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Original Article

Determination of Local Background Values and Potential Ecological Risk Evaluation of Heavy Metals in Vina's Ferralitic Soil, Adamawa Cameroon

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Abstract *- Local geochemical background (LGB) has great importance for environmental assessment and management. In this study, 53 core soil samples were collected in 3 different sites with minimal or no human intervention to determine H.M. (Cr, Cu, Zn, Cd, Pb, Ni, Mn, As and Sn) concentration and pH. This study is aimed to define the Local Geochemical Background (LGB) of feralitic soil in Vina Cameroon. H.M. were determined using ICP-ES, and Excel was used for descriptive analysis. LGB was determined using the median ±2×MAD as the data are not normally distributed. Ei,r, and potential ecological risk index (PERI) were determined considering calculated LGB and Upper Continental Crust (UCC) standard values. Some obtained LGB (Pb, Zn, Cr and Sn) are greater than the UCC standard values that are mostly used to assess heavy metals in Cameroon. All the study sites present acidic pH. The obtained results are necessary to assess H.M.s pollution in the region and can be used as the basis for taking appropriate measures when restoring agricultural soils and protecting the quality of soil resources.*

Keywords *- Local geochemical background, Ecological risk, Soil pollution, Heavy metals, Adamawa.*

1. Introduction

Soil provides various vital functions for life and society, specifically food production through agriculture, which is historically considered the first great human activity that influenced soil quality (Ricardo et al., 2020). However, soils in agricultural production are endangered by external factors such as crop rotation, tillage, fertilisation and intensive use of pesticides (Zhao et al., 2018). Unfortunately, a lack of control and unbridled exploitation of the world's soil has seriously modified its properties. Soil serves as a sink for various heavy metals where they present for long periods of time in the soil and create many harmful effects on soil health (Savanoor et al., 2021; Louhar et al., 2020). In recent years, heavy metal pollution in soils has attracted worldwide attention due to its high level of toxicity, non-biodegradability and long-term accumulation behaviour (Patra et al. 2021).

Nowadays, various indexes, such as the enrichment factor (E.F.), geoaccumulation index (Igeo), contamination factor (C.F.), pollution load index (PLI), potential ecological risk index (PERI), have been developed to assess the degree of heavy metal contamination in sediments (Yu et al., 2019) and soil. The most commonly used pollution assessment indices are based on comparing measured heavy metal concentrations and background concentrations (Yu et al., 2019). The average concentrations of heavy metals in the upper continental crust (UCC), shale, preindustrial sediments or other largescale reference systems have been extensively used as heavy metal background values (Adamo et al., 2005; Islam et al., 2015; Costa-Boddeker et al., 2017; Lin et al., 2016; Qaswar et al., 2020). Nevertheless, the background values show significant regional characteristics, as geological and hydrological conditions differ greatly from region to region (Yu et al., 2019). In the tropical region and mainly in Cameroon, there exist few or no local geochemical background values. This leads researchers to compare the values obtained with the background considered elsewhere, which could bias the results obtained or the conclusions drawn. Grygar and Popelka (2016) strongly recommended using the local geochemical background for H.M.s evaluation.

Important agricultural areas in Ngaoundere and Adamawa generally have acidic and nutrient-depleted soils; this justifies the decline in agricultural production in the locality and forces many farmers to adopt pesticides. The use of various chemicals in agriculture has exploded during the last decade in Cameroon; it has become very urgent to determine regional or local background to assess heavy metal pollution properly. In this region, there are various soil types in the study site, with a predominance of ferralitic soil. Many studies in the region have focused on the assessment of heavy metals, but there exist no published results discussing Regional Geochemical Background determination. This work aims to determine the local geochemical background of some H.M.s (Cr, Cu, Zn, Cd, Pb, Ni, Mn, As and Sn) and calculate the associate environmental risk assessment in the Vina subdivision.

