Full Length Research Paper

Cadmium and lead contents in compost amended oxisols in the western highlands of Cameroon

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This study evaluates the Cadmium (Cd) and Lead (Pb) concentrations of an oxisols in a field where the plots had received one, two, and three year's application of compost (20 t/ha), together with a control plot. The soil was sampled at depths of 0-10, 10-20, and 20-30 cm for analysis of total Cd and Pb principally, but also other soil physico-chemical properties. Cd and Pb bulk contents were measured by atomic absorption spectrophotometry after HNO_3 and HCl digestion. Results indicate that organic carbon contents increased from the control (4.8 ± 0.9 %MS) to the one year cultivated plot (5.5 ± 0.8 %MS), then two years (5.7 ± 0.5 %MS) and lastly three years (5.9 ± 0.4 %MS), showing that compost increased the carbon contents of the soils. The soil acidity in the other hand decrease, the pH value ranged from 5.2 to 6.3. Total Nitrogen (N), Cd and Pb contents increased with the number of years of compost application with the following trends: 0.04 to 0.32 % for N, 0.018 to 0.101 mg/kg for Cd, and 0.73 to 1.74 mg/kg for Pb. Significant correlations were noted between Pb and organic carbon ($p < 0.01$), Pb and clay ($p < 0.05$). Compost application increased the concentration of the TMEs in soil.

**Key words**: Household wastes, compost, organic amendment, trace metallic elements, oxisols, Cameroon.

INTRODUCTION

Inorganic micro pollutants or trace metal elements (TMEs) are naturally present in soils at very low levels and mostly in rather immobile forms. They originate from the parent rock, have a pedogeochemical origin or come from anthropogenic source. Several studies have shown that soils generally behave such as heavy metal elements accumulator systems, and the retention or mobilization of a heavy traffic area in soil is a function of several factors, which differ depending on the element considered and the soil type (Colinet, 2003, Chitou et al., 2021). As this accumulator behavior of soils vis-à-vis the TMEs is irreversible, when these TMEs become mobile, they can present serious dangers in the environment (Rattan et al., 2005; N'diaye et al., 2006; Bambara et al., 2019). These translate into a loss of fertility due to inhibition of bacterial activities, a reduction in the diversity of edaphic populations, destruction of the soil structure, acidification followed by release of toxic heavy metals, etc. (N'diaye et al., 2006). However, organic amendments can restore soil fertility (Batcha Lambo, 2011; Konaté et

