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Assessment of Agricultural soil pollutionat Ouagadougou and Loumbila, Burkina Faso

BambaraTelado Luc [1], DerraMoumouni [2], KaboréKarim [3], Beogo Cedric[4], Ousmane I. Cissé[5], Francois Zougmoré[5]

[1]*Physics and chemical Department, Institute of Sciences, Ouagadougou, Burkina Faso*
[2] *Physics Department; University Norbert Zongo, Koudougou, Burkina Faso*
[3] *Physics Department; Virtual University, Ouagadougou, Burkina Faso*
[4] *Physics Department; University Thomas Sankara, Ouagadougou, Burkina Faso*
[5] *Physics Department; University Joseph KI-ZERBO, Ouagadougou, Burkina Faso*

Abstract

The present work is to evaluate the degree of heavy metal contamination and pollution such as: Pb, Zn, Ni, Cd, Mn, Cr, Fe, Co, Hg and As in Ouagadougou (Paspanga and Goudrin) and Loumbila agricultural soil. This study concerned top soils (0-5cm). The soil samples were analyzed using the VARIAN AA 240FS flame atomic absorption spectrometry (FAAS).

The results of average concentrations of the heavy metals for the four study areas showed that the concentrations of iron and manganese were high compare to the other metals. But the heavy metals average concentrations in soils were less than the limit set by the WHO. The distribution of the heavy metals concentrations for the four sites is given in this paper. The index of geo-accumulation show that the agriculture soil from Goudrin was the moderate polluted with As. Also the Co, Cr, Fe, Ni, Mn, Zn and Hg were uncontaminated metal in the pollution of agriculture soil from Paspanga, Goudrin and Loumbila. The pollution load index (PLI) showed that the quality of Loumbila, Paspanga 1 and Goudrin soils are deteriorated with time and this deterioration can lead to an important pollution by the effect of accumulation.

Key-words:*Heavy metals, concentration, index of geo-accumulation, pollution load index, agricultural soils and accumulation.*

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I. Introduction

The environmental pollution due to the toxic metal began the problem in the metropolitan cities; the geo-accumulation, bioaccumulation and bio-magnifications in the ecosystem can be due to the toxic heavy metal. The biologic system need the heavy metal but their lack or excess can lead to several messes. The heavy metals contamination of water, soil and air can lead to the contamination of the food and cause their accumulation in the biologic organism (Sonawane*et al.*, 2013). Conventional inorganic phosphorus fertilizers and organic manures can be an important source of heavy metals in agricultural soil (Huang *et al.*, 2007). A heavy metal in soil can negatively affect crop growth and also interferes with metabolic functions in plants, inhibition of photosynthesis, respiration and degeneration of main cell organelles (Begum *et al.*, 2014). The heavy metal can pollute ground water because of its rapid transfer in soil profiles. The potential accumulation and bioaccumulation of heavy metals in agricultural soils affects seriously food chain contamination (Jayadev*et al.*, 2012). Therefore an estimate of the concentration, a better understanding of sources of heavy metal contamination and their accumulation in agricultural soil can be particularly important issues for related risk assessments. The objective of this study was to assess the concentration of heavy metals and the state of pollution of market garden soils in the central region of Burkina Faso to provide the scientific basis for improving the quality of the environment in agricultural soils.

II. MaterialsAnd Methods

A. Presentation of the areas of study

The study was carried out in Ouagadougou and Loumbila. The cities of Ouagadougou and Loumbila are cities with strong market gardening activities. These market gardening activities are generally developed around dams, around wastewater evacuation canals, on developed perimeters and lowlands. Market garden products from Ouagadougou and Loumbila are largely consumed in the city of Ouagadougou.