2. Materials and Methods

2.1. Study Site

In Cameroon, Adamawa is located in the northern part of the country and is a vast plateau in Central Africa. The region stretches across the width of Cameroon, from the Nigerian border in the west to the Central African border in the east. It is bounded to the south by the Mbere-Djerem division, to the north by the Benoue plain and to the west by the western highlands. The capital of the Adamawa Region, Ngaoundere occupies the northern part of the central Adamawa plateau (Tchotsoua, 2006) and is located between 7°03' and 7°32' North latitude and from 13°20' to 13°54' East longitude. The study site is the Vina subdivision located north of the region (Figure 1). The climate of the Adamawa plateau is the humid tropical Sudanian type (FAO, 2008; FAO, 2013) with a dry season of at least 4 months (November to March) and a long rainy season from April to October. The Adamawa plateau consists of a steep cliff in the north and slopes gently down to the south and east (Essama, 2013). Three morphological units can be distinguished. The study area belongs to the middle unit with an altitude between 1000 m and 1200 m. From a lithological point of view, 4 main types of geological formations can be distinguished in the Adamawa plateau: volcanic formations, plutonic formations, metamorphic formations and secondary formations (Lassere, 1961). Adamawa is made up of several soil types (Feuzeu, 2006). The region is dominated by ferrallitic formations from various or acidic rocks (Tchotsoua, No date). In the study site, the predominant soil type is ferralitic soil.

The main economic activities in the region are cattle rearing on the slopes and summits of the Ngaou (or Mornes) and agriculture. A good knowledge of heavy metal sources is necessary to estimate reasonable regional background values and properly assess the contamination status of heavy metals. The main source of soil pollution in the study site is agriculture; there is no industry in the locality.

2.2. Heavy Metal Determination

2.2.1. Sampling and Pre-Treatment

For the current study, 53 core soil samples were collected in 3 different sites with minimal or no human intervention. 18 samples were collected in site 1; 18 samples were collected in site 2 and site 3, and 17 samples were collected. Each soil sample was collected by sampling vertically from the topsoil to a depth of about 30 cm. The soil samples were collected from approximately the same slopes for each site. Figure 1 shows the locations of the sampling stations.