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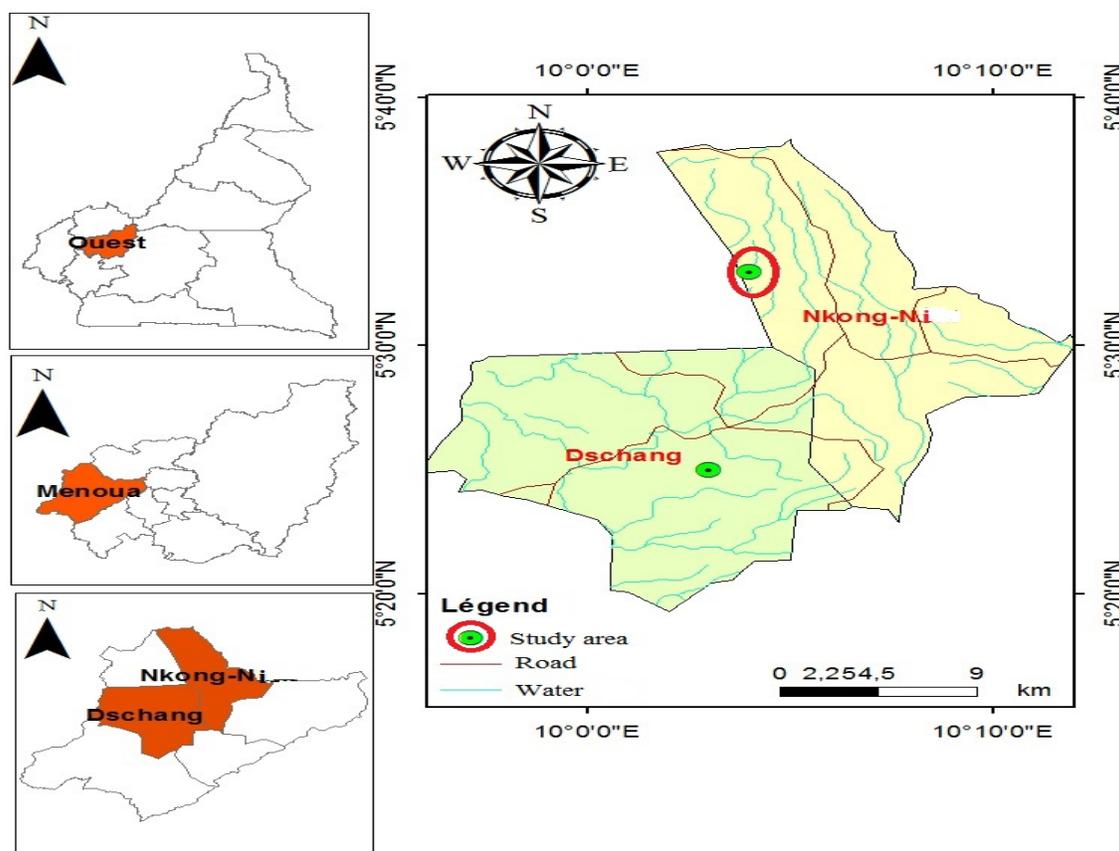
**Figure 1.** Location of the Nkong-Ni district in the Menoua Department, Western Region and Cameroon.

al., 2018). For over eight years, the municipality of Dschang values garbage by their composting in the Ngui site. Compost produced serves as a soil organic amendment in the periphery of Dschang especially for Oxisols. Since waste comes from many different places, many TMEs often escape sorting which is manual and are found in field products (Temgoua et al., 2014; Bambara et al., 2019). TME are not biodegradable, only actions for selective collection of toxic waste and mechanical sorting on site before composting or during the process (screening, refining) can limit the content of TMEs composts (Houot et al., 2009; Bambara et al., 2019). So, the repeated application of these urban wastes (compost) in the fields in addition to increasing organic carbon and nitrogen may result to the accumulation of heavy metals in the soil and their transfer to the plants and the environment. Man obviously exposes himself, if he consumes the products of harvest (Temgoua et al., 2015). The present work has targeted the most toxic heavy metals in compost produced in Ngui: cadmium (Cd) and lead (Pb) for the evaluation of their mobility in agricultural soil. Baize (1997) reports that these two elements have a higher toxicity and their geochemical properties are different. Very few studies have focused on monitoring the pedogeochemical behavior of these two elements on Oxisols (Temgoua et al., 2003, Ignatowicz, 2017) especially for soils of Western Highlands of Cameroon (Temgoua et al., 2015). These soils, however, have characteristics that expose them to numerous contaminations due to the transfer of TMEs (Baize, 1997). The objective of this work was to evaluate the contents of Cd and Pb in soils that have received more or less long-term compost, and evaluate the correlation of these metals content with others physicochemical characteristics of soils.