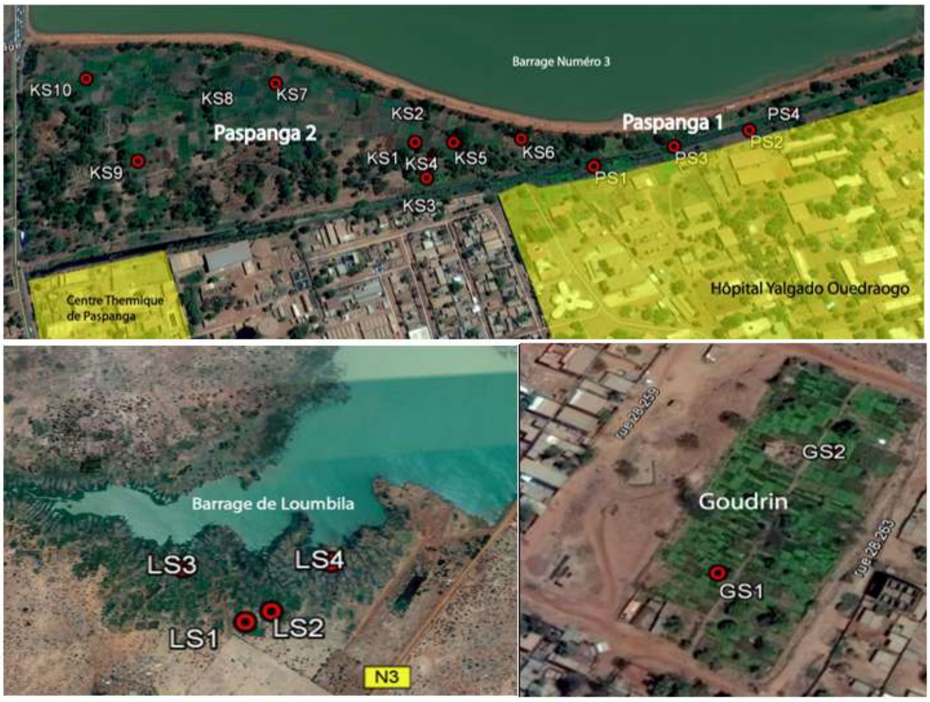

Figure 1: Presentation of the study areas

B. Flame atomic absorption spectrophotometer (SAAF)

Atomic absorption is a process that takes place when an atom changes from a ground state to an excited state by absorbing electromagnetic radiation, which corresponds to a specific wavelength. The atomic absorption spectrum is made up of a series of resonance lines, which originate from the ground electronic state and end in different excited states. The strongest absorption capacity is generally between the ground state and the first excited state: this is the line usually used. Incident radiation from a light source is at the origin of the transitions between the ground state and the excited state. The frequency of the incident radiation is exactly equal to that of a specific transition. Part of the energy of the incident radiation is absorbed. The variation in the radiant power of the incident beam in the presence and absence of analyte atoms in the atomizer makes it possible to determine the atomic absorption. The line width emitted by the light source should be smaller than the line width absorbed by the analyte. The amount of energy absorbed from the radiation beam for the wavelength of a resonance line will increase with increasing number of atoms of the selected element in the absorption chamber. The relationship between the amount of light absorbed and the concentration of the analyte present in the standards can be determined. The concentrations of the samples can be determined by comparing the amounts of radiation absorbed by the samples with the amount of radiation absorbed by the standards. The instrument reading can be calibrated to display sample concentrations directly (Bendada*et al.*, 2011; Dante, 2007).

C. Determination with a flame atomic absorption spectrophotometer (FAAS)

The concentrations of the different metals in the samples were determined by atomic absorption spectrometry at the Accra nuclear center (Ghana Atomic Energy Commission). The device used is a flame atomic absorption spectrometer, make VARIAN AA 240FS, supplied by an air-acetylene flame at an air pressure of 2.5-4 bars and that of acetylene: 0.5 -0.6 bar.

D. Digestion procedure of soil samples

The samples were digested with a microwave oven (Milestone microwave Labstation (ETHOS 900)). A sample of soil with a mass of 1.5 grams was weighed and placed in a tube of Teflon (polytetrafluoroethylene (PTFE)) with a capacity of 100ml. Then, a concentrated acid, formed of 6ml of concentrated nitric acid (HNO3, 65%), 3ml of concentrated hydrochloric acid (HCl, 35%) and 0.25ml of hydrogen peroxide (H2O2, 30%) was added to each sample. The sample acid mixture obtained was irradiated for 26 minutes in a microwave oven, make ETHOS 900, INSTR, ML 1200 MEGA. After digestion was completed, the Teflon tube containing the sample was cooled in a bath (water) to reduce internal pressure and to re-stabilize and prevent the material from volatilizing. Finally, the obtained solution was diluted up to 20ml with distilled water and analyzed to determine the concentration of the elements (Zn, Pb, Fe, Mn, Cr, Hg, Co, Ni, Cd and As) using the VARIAN AA 240FS, flame atomic absorption spectrometer which uses acetylene-air under the recommended parameters of the instrument.