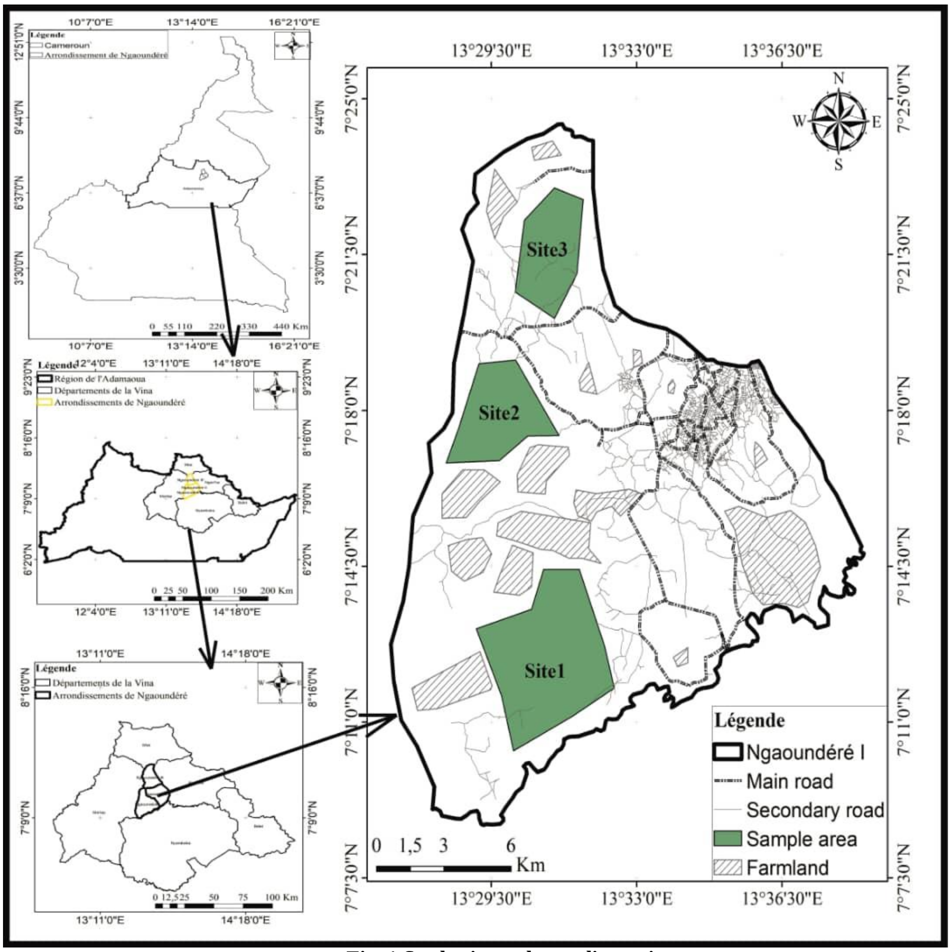

Fig. 1 Study site and sampling point

All samples were well mixed again in the laboratory, were spread on plastic trays and dried at room temperature for about 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 (Cr, Cu, Zn, Cd, Pb, Ni, Mn, As and Sn) in the topsoil composite samples were analysed and determined by Inductively Coupled Plasma-Optical Emission Spectroscopy (ICP-ES; Optima 3000, Perkin Elmer). In order to monitor the accuracy and precision of the analytical methods used, standards reference materials of soil (SSTD OREAS25A-4A and STD OREAS45E) were analysed simultaneously.

2.3. Determination of Geochemical Background

Currently, there are two kinds of methods for determining environmental background values, including the direct (geochemical) and indirect (statistical) methods (Sun Linhua, 2018). Among these two kinds of methods, the direct method is often criticised as having subjective sample selection criteria, heavy laboratory workload, and high costs, and therefore the application of the direct method is limited. For this study, the indirect method will be used. Many statistical methods can be used to compute background values like classical (mean ± (2 × standard deviation)), iterative (mean ± (2 × standard deviation)), boxplot, and (median ± (2 × median absolute deviation)) (MAD) (Tumova et al., 2019). The first two methods require a normal data distribution and are highly sensitive to extreme values and outliers. In contrast, the last two approaches are robust and resistant to aberrant values. The Grubbs test was applied to the background population to remove outliers, and the Shapiro-Wilk (S-W) test was performed to test the normality of the distribution. For the current study, LGB is calculated using the robust statistical method (median ± (2 × MAD)). MAD is a robust indicator of variation around the median (Reimann et al., 2018; Deyvison et al., 2022).

2.4. Potential Ecological Risk Load Index

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

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

Where C.F. 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 symbolises the toxic response coefficient of heavy metal (Mn = Zn = 1=Cu= < Cr = 2 < Ni = Pb = 5 < As = 10) (Guo et al., 2010; Ali Akber et al., 2019). PERI is the comprehensive potential ecological risk index computed as the sum of all E^r_i.

The single potential risk index (E^r_i) is calculated and classified as follows: 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). PERI is calculated and classified as follows: low risk (PER < 65), moderate risk (65≤ PER <130), considerable risk (130≤ PER < 260), and very high risk (PER ≥2600).

The descriptive statistics were carried out using Excel 2013.

3. Results and Discussion

3.1. Determination of Heavy Metals and Descriptive Statistic

H.M.s concentrations are present in Table 1.

Table 1. Heavy Metals concentration

	Cu	Pb	Zn	Ni	Mn	As	Cd	Cr	Sn
Concentration (mg/kg)	4-35	5-149	8-192	3-83	28-934	5-9	-	4-241	2-8
Lower Detection Limit	2,00	5,00	2,00	2,00	5,00	5,00	0,40	2,00	2,00

Table 2 below presents the mean values of studied H.M. and descriptive statistic results.

Table 2. Descriptive Statistics of Heavy Metal Concentrations (mg/kg)

	Cu	Pb	Zn	Ni	Mn	As	Cd	Cr	Sn
Mean	17,66	30,58	65,75	26,42	342,13	6,13	-	58,28	4,21
Median	14,00	28,00	46,00	17,00	303,00	6,00	-	33,00	4,00
SD	9,07	22,69	46,24	23,42	218,32	1,36	-	57,09	1,36
CV	8,99	22,47	45,80	23,20	216,25	2,36	-	56,55	2,04
Lower limit	-13,00	10,00	-11,50	-43,00	-256,00	3,13	-	-60,00	2,50
upper limit	51,00	42,00	120,50	93,00	920,00	8,13	-	148,00	6,50
number of outliers	0,00	9,00	8,00	0,00	1,00	1,00	-	3,00	8,00
% of ouliers (%)	0,00	17,00	15,00	0,00	2,00	2,00	-	6,00	15,00
quartile1	11,00	22,00	38,00	8,00	185,00	5,00	-	18,00	4,00
quartile3	27,00	30,00	71,00	42,00	479,00	6,25	-	70,00	5,00
MAD	7,83	11,66	34,70	19,81	177,17	0,94	-	45,40	1,01
Number	53,00	53,00	53,00	53,00	53,00	53,00	53,00	53,00	53,00

Table 3 presents the calculated background and some obtained backgrounds around the world. Considered background are Worldwide average soil, Shaw et al. (1986) Eade and Fahrig, Condie (1993), Eade and Fahrig (1973) and Gao et al. (1998a).