MATERIALS AND METHODS

Location and characteristics of the study site

The research work was carried out in the Western Highlands of Cameroon, precisely in the Menoua division in Ndziihh village. The village Ndziihh has a coordinates latitude 5 º 28 '00 "North, longitude 10 º-10 º 07' East and the altitude is 1827 m above sea level. It is located about twenty kilometers from the city of Dschang, on the southern flank of the Bamboutos Mountains (Figure 1) It is thus in the subequatorial domain: the wet season extends from March to October and the dry season from November to February, temperatures ranging from 13 to 28 ºC, with an average of 20.5 ºC
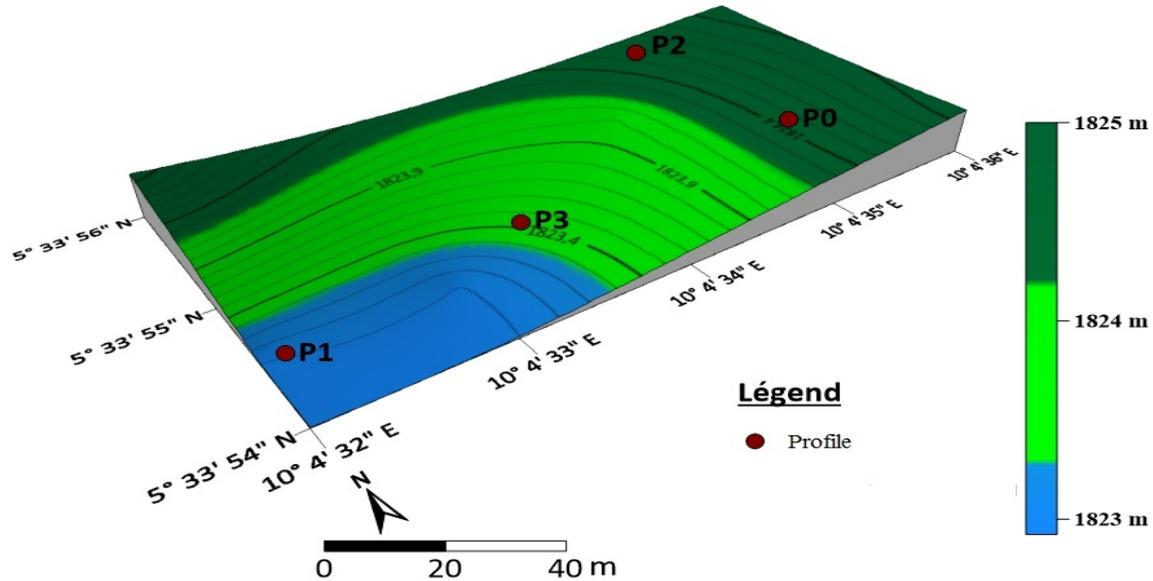
Figure 2. Block diagram of the study area showing the four plots of the study, in the village Ndziihh.
Source: generated by an MTN at the Geomatics Laboratory of the University of Dschang).

and average rainfall of 1900 mm / year (Temgoua et al., 2015). This tropical climate of Cameroonian type has made the region an agricultural hotspot of the country, and agriculture accounts for almost 80% of the employment sector.

Soil sampling location and technic

A survey of the whole village helped to identify the farmers applying organic amendments in the form of compost from Dschang. The compost used are from Dschang council and are composed according to Temgoua et al. (2014) by 20-22 %MS organic matter, 3-18 mg/kg of Cd, 7-79 mg/kg of Pb. It was then necessary to investigate and identify fields with different years of amendment and plot history, quantity of household waste amendment added (20t/ha) as well as cultivated crops. Thus, plots cultivated and amended with compost for one year (P1), two years (P2), three years (P3) and the control, having received nothing (P0) were identified and studied. The different soil pits dug in each parcel have been represented on the block diagram (Figure 2). This 3D representation of the study site was carried out from a satellite DEM (Digital Elevation Model). Each realized profile was geo referenced (latitude / longitude).

Soil prospecting (manual auger and opening of pits) allowed the characterization of the different soil types of the different study plots. The soil profiles were described following the Soil Description Guide recommended by FAO (1990) and the Soil Survey Staff (2003). Soil samples representative of different depths (0- 10, 10-20 and 20-30 cm) of each profile were collected.