E. Estimation of pollution level

In this study, to quantify the degree of pollution in the refuse dump soils the geoaccumulation index, Igeo, was used (Agyarko*et al.*, 2010 ; Hashim *et al.*, 2015 ; SEMRA *et al.*, 2010 ; Huang *et al.*, 2017 ; Sapana *et al.*, 2014 ; Sekabira *et al.*, 2010 ; Maurizio, 2016) :

$$I_{geo} = \ln(\frac{C_n}{1{,}5B_n}) \qquad (1)$$

Where: C_n: measured concentration of metal in the refuse dump soil (µg/g);

B_n: background value of heavy metal (µg/g);

and 1.5: background matrix correction factor.

The degree of pollution of the refuse dumps by the metals was assessed using the geoaccumulation index (igeo) classification (table 1) by Förstner et al. (Förstner *et al.*, 1993 ;Sana'a,2015 ; Silva *et al.*, 2017 ; Walla *et al.*, 2015).

Table 1.Geoaccumulation index classification.

Geoaccumulation index, I_{geo}	I_{geo} class	Contamination intensity
> 5	6	very strong
> 4–5	5	strong to very strong
> 3–4	4	strong
> 2–3	3	moderate to strong
> 1–2	2	moderate
> 0–1	1	uncontaminated to moderate
< 0	0	practically uncontaminated

F. Quantification of the soil pollution

In this study, the soil pollution degree was quantified using the Pollution Load Index (PLI).

The pollution load index of sampling site was calculated using the contamination factor of the heavy metal. The PLI for a single site is the nth root of the product of the n CF values (Begum *et al.*, 2014 ; Bentum *et al.*, 2011 ; Fahad*et al.*, 2016 ; Mandeng *et al.*, 2019; Sadhu *et al.*, 2012).

$$PLI = (CF_1 * CF_2 * CF_3 * .... * CF_n)^{1/n} \qquad (2)$$

Where, n is the number of metals index provides a simple, comparative means for assessing the level of heavy metal pollution.

The CF is the concentration of each metal in the soil divided by the background concentration of the metal (concentration in unpolluted soil)(Afrifa *et al.*, 2013 ;Qingjie*et al.*, 2008).

$$CF = \frac{C_{\text{heavy metal}}}{C_{\text{background}}} \qquad (3)$$

The background concentrations were calculated from the heavy metals concentration in unaffected soils of the studied area (Esshaimi *et al.*, 2012).

Where a value of PLI < 1 denote perfection; PLI = 1 present that only baseline levels of pollutants are present and PLI > 1 would indicate deterioration of site quality (Oludare *et al.*, 2014 ; Tomgouani*et al.*, 2007).

III. ResultsAnd Discussion

The heavy metals concentration in the soil samples wereevaluated. The samples were taken from the surface (0 - 5 cm). After the determination of the heavy metals concentrations in the soils samples, an assessment of the pollution was carried out from the geoaccumulation index and the pollution load index.

A. Average concentration of heavy metals in the soil

Tables 2 to 5 shown the average concentrations of heavy metals at the surface (0-5cm) of the soil for the sampling areas.

Table 2: Heavy metals average concentration (ppm) in Paspanga 1 soils

	Paspanga 1	[Co]	[Cr]	[Fe]	[Mn]	[Zn]	[Pb]	[Ni]	[As]	[Hg]
Surface (0-5 cm)	Average	2,58	5,79	186,77	58,72	5,62	5,94	1,25	1,34	0,06
	Median	2,55	5,71	183,79	56,58	5,69	6,08	1,21	1,35	0,06
	Standard Deviation	0,23	1,32	8,13	22,69	1,31	1,45	0,37	0,26	0,02

		[Co]	[Cr]	[Fe]	[Mn]	[Zn]	[Pb]	[Ni]	[As]	[Hg]
	Minimum	2,35	4,32	180,99	33,45	4,19	4,04	0,87	1,08	0,03
	Maximum	2,87	7,41	198,49	88,29	6,91	7,55	1,72	1,59	0,08
WHO limit		-	150	-	-	300	100	50	40	-

Table 2 presents the average concentrations, Median, standard deviations, minimum and maximum values of the heavy metals concentration in the soils fromPaspanga 1. The average values of the concentration in Paspanga 1 soil were 186.8 ppmfor Fe, 58.72ppm for Mn, 5.94ppm for Pb, 5.79 ppm for Cr, 5.62ppm for Zn, 2.58ppm for Co, 1.34 ppm for As, 1.25 ppm for Ni and 0.06 ppm for Hg. Cadmium had a concentration below the detection limit. The limit concentrations defined by the WHO in soils are 100 ppm for Pb, 3 ppm for Cd, 50 ppm for Ni, 150 ppm for Cr, 40 ppm for As and 300 ppm for Zn (Tomgouani*et al.*, 2007 ; Matech*et al.*, 2014). The mean concentrations of Cr, Zn, Pb, Ni and As obtained at Paspanga 1 in this study are all below WHO recommended limits.

