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Assessment of Heavy Metals Contamination in Agricultural Soil of Loumbila and Paspanga, Burkina Faso

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ABSTRACT:Agricultural soil quality deterioration resulting from increase in the level of heavy metals is becoming more and more pronounced, thus raising the question on safety status of human health and environment. Determination of concentration and contamination factor assessment of heavy metal in agricultural soil including top soils and subsoil in Loumbila and Paspanga, Burkina Faso was undertaken. The soil samples were analysed for trace metals employing flame atomic absorption spectrometry (FAAS). The soil data were analyzed using the quality indices as contamination factor (CF) and pollution load index (PLI) to characterize the contamination and the pollution. The decreasing order of metals observed in Loumbila top soil samples is Fe>Mn>Pb>Zn>Cr>As>Co>Ni while that of Paspanga top soil samples is Fe>Mn>Pb> Cr> Zn> Co> As> Ni. The levels of heavy metals analyzed are within the threshold limit set by the WHO. The concentration of heavy metal in the top soil are high than the subsoil concentration. The PLI indicates the build-up of metals pollution in Loumbila and Paspanga market garden (soil) particularly Pb.

KEYWORDS:Heavy metals, agricultural soil, contamination factor, pollution load index.

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 [1]. Conventional inorganic phosphorus fertilizers and organic manures can be an important source of heavy metals in agricultural soil [2]. 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 [3]. 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 [4]. Therefore an assessment and a better understanding of sources of heavy metals, their accumulation in the agricultural soil and their presence in water and the plants can be particularly important questions on the evaluations of the risk.

The objective of this study was to assess and analyze the concentration of heavy metals and their contamination status in agricultural soils in Burkina central region and provide scientific basis for improving environmental quality in agricultural soils.

II. MATERIALS AND METHODS

A. **Study Area**

In this study, the soil samples were collected in two different agricultural areas: market garden of Loumbila and market garden of Paspanga. Distance of 18 kilometers from Ouagadougou capital city of Burkina, the market garden of Loumbila is expanding around the dam. The dam of Loumbila is located at a longitude of 01°24’07.4 West and a latitude of 12°29’35.8 North with the water capacity of 42.2 million cubic meter. It is used by market gardeners to irrigate the plants [5]. The market garden of Paspanga is located in Ouagadougou behind the

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YalgadoOuedraogoTeaching Hospital with the surface of 1ha. It is irrigated with the water well located two meters from the hospital waste water pipe.

B. **Samples and Sampling Techniques**

The samples were collected from the market garden of Loumbila and Paspanga at two different levels: top soil 0-5cm and sub soil15-20cm. The agricultural soil sample was collected at three or four different points on the diagonal profile of each site. The soils from the different points were mixed and kept in sterile bottle glass. The samples were collected from ten sites (five from Loumbila and five from Paspanga). Loumbila samples were noted LS and PS for Paspanga samples.

C. **Laboratory Analysis**

The heavy metals such as cobalt (Co), chromium (Cr), iron (Fe), manganese (Mn), zinc (Zn), lead (Pb), nickel (Ni), cadmium (Cd), arsenic (As) and Mercury (Hg) were analyzed in the sample by Atomic Absorption Spectrometer. The soil sample(1.5g) were weighed into a 100ml polytetrafluo-roethylene (PTFE) Teflon tube and concentrated acids of 6mL of concentrated nitric acid (HNO_3, 65%), 3mL of concentrated hydrochloric acid (HCl,35%) and 0.25mL of Hydrogen peroxide (H_2O_2,30%) were added to each sample. The samples were then loaded on the microwave carousel. The vessel caps were secured tightly using a wrench. The complete assembly was microwave irradiated for 26 minutes using milestone microwave Labstation ETHOS 900, INSTR: MLS-1200 MEGA. After digestion the Teflon tube mounted on the microwave carousel were cooled in a water bath to reduce internal pressure and allow volatilized material to re-stabilize. The solution was then diluted to 20 ml with distilled water and assayed for the presence of elements (Zn, Pb, Mn...) using VARIAN AA 240FS- Atomic Absorption Spectrometer in an acetylene-air flame. The metal final concentration was calculated using the following formula:

$$\text{Final concentration (mg/kg)} = \frac{\text{concentration of metal} * \text{dilution factor} * \text{nominal volume}}{\text{Sample weight (g).}}$$

D. Quantification of the soil pollution

In this study, the soil pollution degree and the contamination level were quantified using the Contamination Factor (CF) and Pollution Load Index (PLI) [6].

