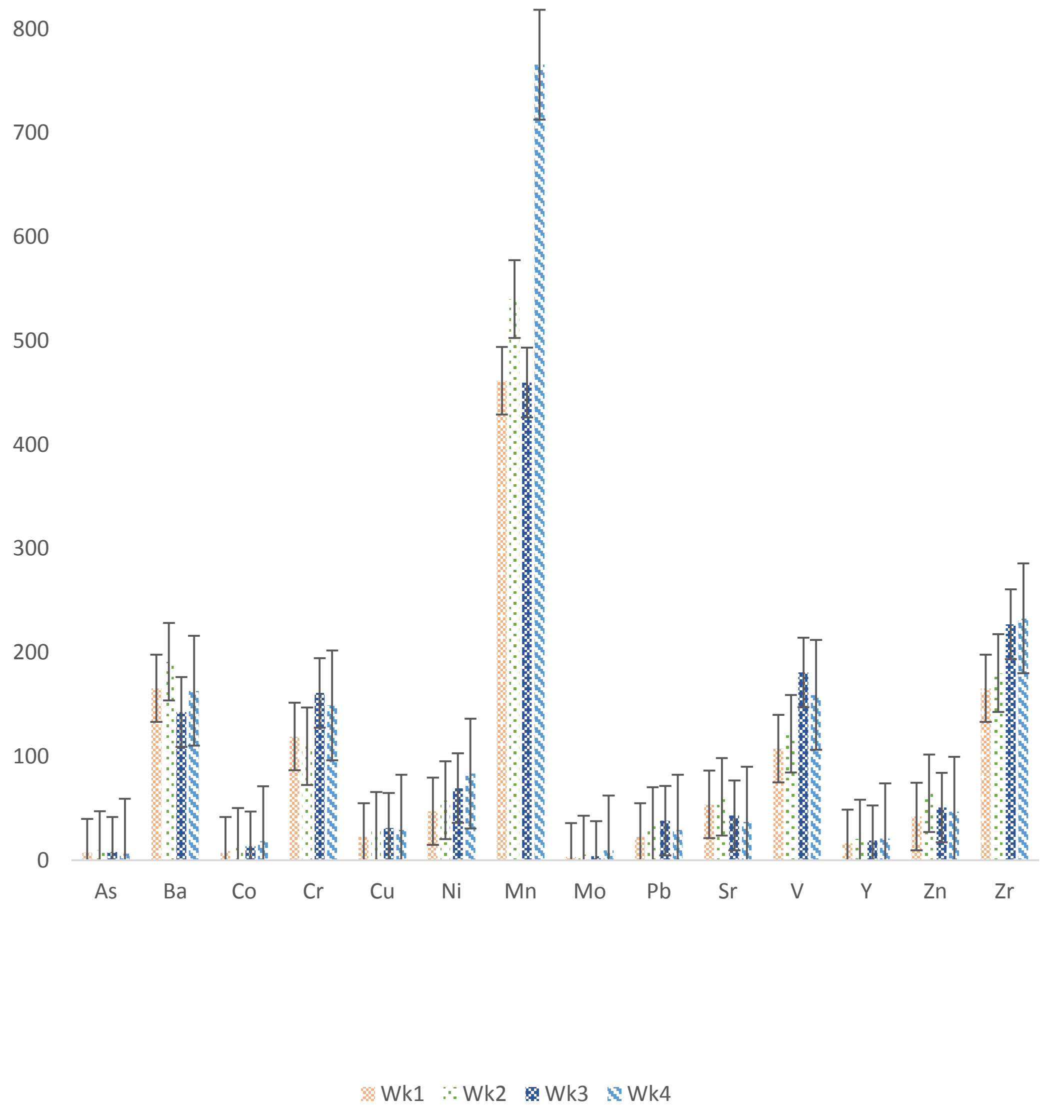

Figure 2: Mean concentration values of heavy metals

Table 2: Average enrichment factor for the soil

EF	As	Ba	Co	Cr	Cu	Ni	Mn	Mo	Pb	Sr	V	Y	Zn	Zr
WK_1	0.51	0.26	0.43	1.19	0.45	0.62	0.49	1.15	1.00	0.14	0.74	0.57	0.40	0.93
WK_2	0.61	0.27	0.54	0.99	0.51	0.69	0.52	1.67	1.33	0.14	0.76	0.65	0.55	0.92
WK_3	0.38	0.15	0.43	1.09	0.42	0.62	0.33	0.94	1.16	0.08	0.85	0.45	0.33	0.87
WK_4	0.32	0.18	0.63	1.08	0.43	0.80	0.59	2.35	0.96	0.07	0.80	0.53	0.32	0.95

