Heavy Metals Distribution in Soil at Different Depths and Radiuses around Landfills in Districts of Nyékonakpoè, Akodesséwa and Amoutivé in Lomé City

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ABSTRACT

This study aims to provide baseline data about soil contamination by some heavy metals at different depths around landfills in areas at high risk of groundwater contamination. Soil samples were taken in three replicates at depth of 0 – 20 cm, 20 – 40 cm and 40 - 60 cm in the radiuses of 0 to 10 m, 10 to 20 m and 20 to 30 m around landfills. In all, 81 homogenized composite soil samples were collected. The heavy metals were measured in soil samples by atomic absorption spectrophotometer. The results show that the concentration of mercury (0.03 – 0.29 mg kg^{-1}), cadmium (0.04 – 0.69 mg kg^{-1}), arsenic (0.05 – 2.30 mg kg^{-1}) and nickel (0.05 – 2.35 mg kg^{-1}) in analyzed soil samples were lower than the limit values set by WHO, Finland and Dutch environment ministries. However, lead concentrations (90.15 – 129.14 mg kg^{-1}) in topsoil in vicinity of landfills in Amoutivé and Akodesséwa were above reference values set by WHO, Finland and Dutch environment ministries. As the heavy metals may be leached to reach groundwater, the landfills management must be great concern to municipal authorities. The frequent monitoring of the quality of soil and groundwater will be necessary to follow the level environmental contamination by heavy metals around landfills and the possible initiate remedial measures.

Keywords: Landfill, heavy metal, soil contamination.

1. INTRODUCTION

Landfilling still remains the most common form of removal and disposal of household solid waste in Lomé city as in others cities in West African countries. The solid waste landfills contain hazardous materials which are potential sources of soil, groundwater and plant contamination by heavy metals [1]. Leaching of heavy metals is the process through which contaminants are released into the environment upon contact with water [2]. Landfill leachate produced from a combination of decomposing waste and liquids percolating through waste in landfills is the main vector of these contaminants from the landfill to the environment [3]. Heavy metals constitute real problems in waste management because of their multiple sources and their potentially high toxicity [4]. They have been reported to produce damaging effects on human and animals because there is no good mechanism for their elimination from the body [5].

Togo, like many developing countries, knows the real waste environmental problems. The literature reported that lagoon systems in urbanized areas are easily exposed to inorganic, in particular heavy metals [6]. Unfortunately, the solid waste landfills in the districts of Nyékonakpoè, Akodesséwa and Amoutivé situated between Lomé city lagoon system and Atlantic Ocean are located on the coastal sandy soil with high permeability and high risk of groundwater contamination. Although some studies have been carried out in Togo on some heavy metals in urban waste composting [4] and their accumulation in aquatic ecosystems [7, 8, 9], few attentions has been paid about soil contamination around dumping. The lateral and vertical distributions of heavy metals into soil can pose potential health risks to inhabitants around landfills if these metals migrate into groundwater. Soils contaminated by heavy metals have received special attention because of their serious threats to the food chain, human health and terrestrial ecosystems [10]. It is therefore important to understand the concentration heavy metal level in soil surrounding the solid waste landfills everywhere.

The objective of this study is to determine the presence and concentration of some heavy metals as mercury, lead, nickel, cadmium and arsenic in soil at different depths and radiuses around solid waste landfills in three districts in Lomé city.

2. MATERIAL AND METHODS

2.1 Study area

The study was carried out in coastal plain in the districts of Nyékonakpoè, Amoutivé and Akodesséwa situated between Lomé city lagoon system and Atlantic Ocean. The sites selection was based on the types of the landfill, waste collected and localisation. The geographic position of the landfills in space were determined using a geographic positioning system as recorded: Nyékonakpoè landfill (N 06°.0833.0" and E 001°.13'19.9"), Amoutivé landfill (N 06°.08'42.9" and E 001°.13'54.6") and Akodesséwa landfill (N 06°.09'17.6" and E 001°15'40.8"). The soils of the study area are deeps, non-gravelly with sandy texture. These are mineral hydromorphic leached soils with low humus content where the groundwater rises and emerges in the rainy season.

2.2 Laboratory material

These are chemical reagents, nitric acid (HNO_3) and chloruretic acid (HCl) used for the digestion, Sartorius CP225D analytical microscale (Data Weighting Systems, IL, USA), and Ethos EZ microwave digestor (Milestones, CT, USA), Inductively Coupled Plasma Atomic Emission Spectrometer Optima 3000 XL (Perkin Elmer, CA, USA), calibration standard solution (Fisher Scientific, CA, USA). All chemicals reagents used were analytical grade. Deionized water was used to prepare samples and standards for analysis.