Table 3: Heavy metals average concentration (ppm) in Paspanga 2 soils

Paspanga 2		[Co]	[Cr]	[Fe]	[Mn]	[Zn]	[Pb]	[Ni]	[As]	[Hg]
Surface (0-5 cm)	Average	0,629	3,446	264,326	34,208	6,813	7,147	0,783	0,495	0,033
	Median	0,585	2,775	264,244	36,885	6,240	6,555	0,660	0,450	0,015
	Standard Deviation	0,290	3,035	2,697	11,185	2,593	2,244	0,358	0,287	0,021
	Minimum	0,075	1,680	260,585	13,725	4,860	4,845	0,345	0,165	0,015
	Maximum	1,155	12,495	270,621	51,360	14,265	11,205	1,500	0,900	0,060
WHO limit		-	150	-	-	300	100	50	40	-

The average, median, standard deviations, minimum and maximum values of the heavy metals concentration in the soils fromPaspanga 2 are presented in Table 3. The average values of the concentration in the soil were 264, 33 ppm for Fe, 34.21ppm for Mn, 7.15ppm for Pb, 6.81ppm for Zn, 3.45ppm for Cr, 0.78ppm for Ni, 0.63ppm for Co, 0.50ppm for As and 0.03 ppm for Hg. Cadmium had a concentration below the detection limit. The mean concentrations of Cr, Zn, Pb, Ni and As obtained inPaspanga 2 soil in this study are all below WHO recommended limits(Tomgouani*et al.*, 2007 ; Matech*et al.*, 2014).

Table 4: Heavy metals average concentration (ppm) in Loumbila soils

Loumbila		[Co]	[Cr]	[Fe]	[Mn]	[Zn]	[Pb]	[Ni]	[As]	[Hg]
Surface (0-5 cm)	Average	1,31	2,98	203,27	39,46	4,37	5,75	1,05	1,35	0,06
	Median	1,33	2,91	203,97	33,26	3,60	6,18	0,99	1,46	0,06
	Standard Deviation	0,47	0,52	2,29	22,02	1,91	2,73	0,28	0,33	0,02
	Minimum	0,77	2,53	200,03	21,97	3,07	2,54	0,78	0,87	0,04
	Maximum	1,79	3,59	205,11	69,34	7,20	8,12	1,43	1,63	0,08
Limites OMS		-	150	-	-	300	100	50	40	-

The results of the average, standard deviations, minimum and maximum values of the heavy metals concentration in Loumbila soils are given in Table 4. The average values of the concentration in the soil from most to least concentrated were 203 , 27ppm for Fe, 39.46ppm for Mn, 5.75ppm for Pb, 4.37ppm for Zn, 2.98ppm for Cr, 1.35ppm for As, 1.31ppm for Co, 1.05ppm for Ni and 0.06 ppm for Hg. Cadmium had a concentration below the detection limit. The mean concentrations of Cr, Zn, Pb, Ni and As obtained at Loumbila during this study are all below the limit by WHO (Tomgouani*et al.*, 2007 ;Matech*et al.*, 2014).

Table 5: Heavy metals average concentration (ppm) in Goudrin soils

Goudrin		[Co]	[Cr]	[Fe]	[Mn]	[Zn]	[Pb]	[Ni]	[As]	[Hg]
Surface (5cm)	Average	0,470	2,667	192,253	34,430	4,513	1,893	0,293	1,567	0,073
	Median	0,470	2,667	192,253	34,430	4,513	1,893	0,293	1,567	0,073
	Standard Deviation	0,250	0,999	8,817	1,391	0,462	0,490	0,075	0,028	0,009
	Minimum	0,293	1,960	186,018	33,447	4,187	1,547	0,240	1,547	0,067

Maximum	0,647	3,373	198,487	35,413	4,840	2,240	0,347	1,587	0,080
Limites OMS	-	150	-	-	300	100	50	40	-

Table 5 gives the average concentrations, the standard deviations and the minimum and maximum values of heavy metals concentration in the soils fromGoudrin. The mean values of the concentration in the soil from most to least concentrated were 192.25ppm for Fe, 34.43ppm for Mn, 4.51ppm for Zn, 2.67ppm for Cr, 1.89ppm for Pb , 1.57ppm for As, 0.47ppm for Co, 0.29ppm for Ni and 0.07 ppm for Hg. Cadmium had a concentration below the detection limit. The mean concentrations of Cr, Zn, Pb, Ni and As obtained at Goudrin during this study are all below the limit recommended of WHO (Tomgouani*et al.*, 2007 ;Matech*et al.*, 2014). The high concentrations of iron in soils can be explained by the ferruginous nature of the soils (Pallo *et al.*, 1989).