Igeo

Most igeo (Table 3) were less than one. For the current study contamination vary from zero to light.

Table 3: Average Geoaccumulation index for the soil

EF	As	Ba	Co	Cr	Cu	Ni	Mn	Mo	Pb	Sr	V	Y	Zn	Zr

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WK_1	-1.41	-2.40	-1.66	-0.18	-1.60	-1.12	-1.47	-0.23	-0.43	-3.29	-0.86	-1.26	-1.76	-0.54
WK_2	-1.01	-2.19	-1.17	-0.30	-1.25	-0.82	-1.24	0.45	0.12	-3.11	-0.68	-0.92	-1.15	-0.42
WK_3	-1.29	-2.61	-1.10	0.25	-1.12	-0.56	-1.47	0.04	0.34	-3.61	-0.11	-1.04	-1.49	-0.08
WK_4	-1.62	-2.42	-0.64	0.14	-1.20	-0.29	-0.74	1.26	-0.03	-3.83	-0.29	-0.89	-1.61	-0.04

PLI

A PLI (Table 4) of less than 1 indicates an unpolluted soil, but in our sites it is close to 1, which could indicate a slight pollution. PLI in deacreasing order are WK_4 >WK_3 >WK_2 >WK_1

Table 4: Average contamination factor and PLI for the soil

	As	Ba	Co	Cr	Cu	Ni	Mn	Mo	Pb	Sr	V	Y	Zn	Zr	PLI
WK_1	0.56	0.29	0.47	1.32	0.50	0.69	0.54	1.28	1.12	0.15	0.83	0.63	0.44	1.03	0.61
WK_2	0.74	0.33	0.67	1.22	0.63	0.85	0.64	2.05	1.63	0.17	0.94	0.79	0.68	1.13	0.76
WK_3	0.62	0.25	0.70	1.79	0.69	1.02	0.54	1.54	1.90	0.12	1.39	0.73	0.53	1.42	0.76
WK_4	0.49	0.28	0.96	1.66	0.65	1.23	0.90	3.59	1.47	0.11	1.22	0.81	0.49	1.45	0.83

Eri and PER

The Ecological risk factors (Eir) for toxic metals in decreasing order were: Pb >As > Ni> Co> Cr> V> Cu >Zn > Mn> Ba. In the surface soils of the study site, all HM present low ecological concern consequently potential ecological risk indices (PER) (Table 5) was also low at different level.

Table 5: Heavy metal and metalloid potential ecological risk index (Eri), comprehensive potential ecological risk index (PER)

Eir	As	Ba	Co	Cr	Cu	Ni	Mn	Pb	V	Zn	PER
WK_1	5.60	0.29	2.25	2.64	0.50	3.45	0.54	5.6	1.66	0.44	22.97
WK_2	7.40	0.33	3.35	2.44	0.63	4.25	0.64	8.15	1.88	0.68	29.74
WK_3	6.20	0.25	3.5	3.58	0.69	5.1	0.54	9.50	2.78	0.53	32.67
WK_4	4.90	0.28	2.45	3.32	0.65	6.15	0.90	7.35	2.44	0.49	28.93

Statistical analysis

Results of the multivariate analysis showed the existence of correlation between HMs (≥0.7). Based on these Pearson correlations (table 6), negative and significant to highly significant correlations were observed for several pairs: Ba/Cr; Co/Sr; Co/pH; Cr/Sr; Cr/pH; Cu/ pH; Ni/Sr; Mo/ pH; Sr/V; Sr/Zr; ; Sr/CE; V/pH; Y/pH; Zr/CE; pH//CE.