Laboratory analyses

The collected soil samples were transported to the Research Analysis Unit of the Soils and Environment Chemistry of the University of Dschang (Cameroon). They were air dried, crushed and sieved at 2 mm, and then following analyses were carried out:

1) Soil pH was measured by electrometry in a soil / water ratio of 1: 2.5;
2) Organic carbon content was determined by the wet digestion method of Walkley and Black (1934);
3) Total nitrogen was determined by the Kjedahl method;
4) Particle size distribution was determined using the Robinson-Köhn pipette method;
5) Cd and Pb were measured by an Atomic Absorption Spectrophotometer (AAS) at the Analytical Laboratory of Soil, Water and Plants of Institute of Agricultural Research for Development (IRAD) Nkolbisson of Yaoundé (Cameroon). Quantification of the total metal content has required solubilization of the soil. The samples were disaggregated by wet-channel mineralization with strong acids: nitric acid (HNO_3) and hydrogen chloride (HCl) before measurement.

Statistical analyses

The measured variables were evaluated statistically by the SPSS 20.0 software. The linear relationships of the variables were established using the Pearson correlation test at 5% and 1% of risk level. The Original 6.0 software was used to highlight the evolution of different metals with respect to the depths.

RESULTS

Soil characteristics of the four studied plots

The various descriptive parameters and indicators of soil properties are presented in Table 1.

Soil pH

The soil pH of all the profiles of different plots varied from

Table 1. Characteristics of the four parcels studied.

Parameter	P0	P1	P2	P3
Vegetation	*Solanum tuberosum*	*Daucus carota*	*Brassica oleracea*	*Allium porrum*
Parent material	Volcano-basaltic	Volcano-basaltic	Volcano-basaltic	Volcano-basaltic
Texture	sandy clay	sandy clay loam	sandy clay loam	sandy clay
Soil type	Oxisol	Oxisol	Oxisol	Oxisol

P0: control plot, P1: amended with compost for one year, P2: amended with compost for two years, P3: amended with compost for three years.

Table 2. Soil pH level of Ndziih cultivated plots.

Depth (cm)	P0	P1	P2	P3
0-10	5.2	6.1	5.7	5.2
10-20	5.2	6.4	5.4	5.4
20-30	5.6	6.5	6.3	5.7

Table 3. Mean total values of trace metal elements and chemical properties of the soils studied in different plots.

Parameter	pH	Clay (%)	OC (%DM)	Ntot (%DM)	Cd	Pb (mg/kg)
Minimum	5.2	24.0	1.0	0.04	0.00	0.00
1stquartile	5.4	24.0	2.5	0.09	0.013	0.12
Median	5.7	26.0	3.8	0.15	0.035	0.67
3rdquartile	6.0	26.0	4.8	0.22	0.075	0.84
Maximum	6.3	28.0	5.9	0.32	0.101	1.74
Average	5.7	25.7	3.7	0.16	0.043	0.62
Standard deviation	0.38	1.44	1.52	0.09	0.036	0.54
CV	6.58	5.59	40.7	54.6	83.03	86.43

OC: organic carbon; Ntot: Total nitrogen; DM: Dry matter.

acid to slightly acidic except in the profiles P0 and P3 which are frankly acidic. The pH values observed were generally greater than 5 (Table 2).

Total contents of Cd and Pb

Total contents of Cd and Pb of all soil horizons are presented in Table 3. The order of abundance of elements is as follows: Pb > Cd, which both had a high coefficient of variation (CV).

Only Pb had a significant correlation with exchangeable bases sum (EBS) and clay at 5% risk while organic matter (OM), total nitrogen correlated positively and highly significant (P=0.01) with Cd and Pb concentrations (Table 4). However, these metals had no significant correlation with each other or with other physicochemical parameters such as pH and clay content. In addition, total nitrogen content correlated highly significant at the 1%

risk level with OM and EBS. Correlation was significant at 5% risk between OM, clay and EBS.