Table 3. Backgrounds Values

	Cu	Pb	Zn	Ni	Mn	As	Cd	Cr	Sn
LGB	29,66	51,32	115,41	56,62	657,34	7,88	-	123,81	6,01
Worldwide average soil		27,00	70,00	29,00	488.00			59.50	
UCC (Wedepohl, 1995)	45,00	20,00	95,00	68,00	850,00	13,00		90,00	2,50
Shaw et al., 1986	14		52	19		-		35	
Eade and Fahrig, 1973	26		60	19		-		76	
Condie, 1993	-		-	60		-		112	
Gao et al., 1998	32		70	38		4.4		80	
Taylor and McLennan, 1995	25		71	44		1.5		85	

Table 4 presents the pH of the study sites.

Table 4. Results of pH

	Site 1	Site 2	Site 3
pH	5.9	4.7	5.3

Potential ecological risk indices and potential toxicity response indices of heavy metals of the mean values (table 5) were calculated using computed LGB and UCC background values. All ETMs present low ecological risk concerns; this could confirm the fact that the study site is a site with no or low human activities.

Table 5. Potential Ecological Risk Indices and Potential Toxicity Response Indices of heavy metals

Eir	Cu	Pb	Zn	Ni	Mn	As	Cd	Cr	PERI
LGB	0,60	2,98	0,57	2,33	0,52	7,78	0,00	0,94	15,72
UCC	0,39	7,65	0,69	1,94	0,40	4,71	0,00	1,30	17,08

4. Discussion

Some obtained LGB (Pb, Zn, Cr and Sn) are greater than the UCC values mostly used to assess heavy metals in Cameroon. The others are below the UCC reference value. The same observation is done by comparing obtained background values with values obtained by Amina et al. (2021) in their study in Yaoundé Cameroon. For Cr (123.8) > Cr (116); Mn (657.33) > 589; Ni (56.61) > 18.4; Pb (51.33) > 16.6. While Zn (115.4) <236 and Cu (29.65) < 188 have lower values than those found by their research team. Obtained background for Cr and Zn is also greater than all considered reference values in this study; this could mean a high content of these two H.M.s in the study area. High Cr (27.8–422.7 mg/Kg) and Pb (0–3320 mg/Kg) contain was also found by Asaah et al. (2006) in their study on ferralitic soil in Douala.

The obtained values for most ETMs are greater than the Worldwide average soil values. With this, we understand the importance of determining local background values, which is recommended by many scientists such as Grygar and Popelka (2016) and particularly for Pb evaluation.

Acidic pH favors metal availability (Oseni et al., 2016), and all pH of the current study are acidic; this could probably explain the high concentration of some H.M.s in the studied site.

5. Conclusion

Based on 53 core soil samples of three different sites, heavy metals concentrations (Cr, Cu, Zn, Cd, Pb, Ni, Mn, As and Sn) were determined using ICP-ES, and each site's pH was also determined. Statistical methods were used to determine the LGB of the Vina subdivision. Ei,r and PERI were determined considering calculated LGB and UCC standard values. Some obtained LGB (Pb, Zn, Cr and Sn) are greater than the UCC standards values mostly used to assess heavy metals in Cameroon. All H.M. present low ecological concern and potential ecological risk indices (PERI) were also low. All sites present acidic pH. Determining environmental baselines for the agricultural site will be useful for ecosystem protection.

Statements and Declarations

Authors' Contributions

This work was carried out in collaboration between authors. Author AMINATOU Amraou designed the study, wrote the protocol, wrote the first draft of the manuscript and corrected the final version.

Author SOUNYA Jean Boris has drawn the map of the sampling point. ONDOU OYONO Joseph Sadrac has performed the statistical analysis. All authors read and approved the final manuscript.

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