Positive and significant to highly significant correlations were observed for several pairs: As/Sr; As/Zn; Ba/Sr; Ba/Sr; Co/Cu; Co/Ni; Co/Mn; Co/Mo; Co/Y; Co/Zr; Co/CE; Cr/Ni; Cr/V; Cr/Zr; Cu/Ni; Cu/Pb; Cu/Y; Cu/V; Cu/Zr; Ni/Mn; Ni/Mo; Ni/V; Ni/Y; Ni/Zr; Ni/CE; Mn/Mo; Mn/CE; Mo/Y; Mo/CE; Pb/V; ; Sr/ pH; V/Zr; Y/CE; Zr/CE.

For the correlation (figure 3), the present study shows 3 groups: for the group1 we have mainly sites Wk_3 and Wk_4 where high concentration of mainly HM is concentrated and we observed also the presence of physical parameter CE. The group 2 which contain mainly site Wk_2 we observe the presence of some HM (As, Ba, Sr and Zn) but not too close to the axes. Group 3 concern Wk_1 there is no HM only physical parameter pH. This demonstrate that there exist correlation between HM in sites mainly for those who are too close to the axes.

Figure 4 shows three main clusters: C1, C2 and C3. C1 contains As, Ba, Sr and Zn; C2 contains Co, Mn, Mo and Y. C3 contains Cr, Cu, Ni, Pb, V and Zr.

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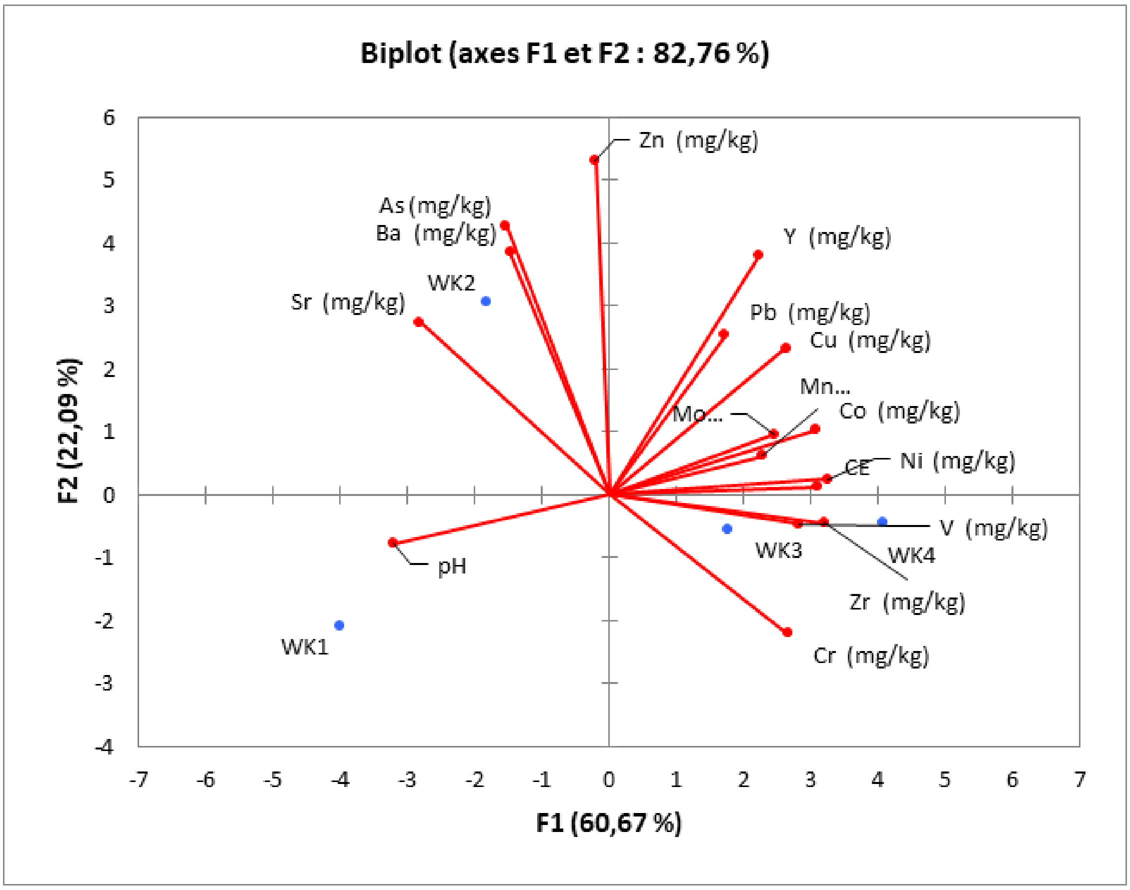