B. Variation of heavy metals in the study areas

Figure 2 shows the variation in the average concentration of heavy metals over the different study areas.
Iron and manganese had the highest concentrations in soil samples from the studied sites. The highest iron concentration was observed in soil samples from Paspanga 2, with a concentration of 264.33 ppm. Zn and Pb concentrations were also highest in Paspanga 2 samples. This high iron concentration may be related to the nature of the soil. High concentrations of Co, Cr, Mn and Ni were observed in soil samples from Paspanga 1, with respective concentrations of 2.58 ppm, 5.79 ppm, 58.72 ppm and 1.25 ppm.

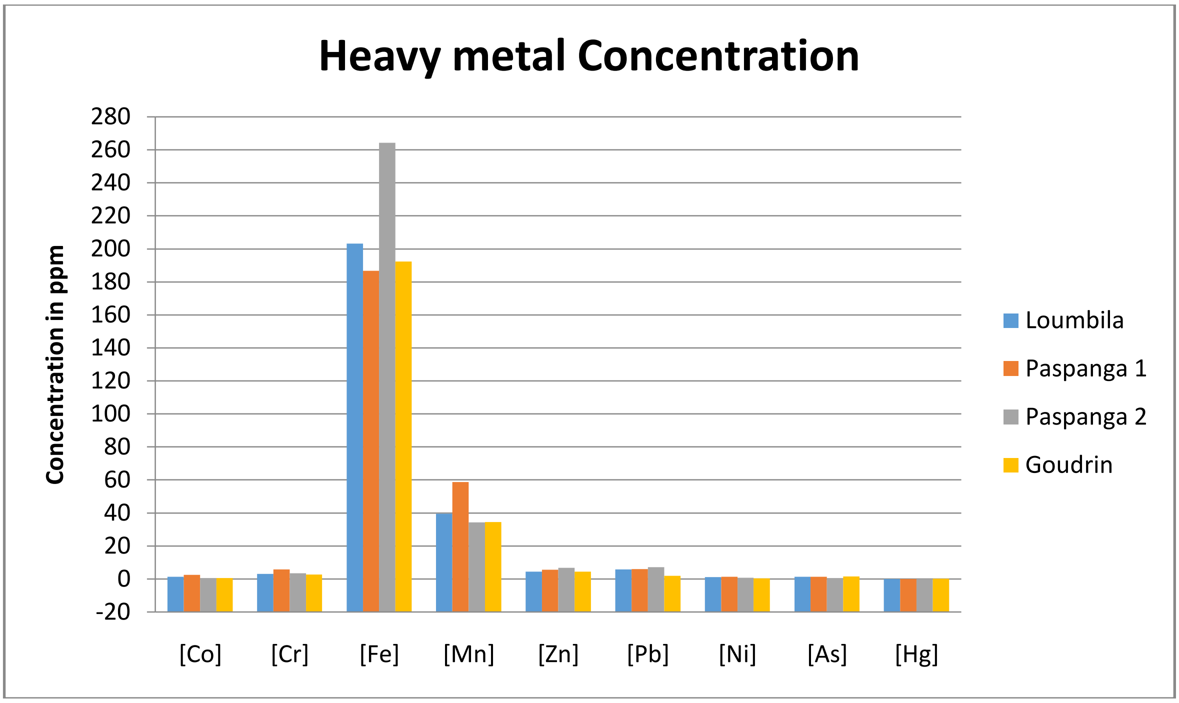

Figure 2: Concentration of heavy metal in studies areas

The distribution of heavy metals is in the following descending order:

- Paspanga 1 soil: [Fe]> [Mn]> [Pb]> [Cr]> [Zn]> [Co]> [As]> [Ni]> [Hg];
- Paspanga 2 soil: [Fe]> [Mn]> [Pb]> [Zn]> [Cr]> [Ni]> [Co]> [As]> [Hg];
- Loumbilasoil: [Fe]> [Mn]> [Pb]> [Zn]> [Cr]> [As]> [Co]> [Ni]> [Hg];
- Goudrinsoil: [Fe]> [Mn]> [Zn]> [Cr]> [Pb]> [Co]> [As]> [Ni]> [Hg];

Mercury is the least concentrated heavy metal in soils. The average concentration of heavy metal in soil samples from the four (4) study areas were below the limit recommended by WHO. To assess the environmental impact on the market gardening perimeters, the geo-accumulation index and pollution load index were calculated.