Vertical distribution of Cd and Pb in the different plots

The concentrations of Cd and Pb increased with the application time of the compost (Table 5). The smallest values were found in the plot that had never received the compost (control) at 30 cm depth (Cd and Pb: 0 mg / kg). The greatest values were found in the three-year plot (0.101 mg / kg for Cd and 1.742 mg / kg for Pb). Pb was more abundant than Cd especially since the smallest value of this element in the plot three years (1.742 mg / kg) was greater than the highest Cd value (0.101 mg / kg) in the same plot. These values all decreased from the surface to the subsurface whatever the parcel.

Figure 3 presents the vertical dynamics of soil Cd and

Table 4. Pearson correlation between trace metal elements (TMEs) and some soil physicochemical parameters.

Parameter	pH	OM	Clay	Ntot	EBS	Cd	Pb
pH	1						
MO	0.50	1					
Clay	0.18	0.63*	1				
Ntot	0.30	0.95**	0.57	1			
EBS	0.27	0.71*	0.45	0.81**	1		
Cd	0.02	0.26	0.34	0.41	0.45	1	
Pb	0.32	0.76**	0.55*	0.81**	0.58*	0.13	1

EBS: Exchangeable bases sum; OM: Organic matter.

Table 5. Distribution of trace metal elements (TMEs) with depth.

Depth (cm)	P0		P1		P2		P3	
	Cd (mg/kg)	Pb (mg/kg)	Cd (mg/kg)	Pb (mg/kg)	Cd (mg/kg)	Pb (mg/kg)	Cd (mg/kg)	Pb (mg/kg)
0-10	0.018	0.726	0.080	0.862	0.091	1.342	0.101	1.742
10-20	0.008	0.408	0.040	0.627	0.070	0.713	0.062	0.817
20-30	0.00	0.00	0.001	0.010	0.020	0.110	0.03	0.130
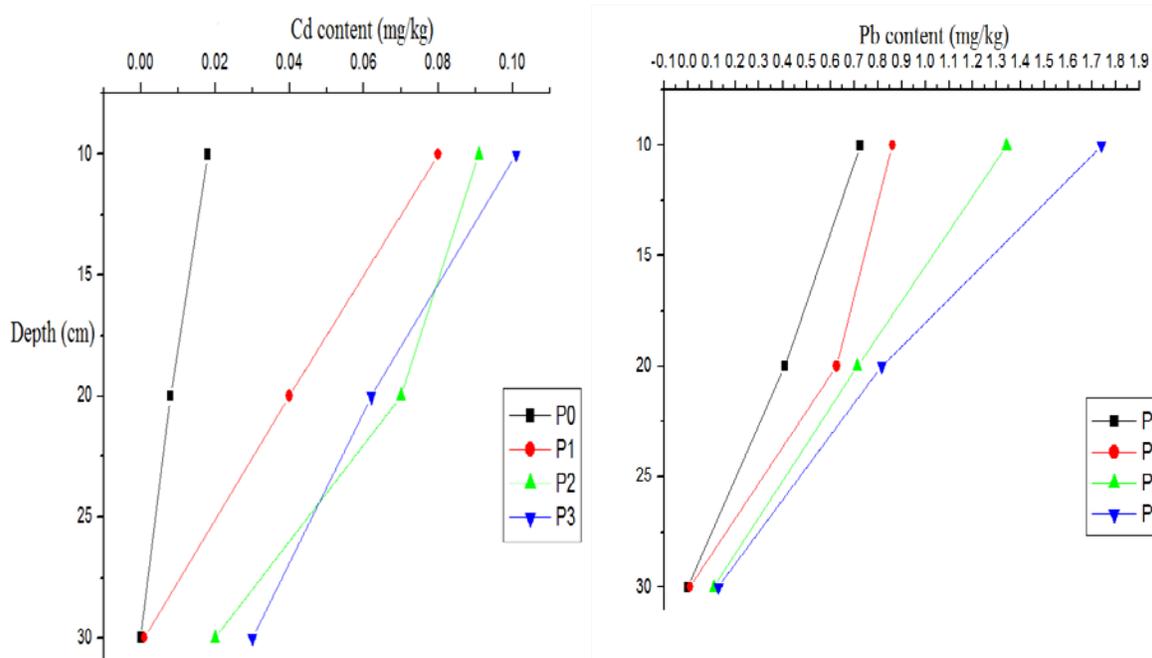
Figure 3. Vertical distribution of different concentrations of Cd and Pb as a function of depth (P0: control plot, P1: plot one year compost amended, P2: plot two years compost amended, P3: plot of three years compost amended).