Figure 3: Correlation between heavy metals and physical parameters

Table 6: Pearson correlation matrix of Heavy metals and soil physical parameters

Variables	As (mg/kg)	Ba (mg/kg)	Co (mg/kg)	Cr (mg/kg)	Cu (mg/kg)	Ni (mg/kg)	Mn (mg/kg)	Mo (mg/kg)	Pb (mg/kg)	Sr (mg/kg)	V (mg/kg)	Y (mg/kg)	Zn (mg/kg)	Zr (mg/kg)	pH	CE (µs/cm)
As (mg/kg)	1															
Ba (mg/kg)	0,562	1														
Co (mg/kg)	-0,406	-0,126	1													
Cr (mg/kg)	-0,540	**-0,881**	0,558	1												
Cu (mg/kg)	0,123	-0,278	**0,713**	0,649	1											
Ni (mg/kg)	-0,476	-0,354	**0,971**	**0,741**	**0,771**	1										
Mn (mg/kg)	-0,515	0,150	**0,884**	0,224	0,320	**0,777**	1									
Mo (mg/kg)	-0,462	0,130	**0,926**	0,274	0,422	**0,826**	**0,994**	1								
Pb (mg/kg)	0,401	-0,287	0,372	0,533	**0,916**	0,464	-0,081	0,030	1							
Sr (mg/kg)	**0,813**	**0,740**	**-0,714**	**-0,899**	-0,467	**-0,834**	-0,554	-0,568	-0,204	1						
V (mg/kg)	-0,276	**-0,719**	0,642	**0,943**	**0,862**	**0,795**	0,237	0,316	**0,769**	**-0,777**	1					
Y (mg/kg)	0,155	0,299	**0,832**	0,185	**0,770**	**0,732**	0,698	**0,766**	0,548	-0,235	0,429	1				
Zn (mg/kg)	**0,875**	0,629	0,076	-0,376	0,446	-0,037	-0,057	0,015	0,555	0,555	-0,047	0,612	1			
Zr (mg/kg)	-0,452	-0,602	**0,844**	**0,907**	**0,829**	**0,946**	0,539	0,602	0,610	**-0,882**	**0,944**	0,573	-0,108	1		
pH	0,319	0,390	**-0,925**	**-0,779**	**-0,889**	**-0,976**	-0,643	**-0,713**	-0,647	**0,776**	**-0,880**	**-0,756**	-0,093	**-0,969**	1	
CE (µs/cm)	-0,551	-0,241	**0,986**	0,630	0,645	**0,979**	**0,887**	**0,918**	0,288	**-0,810**	0,658	**0,728**	-0,091	**0,867**	**-0,912**	1