C. Comparison of agricultural soil concentrations

Table 6 shows the average concentrations of heavy metals in soils at the studies sites (Loumbila, Goudrin and Paspanga 1 and 2) and those of some others in the sub-region (Nigeria, Ghana and Cote D'Ivoire).

Table 6: Comparisons of heavy metal concentrations in agricultural soils

	[Co]	[Cr]	[Fe]	[Mn]	[Zn]	[Pb]	[Ni]	Cd	[As]	[Hg]
Paspanga 1	2.58	5.79	186.77	58.72	5.62	5.94	1.25	0.03	1.34	0.06
Paspanga 2	0.63	3.45	264.33	34.21	6.81	7.15	0.78	0.03	0.50	0.03
Lounbila	1.31	2.98	203.27	39.46	4.37	5.75	1.05	0.03	1.35	0.06
Goudrin	0.47	2.67	192.25	34.43	4.51	1.89	0.29	<0.013	1.57	0.07
Geriyo 1 (Nigeria)	-	11.2	86.9	12.79	74.39	7.18	-	9.86	-	-
Geriyo 2 (Nigeria)	-	199.6	294.7	131.9	310.2	159.2	-	240.2	-	-
KeffI (Nigeria)	8.77	-	-	26.53	16.02	12.74	6.02	0.76	-	-
Attécoubé (Cote d'Ivoire)	-	1.72	-	-	1749.54	496.54	-	1.56	-	-
Cocody (Cote d'Ivoire)	-	1.62	-	-	1002.45	37.13	-	1.84	-	-
Tarkwa (Ghana)	1.8	21	-	-	39	7.20	3.7	0.052	4.4	0.32

Sources : Hong *et al.*,2014 ; Abdullahi *et al.*, 2012 ; Seka *et al.*, 2015 ; Nesta *et al.*, 2015

The analysis of Table 6 shows that the cobalt concentration on the soil of Keffi in Nigeria is higher than that obtained in soils samples from the studies sites. The cobalt concentration on the soil of Paspanga 1 is higher than that of Tarkwa in Ghana. The chromium concentration on agriculture soil of Tarkwa, Geriyo 1 and 2 were higher than those obtained at Loumbila, Goudrin and Paspanga 1 and 2. The iron and manganese concentrations on agriculture soil of Loumbila, Goudrin and Paspanga 1 and 2 were lower than those obtained at Geriyo 1. Zinc, lead and cadmium concentrations on agriculture soil of Tarkwa, Keffi, Geriyo 1 and 2, Attecoube and Cocodywere higher than those obtained in Loumbila, Goudrin and Paspanga 1 and 2. Nickel, arsenic and mercury concentrations on agriculture soil ofLoumbila, Goudrin and Paspanga 1 and 2 were lower than those obtained atTarkwa.

D. Index of geo-accumulation

The table 7 and figure 3 shown the variation and the value of geo-accumulation index for each heavy metal.

Table 7: Index of geo-accumulation (Igeo) of heavy metal in every site.

Igeo	[Co]	[Cr]	[Fe]	[Mn]	[Zn]	[Ni]	[As]	[Hg]
Loumbila	0,267	-0,006	-0,360	0,566	0,376	-0,483	0,997	0,192
Paspanga 1	0,948	0,657	-0,445	0,964	0,627	-0,304	0,989	0,163
Paspanga 2	-0,465	0,139	-0,098	0,423	0,820	-0,775	-0,009	-0,414
Goudrin	-0,756	-0,118	-0,416	0,430	0,408	-1,757	1,143	0,393