Pb. Cd varied very slightly with depth and time of application of the compost, with a concentration always less than 0.2 mg / kg. Pb, on the other hand, varied enormously with time of application of compost and depth.

Concentrations increased significantly with the application time of the compost (0.73 mg / kg for P0 and 1.74 mg/kg for P3). However, the concentrations decreased with depth. Total concentrations were measured

for the two studied TMEs (cadmium and lead), in the horizons of the four profiles made in our study site. Table 5 and Figure 3 show the order of variation of these metals with respect to the depth. The abundance of the TMEs decreased considerably from the surface to the subsurface until it became lower than the detection limit in the control profile. All plots showed a tendency for higher values in the surface horizons, while none of the parcels appeared to be enriching in the subsurface. The order of abundance of the two TMEs of each plot, taken individually, is identical to the order of global abundance (Pb> Cd).

The values of the different concentrations were very low (Table 5) compared with the France standards of soils, 2 mg / kg for Cd and 50 mg / kg for Pb (Baize, 1997; Chitou et al., 2021). These concentrations vary weakly around the average, which is generally low. The maximum value is found in the surface horizon of P3. These concentrations show a strong similarity with pH, and the organic carbon content. These small quantities can be due on the one hand to the extraction procedure with a maximum recovery rate of only 90%, and secondly to the low specific surface area of samples with a fraction of 2 mm. It should be noted that the smallest values of these parameters are found in the cultivated plot without application of the compost (control), while the high levels of Cd and Pb are recorded in the cultivated plot of three years. Whatever the element considered, the concentrations increase from plot P1 to plot of three years of age (P3).

DISCUSSION

Distribution of Cd and Pb as a result of organic amendments

The frankly acidic pH in the present Oxisols of with andic character are similar to those observed on other typical ferralitic soils (Yerima and Van Ranst, 2005). These low pH values can be responsible for the dissolution of Cd and Pb and increase their mobility. In effect, according to Kabata-Pendias and Pendias (2001), in acidic medium, the Cd and Pb are soluble in the soil solution. These Cd and Pb could thus enter the food chain, especially under high crop production.

The average total contents of Pb and Cd in the shallow layers (0-20 cm) of soils are relatively higher than deep layers (20-30 cm). This indicates that these elements are of surface origin where they accumulate and migrate to deeper layers (Madrid et al., 2007). The presence on the surface is related to the origin of the organic amendment and the low migration to the subsurface layers can be attributed on the one hand to the strong presence of organic matter that forms complexes with these metals and their low mobility (Amir, 2005; Madrid et al., 2007). Pb is the least mobile metal micropollutant in the soil and

having a very high affinity with OM. Cd is more mobile than Pb, and is strongly adsorbed by clays, organic matter, with which it forms complexes (Nabil et al., 2015, Chitou et al., 2021).

The behavior of a metal in the soil is less dependent on the physical, chemical and especially biological soil characteristics than the input itself (Fardeau, 2000). Compost brought to the soil has increased the availability of lead and cadmium in the first three layers of soil. These results are consistent with those of Adjia et al. (2008) and Ignatowicz (2017) who found an increase in the availability of metals in soils amended with solid urban waste. Indeed, the oxisols of the studied zone are strongly deficient in TMEs. None of these elements on the studied plots presents contents similar to those usually found in most soils of the world. Even more, these values are almost insignificant, as they are all in the range of normal levels in soils, as some authors have found (Vázquez and Soto, 2017; Dauguet et al., 2011; Baize, 1997). These elements have a very high coefficient of variation, so weakly retained in the soil, which would make them more labile and bioavailable to plants. This is important because the soil has a predominantly sandy texture to promote the leaching of these metals towards the subsurface layers. Household compost has led to redistribution of lead and cadmium in the different horizons of the soil.