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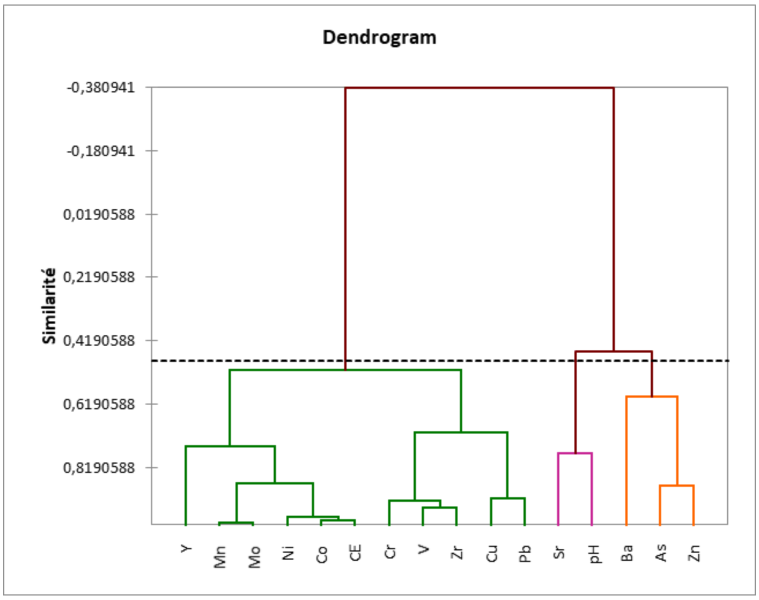

Figure 4: Dendrogram demonstrating the cluster of variables based on similarity

Discussion

Heavy metals

Comparisons of toxic and potentially toxic elements in the fourth agricultural farms showed relatively high values in sites WK_3 and WK_4.

Lead mean values are between 22.333 and 38 mg/kg; those values are greater than average shale reference value and also greater than values found by Aschale et al., (2016c) (18.35–62.80 mg/kg) in agricultural soil in Ethiopia. In urban agricultural soils of Yaoundé, Cameroon minimum Pb concentrations was 9.87 mg/kg (Amina et al., 2021). In the study carried out by Defarge et al., (2017) on glyphosate-based herbicides and other pesticides, Pb amount in most of samples are above the permitted level (up to 11times). Noubissié et al. (2016) found residues of Pb in the leaves of three plants species, with concentrations which, in some cases, exceeded the recommended limit values this demonstrate how chemical are dangerous for the ecosystem. Briffa et al., (2020) demonstrate that HM present in the soil can alter its properties such as pH and can also contaminate water; WK_4 where most of studied HM are above the limit has the lowest pH (5.18). Acidic pH favors metal availability (Oseni et al., 2016). This could explain why many HM are found to be greater than some reference values and other study in site Wk_4. Tomakov and Tomakov, (2021) reported that Pb has a cumulative effect and causes damage to the central and peripheral nervous system; human health is in danger through food chain. Excessive pollution of site Wk_4 could affect the marine ecosystem of the downstream Lake. Heavy metals are highly persistent, toxic in trace amounts, and can potentially induce severe oxidative stress in aquatic organisms. In addition, since this study, we observe the expansion of agricultural activities with the use of various agrochemicals around this lake.

Chrome mean values are between 109.67 and 161 mg/kg and is greater than all the reference values considered in this study in all sites. Those values are 2 to 3 times greater than the minimum value found by Narsimha et al., (2019) (55.9 mg/kg) in agricultural soil in northern Telangana in India. They are also greater than the minimum value (8.7mg/kg) found by Machender et al. (2013) in the study carried out in the agricultural region of Chinnaeru river basin in India and they conclude that it is due to the excessive usage of fertilizers and pesticides. Chibuike and Obiora (2014) demonstrate that the presence **Cr, Pb** in soil reduced the growth and protein content of maize.

Molybdenum mean values are between 3.33 and 9.33 mg/kg while the average value for average shale is 2.6 mg/kg. For the case study Mo concentrations are very high. Knowing that Mo belongs to the second class of danger and has a General toxic, carcinogenic and mutagenic effect at significant concentrations (Tomakov and Tomakov, 2021); it can be dangerous for human and environment. In addition, a diet rich in molybdenum caused deformities in the joints of the extremities of cattle; so, this high concentration in **molybdenum** exposed also animals present in the agroecosystem. The site Wk_4 which is upstream the lake Piu has the maximum concentration and this exposed also marine ecosystem. But Mo is not present in herbicides; this means that probably there exist another source of pollution that must be explore to preserve public and ecosystem health.