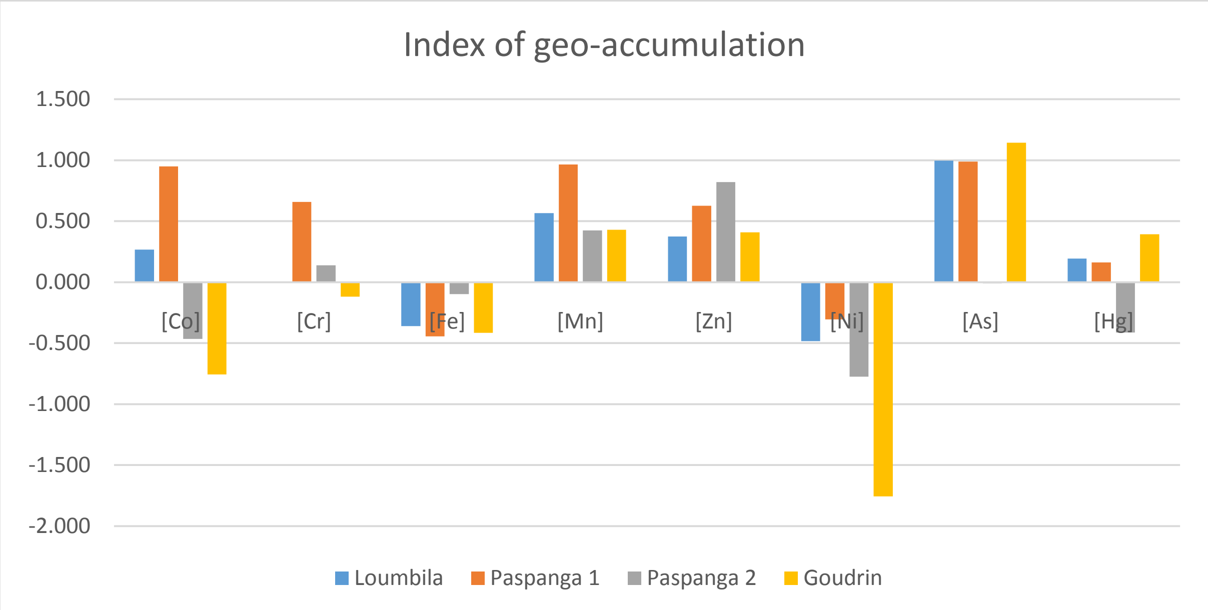

Figure 3: Index of geo-accumulation of heavy metal in surface soils

The geo-accumulation index various between -0.483 to 0,997in agriculture soil from Loumbila. The pollution levels in agriculture soil from Loumbilafor Cr, Fe, and Ni were practically uncontaminated but uncontaminated to moderate for Co, Mn, Zn, As and Hg.

The maximal value of geo-accumulation indices was 0,989 in agriculture soil from Paspanga 1. The metal who contribute more to the soil pollution at Paspanga 1 was As, with a level of uncontaminated to moderate.

The pollution levels in agriculture soil from Paspanga 2 were practically uncontaminated except for Cr, Mnand Zn with a level of uncontaminated to moderate.

The pollution levels in agriculture soil from Goudrin for were practically uncontaminated for Co, Cr, Fe, Ni and uncontaminated to moderate for Mn, Zn, Hg. Only the geo-accumulation indices of As was greater than one in agriculture soil from Goudrin with a level of moderate.

In conclusion, the classifications show that the agriculture soil from Goudrinwas the moderate polluted with As. The Co, Cr, Fe, Ni, Mn, Zn and Hg were uncontaminated metal in the pollution ofagriculture soil from Paspanga, Goudrin and Loumbila.

E. Pollution load index (PLI)

To assess the soil pollution of the sites, the pollution load index was calculated from the heavy metal contamination factor using equation 2. The soil is polluted when the pollution load index is greater than one. Figures 4 and 5 shown the pollution load index (PLI) of the Loumbila, Paspanga and Goudrin sites.