Contamination Factor (CF): The CF is the concentration of each metal in the soil divided by the background concentration of the metal (concentration in unpolluted soil).

$$CF = \frac{C_{heavy metal}}{C_{background}}$$

The background concentrations were calculated from the heavy metals concentration in unaffected soils of the studied area[7].

To classify the contamination levels, four categories were defined depending of the value of CF: low contamination for CF<1; moderate contamination for 1<CF<3: considerable contamination for 3<CF<6 and very high contamination for CF>6 [8][9].

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 [10]

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

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

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 [11][12].

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III. RESULT AND DISCUSSION

A. Heavy metals concentration in soil

Table 1: Average concentration of heavy metal in Loumbila top soil and sub soil

	Loumbila	Co	Cr	Fe	Mn	Zn	Pb	Ni	Cd	As	Hg
top soil (0-5 cm)	Mean	1.31	2.98	203.27	39.46	4.37	5.75	1.05	0.03	1.35	0.06
	Median	1.33	2.91	203.97	33.26	3.60	6.18	0.99	0.03	1.46	0.06
	Standard Deviation	0.47	0.52	2.29	22.02	1.91	2.73	0.28	0.00	0.33	0.02
	Minimum	0.77	2.53	200.03	21.97	3.07	2.54	0.78	0.03	0.87	0.04
	Maximum	1.79	3.59	205.11	69.34	7.20	8.12	1.43	0.03	1.63	0.08
sub soil (15-20 cm)	Mean	0.21	1.33	196.18	28.85	0.41	1.52	0.65	0.02	0.36	0.02
	Median	0.11	1.24	196.15	17.72	0.38	1.54	0.65	0.01	0.39	0.01
	Standard Deviation	0.23	1.23	4.21	26.25	0.09	0.15	0.20	0.01	0.14	0.01
	Minimum	0.07	0.01	191.31	12.35	0.35	1.32	0.46	0.01	0.17	0.01
	Maximum	0.55	2.83	201.11	67.60	0.54	1.67	0.83	0.03	0.50	0.03

Table 2: Average concentration of heavy metal in Paspanga top soil and sub soil

	Paspanga	Co	Cr	Fe	Mn	Zn	Pb	Ni	Cd	As	Hg
top soil (0-5 cm)	Mean	2.58	5.79	186.77	58.72	5.62	5.94	1.25	0.03	1.34	0.06
	Median	2.55	5.71	183.79	56.58	5.69	6.08	1.21	0.03	1.35	0.06
	Standard Deviation	0.23	1.32	8.13	22.69	1.31	1.45	0.37	0.00	0.26	0.02
	Minimum	2.35	4.32	180.99	33.45	4.19	4.04	0.87	0.03	1.08	0.03
	Maximum	2.87	7.41	198.49	88.29	6.91	7.55	1.72	0.03	1.59	0.08
sub soil (15-20 cm)	Mean	0.44	2.33	184.69	27.17	3.96	1.83	0.28	0.01	1.16	0.04
	Median	0.41	2.35	180.70	28.65	4.75	1.86	0.27	0.01	1.14	0.04
	Standard Deviation	0.19	0.92	8.09	8.43	2.28	0.45	0.05	0.00	0.40	0.02
	Minimum	0.27	1.27	180.53	15.98	0.67	1.35	0.23	0.01	0.79	0.03
	Maximum	0.65	3.37	196.82	35.41	5.65	2.24	0.35	0.01	1.57	0.07

