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Assessment of Heavy Metals Contamination in Controlled and Uncontrolled Landfill Soil, Ouagadougou, Burkina Faso

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Abstract: The study was conducted to evaluate the concentrations of heavy metals in landfill soils. The soils samples were collected in some selected landfill, at Ouagadougou. Determinations of heavy metal concentrations, calculation of contamination factor and pollution load index of heavy metal in landfill soil were undertaken. The atomic absorption spectrophotometer was used to determine the concentrations of heavy metals (Cr, Mn, Fe, Ni, Cu, Zn, As, Cd, Hg and Pb) in the soils samples. The results showed that the average concentrations of chromium, lead and zinc determined in soils exceed the limits recommended by AFNOR NF U 44-04 and the recommended values proposed by CCME. This study showed that the soils from landfill sites were polluted by heavy metal.

Keywords: Soil, Heavy Metals, Solid Waste, Landfill Sites

Introduction

The socioeconomic development and the demographic growth in Africans capitals city increase the quantity and the quality of the solids waste essentially produced by the households, the industries and the different establishments. These wastes represent important sources of nuisances for the human and the environment (El Maguiri *et al*., 2014).

The sites of controlled and uncontrolled landfill constitute a potential source of contamination for the environment, due to the accumulation aspect of the heavy metals and the organic products transformed (Chaer *et al*., 2016). The analysis of the samples of soil from Ahfir-Saidia landfill showed an important spatial distribution of heavy metals (Nhari *et al*., 2014). Besides, the study on Akouédo landfill in Cote D'Ivoire showed that the environment of landfill presents a high level of pollution and the great concentrations of heavy metals in soil (Adjiri *et al*., 2008). Indeed, the accumulation of heavy metals in soils can reverberate on the animals and the human health (Chaer *et al*., 2016).

The objective of this work was to evaluate the contamination degree of soils from controlled and uncontrolled landfill at Ouagadougou. The analyzed heavy metals in the soils samples were the cadmium, the lead, the arsenic, the chromium, the manganese, the iron, the nickel, the copper, the mercury and the zinc.

Materials and Methods

Study Area

Burkina Faso is located in the West Africa. Its area is 274,000 square kilometers. It shares its borders with 6 countries, namely Mali to the north and west, Niger to the north and east, Benin to the south-east, Ghana and Togo to the south, the Côte-d'Ivoire to the west and south.

The Ouagadougou is administrative capital of Burkina Faso (1°28 to 1°36 west longitude and 12°20 to 12°26 north latitude) and is situated in the center part of the country. The Fig. 1 shows the geographical position of landfill where the soils samples have been appropriated.

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) (Sadhu *et al*., 2012).

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):