Nickel average value is 69.33 mg/kg in site WK_3 and 83.33 mg/kg WK_4 while the value for average shale is 68 mg/kg. Those values are higher than the mean value found by Amina et al., (2021) in urban agricultural soil in Yaoundé. In agricultural soil in Kinshasa, Congo Lundemi et al., (2022) found values (0-1.6 mg/kg) which are more than 60 time lower than the values of the current study. In the study carried out by Defarge et al., (2017) on glyphosate-based herbicides and other pesticides, Ni amount in most of samples were above the permitted level (up to 62 times); this demonstrate how chemical are dangerous for the ecosystem.

Vanadium average value is 180.667 mg/kg WK_3 and 159 mg/kg WK_4. Those two values are above average shale values and MPA and are 2 times greater than the minimum value found by Narsimha et al., (2019) (89.2 mg/kg) in agricultural soil in northern Telangana India. Those values are greater than the values (39.8–162.8 mg/kg) found by Machender et al. (2013). It belongs to the third class of danger and causes at significant concentrations of General toxic damage to internal organs, nervous and circulatory systems (Tomakov and Tomakov, 2021).

Arsenic concentrations for the current study in all site are greather than the maximum value found by Narsimha et al., (2019) (5.3 mg/kg) in agricultural soil in northern Telangana India. Arsenic concentration (2.8 and 3.7 mg/kg) found by Lundemi et al., (2022) in agricultural soil in Kinshasa, Congo are lower than those of current study.

Given the expansion of agriculture in Adamawa and the climate variations if nothing is done concentrations of HM could increase for every metal present in used agrochemicals. With the result of the current study ginger and other plant produce can uptake HM and can contaminate human through food chain.

Correlation between parameters

Positive and significant to highly significant correlations observed for several pairs (HM-HM and HM-physical parameter) can reflect same or similar source input for these metals (herbicides), and the difference in distribution and concentration can be controlled by soil physical parameters. This is evidence of the synergic effects of pollutants, which in the field could entail environmentally adverse consequences (Ricardo et al., 2020).

The results of the PCA and HCA reveal that all metallic elements have same sources which could be anthropogenic, mainly from agricultural activity. Consequently, it can be concluded that agricultural practices have led to the presence of these toxic elements in the soil's ecosystem. The uncontrolled use of agrochemicals automatically leads to the higher concentrations of metallic substances in the soil, and the increasing accumulation of these elements can lead to their uptake through food chain.

Conclusion

In current study, EF, Igeo, PLI, E^i_r, PER and statistical analysis were used for understanding the degree of HM contamination in Wakwa's soil. Electric conductivity and pH were also determined. The following conclusions were drawn from the study. The mean concentrations of some metals (As, Ba, Cu, Mn, Sr, Y and Zn) were found to be lower than the average shale reference values in all sites. While others (Cr, Zr, Mo and Pb) are above the average shale reference values in all sites. Ni and V values are higher than the average shale reference values in sites WK_3 and WK_4. The EF and Igeo results show zero to moderate enrichment and zero to light contamination, respectively for most of the studied HMs. PLI of less than 1 indicates an unpolluted soil, but in our sites, it is close to 1, which could indicate a slight pollution. In the surface soils of each site, all HM present low

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ecological concern and low potential ecological risk indices (PER) at different level. The Ecological risk factors (Eir) for toxic metals were: Pb >As > Ni> Co> Cr> V> Cu >Zn > Mn> Ba. All site recorded acidic pH except WK_1 which has pH close to neutral. Positive and highly significant correlations were observed for several pairs. The presence of these heavy metals that can be found in food raises questions about the quality of food produced in Wakwa's agroecosystem. Human exposure through consumption of agricultural product is necessary to be assessed and also the pollution of marine ecosystem.

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Authors' contributions:

This work was carried out in collaboration between authors. Author AMINATOU Amraou designed the study, wrote the protocol, and correct the final manuscript. Author YABOKI Elisabeth wrote the first draft of the manuscript. Author Yvette Clarisse MFOPOU MEWOUO managed the lab analysis of the study. Author ZING ZING Bertrand performed the statistical analysis. Author NDO Eunice manage the study and coordinate the project. All authors read and approved the final manuscript.

Data availability and material: the data and materials that support the findings of this study are available on request from the corresponding author.

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