Tables 1 and 2 show the averages values of heavy metals concentrations in topsoil and subsoil for Loumbila and Paspanga sites. For Loumbila sites, the average values of metal concentration were: 203.27 ppm for Fe, 39.46 ppm for Mn, 5.75 ppm for Pb, 4.37 ppm for Zn, 2.98 ppm for Cr, 1.35 ppm for As, 1.31 ppm for Co et 1.05 ppm for Ni. For Paspanga sites, the average values of metal concentration were: 186.77 ppm for Fe, 58.72 ppm for Mn, 5.94 ppm for Pb, 5.79 ppm for Cr, 5.62 ppm for Zn, 2.58 ppm for Co, 1.34 ppm for As et 1.25 ppm for Ni. The concentrations of Hg and Cd were very low for Loumbila and Paspanga sites. The concentrations of metal in Paspanga topsoil were higher than the concentration of metal in Loumbila sample except for the Fe. The WHO concentration limits in the soil are 100 ppm for Pb, 3 ppm for Cd, 50 ppm for Ni, 150 ppm for Cr, 40 ppm for As et 300 ppm for Zn [12][13]. The concentration of heavy metals obtained in this study are less than the WHO concentration limit.

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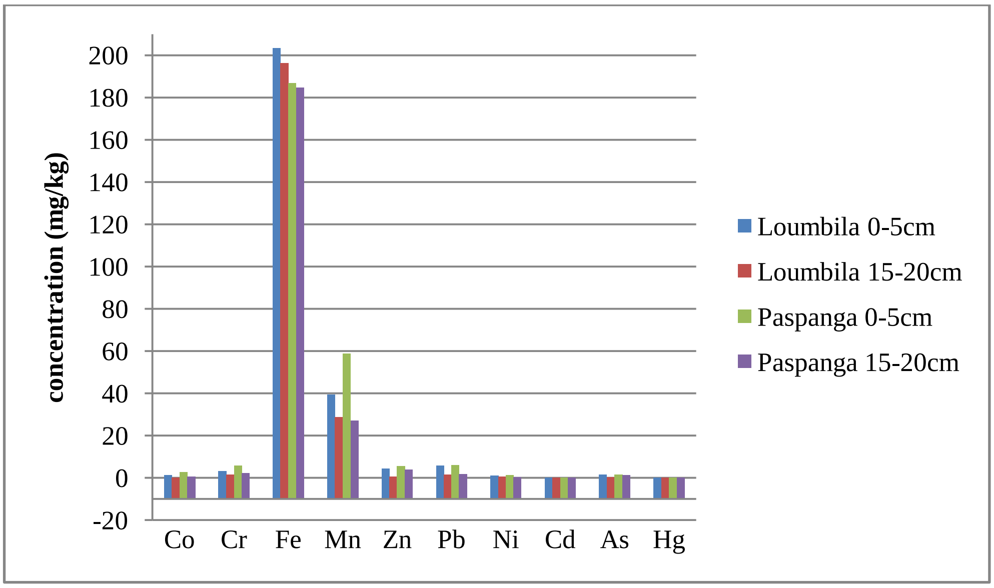

Fig. 1: Variation of the heavy metal concentration in Loumbila and Paspanga Soil

Fig.1 shows the variation of heavy metals concentration in topsoil (0-5cm) and subsoil (15-20cm). The higher values of heavy metal concentration were obtained for Fe and Mn. The concentrations of metal in subsoil were less than the topsoil concentration [12].

B. **Pollution degree in soil**

Figure 2 shows the contamination factor (CF) of different heavy metals from Loumbila and Paspanga soils.

Cobalt (Co): The highest values of Co Contamination Factor are observed in samples from Paspanga areas. The lowest and highest contamination factors of Co are 3.53 and 4.30 respectively. The contamination factor of Co varies between 1.15 and 2.67 for samples from Loumbila. The contamination of Co is considerable for samples from Paspanga, moderate for samples from Loumbila.

Chromium (Cr): The highest values of Cr Contamination Factor are observed in samples from Paspanga areas. The lowest and highest contamination factors of Cr are 2.16 and 3.71 respectively. The contamination factor of Cr varies between 1.26 and 1.80 for samples from Loumbila. The contamination of Cr is considerable for samples from site PS1 and PS2, moderate for samples from Loumbila and site PS3 and PS4.

Iron (Fe): The contamination factor is close to one for the samples from all the studies areas. The contamination of Fe is low in the entire sample site.

Manganese (Mn): The highest values of Mn Contamination Factor are observed in samples from site PS2 and the sample from site LS1 of Loumbila with the factor of 5.91 and 4.64 respectively. The contamination of Mn is considerable for samples from PS1, PS2, PS4 and LS1, moderate for samples from LS2, LS3, LS4 and PS3.