$$CF = \frac{C_{heavy\ metal}}{C_{background}} \quad (1)$$

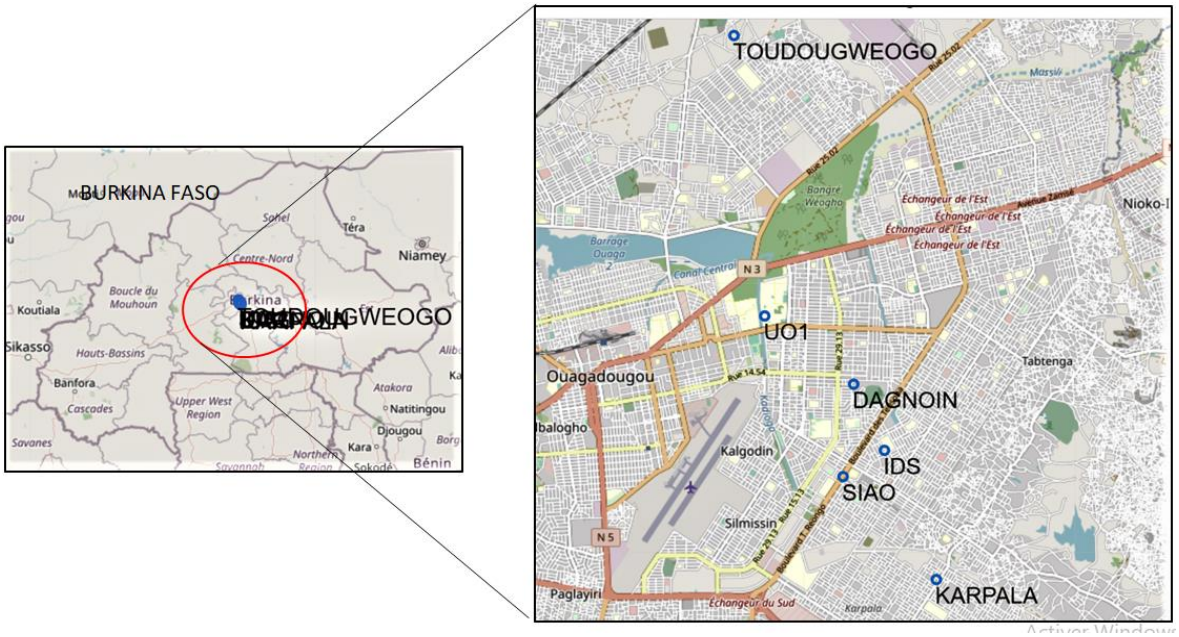

Fig. 1: Geographical position of some landfill at Ouagadougou; Legend: UO1 is the landfill of University of Ouagadougou; IDS is the landfill of Institut of Sciences

The background concentrations were calculated from the heavy metals concentration in unaffected soils of the studied area (Esshaimi *et al*., 2012). To classify the contamination levels, four categories were defined depending on 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 (Afrifa *et al*., 2013; Qingjie *et al*., 2008).

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):

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

where, *n* is the number of metals index which provides a simple, comparative means for assessing the level of heavy metal pollution. A value of *PLI* < 1 denote perfection; *PLI* = 1 shows that only baseline levels of pollutants are present and *PLI* > 1 would indicate a deterioration of site quality (Adedeji Oludare *et al*., 2014; Tomgouani *et al*., 2007).

Results and Discussion

Heavy Metals Concentration in the Soils of the Studied Landfill

The concentrations of heavy metals (Cr, Mn, Fe, Ni, Cu, Zn, As, Cd, Hg and Pb) in soils samples from some landfill at Ouagadougou were determined. The results shows that the means concentrations in the different samples vary between 35,69 and 2371,13 mg/kg for the Copper; 0,00 and 6,35 mg/kg for the arsenic; 0,00 and 742,09 mg/kg for the Chromium; 24,64 and 723,73 mg/kg for Lead; 137,45 and 3668,07 mg/kg for Zinc; 0,00 and 42,62 mg/kg for the Nickel; 0,00 and 13,02 mg/kg for the Mercury.

The concentrations of heavy metals in the various landfills studied will be compared with two standards: The AFNOR NF U 44-041 standard (Nhari *et al*., 2014; Chaer *et al*., 2016) from France and the Canadian Council of Ministers of the Environment (CCME) standard (Nhari *et al*., 2014; Chaer *et al*., 2016; CCME, 1999) from Canada (Table 1). The arsenic concentrations obtained in this study were all below the value established by the CCME. The Cadmium concentrations in landfill soil samples were below the detection limit. According to the French standard, only the TOUDOUBWEOGO landfill has a very high chromium concentration. Based on the Canadian standard, the chromium concentrations in the IDS and TOUDOUBWEOGO landfills were high than the established value. The landfills at TOUDOUBWEOGO, DAGNOIN and IDS had lead concentrations higher than Canadian and French standards. The zinc concentrations in the landfills were higher than the Canadian standard, but the only soil from the IDS landfills was low concentration than the French standard. Studies have shown a higher concentration of metals in surface water than in groundwater (Bambara *et al*., 2015). The high

concentration of zinc, lead and chromium in landfills can lead to increased concentrations of these metals in surface water through runoff due to the uncontrolled nature of landfills.

Comparison between this Study Results and the Results of Others Studies

Table 2 gives the comparison of heavy metals concentrations in landfill soils of this study with Akouedo (Adjiri *et al*., 2008), Tangier (Chaer *et al*., 2016) and Ahfir Saidia (Nhari *et al*., 2014) landfills soils concentrations.

The average arsenic concentration in soil from Ouagadougou landfills was lower than the arsenic concentration in soil from Ahfir Saidia landfills in Morocco. The average concentration of chromium in the studied landfills was higher than the concentration of chromium in the landfills of Ahfir Saidia in Morocco. The maximum value of the chromium concentration in the studied landfills was higher than the maximum value of the Akouedo and Tangier landfills (Table 2).

The average concentration of lead in the studied landfills was lower than the concentration of lead in the Ahfir Saidia landfills in Morocco. The maximum value of lead concentration in the studied landfills was lower than the maximum value of Akouedo landfills in Cote d'Ivoire and higher than that of Tangier in Morocco. The lead is toxic and is one of the least mobile metallic elements in soil. It is frequently recovered in the landfill of the developmental countries because of its use as constituent element of the batteries (Chaer *et al*., 2016).