This result is in agreement with that of Abdu et al. (2011) who demonstrated that the Cd and Pb contents are highest in the surface horizon (0-20 cm) from the surface to the subsurface. Availability of these two elements decreases with depth. The compost thus allowed the accumulation of Pb, and Cd in the surface horizon. This is justified by the strong presence of organic matter in this soil level likely to limit leaching, but this accumulation of metals is not important. This is in disagreement with the work of Baize (1997), which reports that soil TMEs concentrations undergo leaching of metals, and leaching must increase with depth at least up to the accumulation horizon. The application of compost has certainly increased the amount of Cd and Pb in the plots studied, but this increase is not significant and therefore any risk of pollution by the latter is negligible. These results are in agreement with those found by Nangah et al. (2013) who, in their work, have shown that the risk of pollution of an element is related to its concentration in the soil.

The Cd and Pb contents are correlated with the physicochemical parameters of soils

Statistical analysis has shown that these two elements (Cd and Pb) are not inter-correlated linearly, which could suggest that these TMEs do not coexist as constituents of minerals in soils, thus joining Stefaniuk et al. (2017) in their works, who showed that certain elements resulting

from the application of biochar were not correlated with each other. In other cases, it is rather coexistence as a constituent of minerals (Tabatabai and Rogovska, 2011, Konaté et al., 2018). The differences in concentrations observed between plots and compartments of accumulation of TMEs in soils can only be attributed to an anthropogenic contribution and not to pedogenic processes. The correlation between the Pb and organic matter is also strong and highly significant at the probability threshold of 1%.

This may justify the fact that the concentrations vary proportionally with the organic matter decreasing with depth. The great affinity of organic matter for lead, in particular, would explain the preferential accumulation of this metal in surface horizons. These observations corroborate with the results found by several authors (Ignatowicz, 2017; Vázquez and Soto, 2017; Bur, 2008). In addition, the strong correlation between Pb and OM is crucial because it protects them from leaching to the deeper horizons despite the soil texture, and secondly makes them unavailable to the plant by the process of chelation. Unlike lead, Kirkham (2006) finds a highly significant correlation between OM and Cd.

These metals have no correlation with pH. Only Pb has a correlation with clay. This contradicts what some authors say. Indeed, pH is considered as the main chemical parameter controlling the bioavailability of heavy metals in soil (Tudoreanu and Phillips, 2004; Koo et al., 2005).

However, this result can simply attest to the fact that at this moderately acidic pH the low concentrations of TMEs are more influenced by the large amount of organic matter only.

Conclusion

The present study indicates that the studied oxisols are overall moderately acidic (5.7 <pH <6.6), but in some places have frankly acid pH values and have relatively high exchangeable base amounts (10 <EBS <15). The contribution of the resulting compost' OM in these soils for one, two and three years has greatly boosted the level of SOM, Ntot but also neutralized the pH and brought TMEs like Cd and Pb. These TMEs although accumulated on the surface do not exceed the standard values and more are distributed gradually with depth. The high amount of organic matter in these parcels indicates that soil management procedures in cultivated fields should be maintained since they provide more soil organic matter (organic carbon) and total nitrogen. The accumulation of Cd and Pb was observed in the first centimeters of the plots studied, and the authors cannot talk about contamination. The vertical dynamic is very variable according to plot, and remains essentially influenced by compost. However, the vertical distribution of Cd and Pb decreases with depth and increases with the application time of the compost. The levels of Cd and

Pb remain very low and present no danger on the plant and the environment of the site. It would also be interesting to carry out a study on the speciation of trace metal elements in these soils, in order to better prevent possible risks of contamination given the acidic pH in these places.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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