Zinc (Zn): The contamination of Zn is considerable for samples from sites PS1, PS2 and LS3. The contamination factors for the samples PS1, PS2 and LS3 are 3.27, 3.45 and 3.60 respectively. The contamination of Zn is moderate for samples from other sites.

Nickel (Ni): The contamination factor of Ni is less than one, except in the sites LS3, PS2 and PS4 where the factors are 1.26, 1.52 and 1.21 respectively. The contamination of Ni is low in general on the studies sites.

Arsenic (As): The contamination factor of As is greater than three for all the sites, except site LS4 where the factor is 2.60. The contamination of As is considerable for all the sites.

Mercury (Hg): The contamination factor of Hg varies between 1.00 and 2.42. The contamination of Hg is moderate for all the sxcites.

Lead (Pb): The background concentration of Pb is < 0.013 ppm and the average concentration in Loumbila and Paspanga are 5.75 and 5.94 respectively. Therefore the contamination of Pb is very high in Loumbila and Paspanga.

Cadmium (Cd): The background concentration of Cd is < 0.0267 ppm and the average concentration in Loumbila and Paspanga are less than 0.0267. Therefore the contamination of Cd is low in Loumbila and Paspanga.

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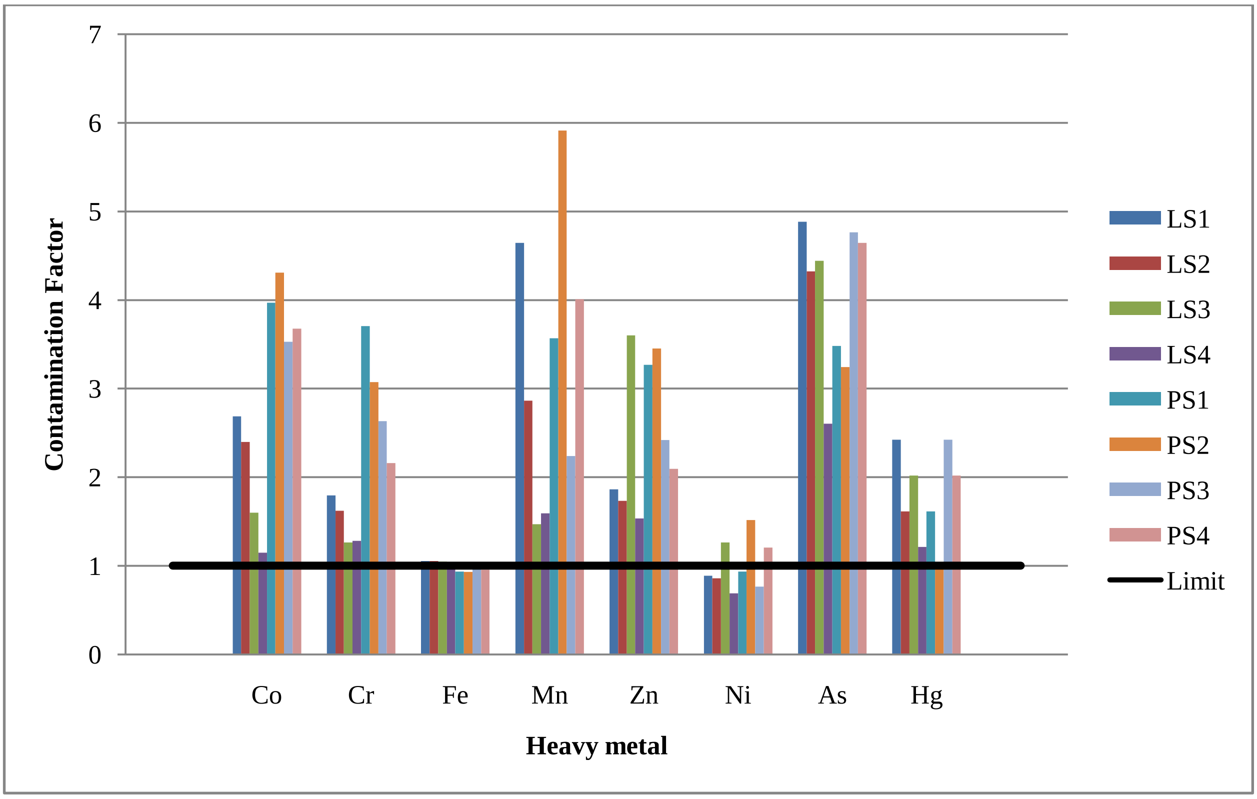