The average zinc concentration in the studied landfills was higher than the zinc concentration in the Ahfir Saidia landfills. The maximum value of the zinc concentration in the studied landfills was higher than the maximum value of the concentration of the Akouedo landfill in and lowers than that of Tangier.

The landfills of the Ouagadougou are more contaminated with chromium and zinc than the Ahfir Saidia landfills in Morocco. The maximum concentrations of chromium and zinc in the Ouagadougou landfills were higher than that determined in the Akouedo landfills in Cote d'Ivoire.

In This study, the heavy metal concentrations in soil from landfill of Ouagadougou were not uniform, this can be due to heterogeneity of the waste but also to a non uniform deterioration of these waste. The securities raised of heavy metals in the samples could be assigned to the nature of soil and the composition of the waste. The pollution of the landfill is a long-term problem because metals distribute themselves in soils under varied shapes. Metals are under exchangeable shape between the clays and the organic matter or as complex or associated to organic molecules.

Heavy Metals Contamination Factor (CF) in Soil

The determination of the contamination level of the heavy metals was done by calculating the Contamination Factor (CF). This contamination factor was determined using the Equation 1. The CF permitted to know the weight of every heavy metal on soil pollution. In this part, the impacts of every heavy metal on the soils samples from landfill were analyzed for each site.

Figure 2 illustrate the variation of contamination factor of every heavy metal in soils samples from the different studied sites.

Table 1: Average concentrations (mg/kg) in soils of studies Landfills

Landfill	As	Cd	Cr	Pb	Zn
IDS	3,78	0,00	72,63	177,52	267,45
UO1	5,76	0,00	59,79	51,68	306,50
SIAO	4,91	0,00	52,51	53,68	442,57
KARPALA	5,37	0,00	47,84	85,39	1261,34
TOUDOUB-WEOGO	2,49	0,00	400,40	316,33	2103,33
DAGNOIN	5,64	0	54,43	141,75	842,43
AFNOR NF U 44-041 (France)	-	2,00	150,00	100,00	300,00
CCME (Canada)	12,00	1,40	64,00	70,00	200,00

Table 2: Comparison of average concentrations in soils of this study with the others results (mg/kg)

Landfill		As	Cd	Cr	Pb	Zn
This study	Range	0,00-6,35	0	0,00-742,09	24,64-723,73	137,45-3668,07
	Average	4,428	0	105,72	145,82	759,04
Akouedo (Cote d'Ivoire)		-	1-11,5	27,7-125	10,3-1500	18,6-1163,7
Maroc	Tangier	4,47-7,30	1,29- 4,41	85,72-340,84	44,44-298,36	488,9-16117,7
	Ahfir Saidia	33,96	-	75,74	656,46	62,87

The soils samples from the landfill at IDS, present contamination factors that vary between 0,75 and 7,31. The contribution of zinc and mercury to the soil pollution at IDS is lower and moderate for the chromium, the manganese, iron, the nickel and the arsenic. On the other hand the copper contributes considerably and the lead very higher contributes to the soils pollution.

The contamination factors of heavy metals were less three in soils from UO1 and SIAO landfills. Therefore the contribution of heavy metals to the pollution was moderate in the samples from UO1 and SIAO sites.

The contribution of the manganese, the copper, zinc and lead to the pollution were considerable in the samples from KARPALA and DAGNOIN landfills.

The contribution of chromium, copper, zinc and lead in the soil pollution was very high and considerable for manganese and iron in samples from TOUDOUBWEOGO landfill. Pollution of landfill soils can lead to pollution of agricultural soils because of the compost produced on landfill sites. In addition, water runoff on these landfills can cause pollution of surface water.

Pollution Load Index (PLI)

To evaluate the soil pollution in the landfills sites, the pollution load index were calculated from the contamination factor of the heavy metals. A soil is polluted when its Pollution Load Index is superior to one.

The Fig. 3 illustrates the Pollution Load Index of soils from the landfills. The results clearly shows that all Pollution Load Index calculated were superior to one.

This study revealed a pollution of soils form IDS, SIAO, TOUDOUGWEOGO, DAGNOIN, UO1 and KARPALA landfills.