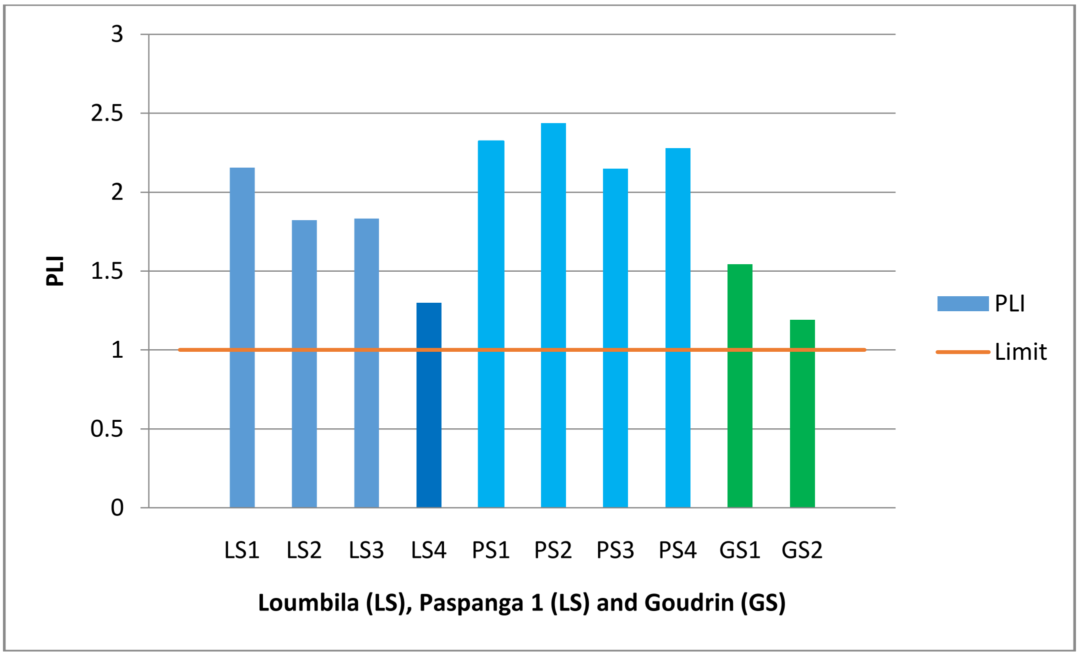

Figure 4: Pollution load index ofLoumbila, Paspanga 1 and Goudrin sites

Figure 4 clearly shows that all the pollution load index ofLoumbila, Paspanga 1 and Goudrin sites were greater than one. For the Loumbila sites, the pollution load index varies between 1.3 and 2.15, for Paspanga 1 it varies between 2.15 and 2.44. The pollution load index of Goudrin was between 1.19 and 1.54. All this indicates a deterioration in soil quality in Loumbila, Paspanga 1 and Goudrin. The deterioration of soil quality were importantinPaspanga 1 soils than on those of Loumbila. The least significant deterioration was observed in Goudrin.

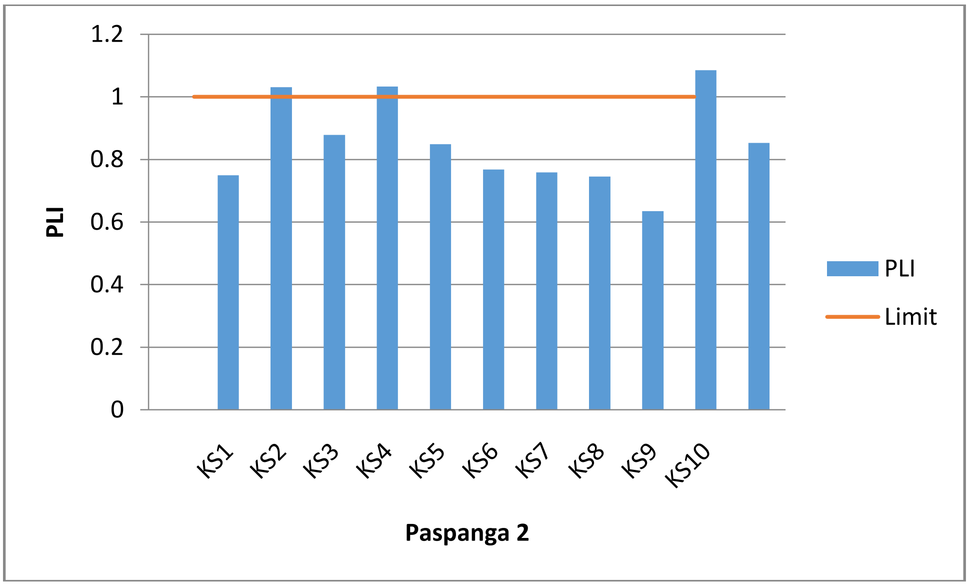

Figure 5: Pollution load index at the surface of the Paspanga 2 sites

The pollution load indices of the Paspanga 2 sites vary between 0.63 and 1.09 depending to the sampling site. The KS2, KS4 and KS10 sites have an index greater than one, but very close to one. Perfection is noted on the Paspanga 2 sites. In General, the quality of the soils in Paspanga 2 siteswas good.

IV. Conclusion

The concentrations of heavy metals in the soils of the study areas were assessed, then the geo-accumulation index was calculated and finally the pollution load index using the concentration and the contamination factors. The concentrations of iron and manganese were very large compared to other metals. However, none of the concentrations determined in soils exceed the limit recommended by the WHO. The classification of geo-accumulation index show that the agriculture soil from Goudrin was the moderate polluted with As. The quality of the soils in Paspanga 2 sites was good. Finally, the quality of Loumbila, Paspanga 1 and Goudrin soils was deteriorated over time and if not taken care of this deterioration can lead to significant pollution through the accumulation effect.

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