Fig. 2: Variation of contamination factor of heavy metals for studied samples

The concentrations of Fe in the samples were very high than the concentration of other metal but considering the contamination factor, it is not contributing to the degradation of soil quality in the different sites. This higher value of concentration can be due to the ferruginous character of the soil [14]. The concentrations of Hg were very low but it most contributed to the degradation of soil quality in the study areas. The As, Co, Mn and Zn contribute more to environment degradation in Loumbila and Paspanga.

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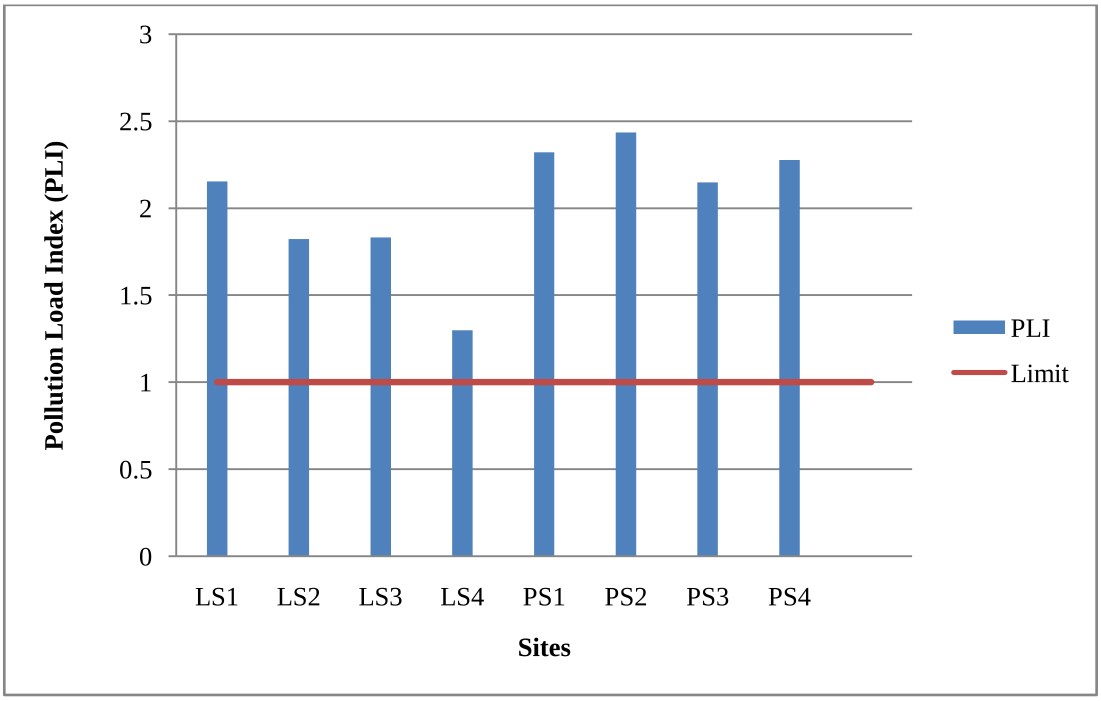

Fig. 3: Variation of Pollution Load Index of heavy metals for the samples from the study areas

Fig. 3 shows the pollution load index (PLI) of different sites where the samples were deducted. The pollution load index of all sample locations in the study area are above the baseline of pollution. The Paspanga sites are more polluted than the sites of Loumbila area.

IV. CONCLUSION

This study presented the concentration, contamination factor and pollution load index of trace metals in agricultural soil of Loumbila and Paspanga. The study reveals that the heavy metals concentrations in the agricultural soil of Loumbila and Paspanga are less than the limit set by the WHO. The concentration of heavy metal decreases with the depth (from 0-5cm to 15-20cm). The study reveals also that the degree of contamination of Pb is very high and Fe with the higher concentration has a low degree of contamination. The pollution load indexes of the studies areas indicate deterioration of site quality.

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