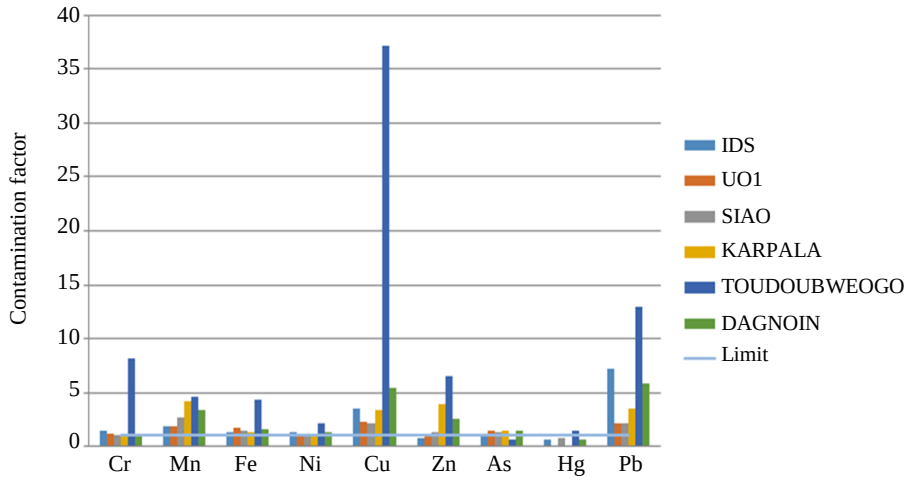

Fig. 2: Variation of the contamination factor for every heavy metal in soils samples from each landfill

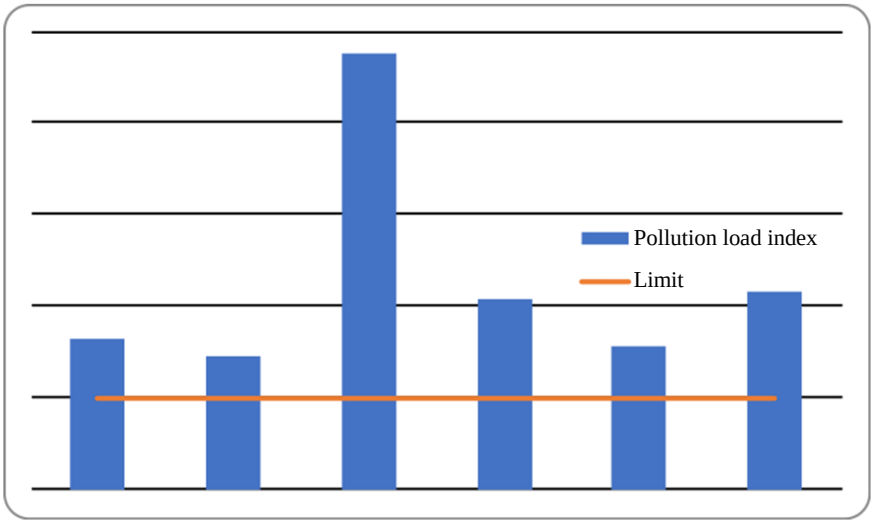

Fig. 3: Pollution load index of each landfill

Conclusion

In this study, the concentrations of the heavy metals (Cr, Mn, Fe, Ni, Cu, Zn, As, Cd, Hg and Pb) in soils samples from some landfill at Ouagadougou (IDS, SIAO, TOUDOUGWEOGO, DAGNOIN, UO1 and KARPALA) were determined and compared with the norms and others studies. The concentrations of iron, manganese and zinc were very higher than the other metals. However, the concentrations of chromium, lead and zinc determined in soils exceed the limits recommended by AFNOR NF U 44-041 and the recommended values proposed by CCME. Based on the concentration, the contamination factors were calculated to see the impact of every heavy metal on the pollution aspect. The calculated contamination factors shows that the copper, zinc, lead and manganese contribute more to the soils pollution.

Finally, the pollution of soils from landfill was evaluating using Pollution Load Index. The results of this study show that the quality of soils from IDS, SIAO, TOUDOUGWEOGO, DAGNOIN, UO1 and KARPALA landfills were deteriorated with time and this deterioration can leads to an important pollution by the effect of accumulation. This pollution can be the source of soil pollution through the compost produced on landfills.

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Author's Contributions

Bambara Telado Luc: Contributed to the design of the study, samples processing and analysis of the results. Wrote the first draft of the manuscript.

Doumounia Ali: Contributed to the design of the study, data processing and analysis of the results.

Kohio Nièssan: Contributed to the samples processing and made contributions in the analysis of interpretation of data.

Ouedraogo Soumaila: Made considerable contributions in the interpretation of obtained data.

François Zougmoré: Supervised the study and give final approval of the version.

Ethics

This article is original and as such has not been previously published. The corresponding author confirms that all of the other authors have read and approved the manuscript and no ethical issues involved.

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