2.3 Samples collection and preparation

Soil samples were collected at various points at different depths and radiuses around solid waste landfills. They were taken in the radiuses of 0 to 10 m, 10 to 20 m and 20 to 30 m around each landfill. They were collected at three replicates at depths of 0 - 20 cm, 20 - 40 cm and 40 - 60 cm. Usually, five subsamples taken from five different points were merged into one single sample (homogenized composite sample). At each sampling point, a volume of 10 × 10 × 10 cm of soil sample was cut out successively from upper 0 - 20 cm layer, (the topsoil) and the bottom 20 - 40 cm and 40 - 60 cm layer (the subsoil) of soil pits. In all, 81 homogenized composite soil samples were collected from all sites. All soil samples were sealed with polythene bags and transported to laboratory where they were prepared for analysis.

2.4 Soil samples analyses

The soil composite samples were air-dried, homogenized and sieved through a 2 mm screen. For heavy metals content determination (adapted from Deheyn and Latz [11]), the soil samples were crushed in a silicon mortar and the < 63 µm fraction separated by dry sieving. About 0.2 g of that fraction was weighed using a Sartorius CP225D analytical microscale (Data Weighting Systems, IL, USA) connected to notebook computer for accurate recording of measurements. Samples were then taken in Teflon digestion vessels and partially digested during 20 min in a HCl:HNO_3 (3:1) mixture at 80°C using Ethos EZ microwave digestor (Milestones, CT, USA). Heavy metals (As, Cd, Pb, Ni and Hg) were analyzed simultaneously using an Inductively Coupled Plasma Atomic Emission Spectrometer Optima 3000 XL (Perkin Elmer, CA, USA) with detection limits ranging from $0.05*10^{-6}$ to $4.0*10^{-6}$ mg g^{-1} depending on the element [7]. The instrument, available at the Analytical Facility of the Scripps Institution of Oceanography, was calibrated before every run by successive dilution of 100 µg g^{-1} multi-element instrument calibration standard solution (Fisher Scientific, CA, USA). Recovery of the quality assurance standards was analyzed every 20 samples over the course of the run was 105%, while internal blanks were analyzed to assess any background contamination originating from the sample manipulation was negligible. The regulatory standards for heavy metal levels in soil have been established, but some discrepancy exists among different standards regarding the critical value of each contaminant (Table 1).

Table 1: Threshold and guideline values of heavy metals in soils (mg kg^{-1})

Reference standards	Cd	Pb	Hg	Ni	As
Dutch Ministry of Housing, Spatial Planning and the Environment [12]	0.8	85	0.3	35	29
Ministry of the Environment, Finland [13]	1	60	0.5	50	5
WHO [14]	0.35	100	-	50	40

2.5 Statistical analysis

All the data were subjected to statistical analysis. The averages and standards deviations were performed using STATISTICA software (2005, 7.1 Version). The results were expressed as means ± standard error (SE).

3. RESULTS AND DISCUSSION

The study results show the presence of heavy metals (Cd, Pb, Ni, As and Hg) in soil around the landfills at various concentrations (Tables 2 to 4). This justifies the fact that most landfills in developing countries are illegal dumps without regulatory control [15]. The mean concentrations of heavy metal in soil varied with depths. The concentrations of all heavy metal in topsoil (0-20 cm) were higher than those found in subsoil at 20-40 cm and 40-60 cm (Tables 2 to 4). These decrease when soil depth increase. It can be assumed that the subsoil is considerably less influenced by contamination processes than the topsoil. In general, it is admitted in literature that the contaminants are found in the topsoil and beyond this layer they can directly reach the groundwater [16]. The heavy metal concentrations varied with distances away from the landfill. This agrees with the results of Olafisoye *et al*. [17] and Othman *et al*. [18] who reported that the concentrations of heavy metals decreased as the soil sampling distance from the dump increased. Except for lead (Pb), the concentrations of other heavy metals in soils of the study area were lower when compared to some soil quality guidelines [12, 13, 14] (Tables 1 to 4).

The lead is known as a toxic metal with exceptionally low mobility and persistent in topsoil for a long time [19]. The concentrations of lead (Pb) in soils around landfills recorded in case of this study were higher than those hardly exceeding 2.15 mg kg^{-1} in soil of Enyimba dumpsite in Aba, Southeastern Nigeria [20]. The concentrations of lead in soil around Nyékonakpoè landfill ranged from 0.51 to 44.58 mg kg^{-1} and were 3 and 2 times less than that obtained respectively from Akodesséwa landfill (2.01 – 129.14 mg kg^{-1}) and Amoutivé landfill (1.09 – 90.15 mg kg^{-1}). The data suggested that the Akodesséwa and Amoutivé landfill sites were more contaminated by Pb than the Nyékonakpoè landfill site. The concentrations of Pb in the radius of 0 to 10 m around landfill were higher than those recorded in the radiuses of 10 to 20

m and 20 to 30 m (Tables 2 to 4). This is in accordance with the conclusions of Olafisoye *et al*. [17] who reported that the concentrations of heavy metals decreased as the soil sampling point distance from the dump increased.

Table 2: Heavy metal concentrations in soil (mg kg^{-1}) at different depths in a radius of 0 to 10 m around solid waste landfills in three districts in Lomé city

Districts	Soil layer (cm)	Cd	Pb	Hg	Ni	As
Nyékonakpoè	0-20	0.34±0.04	44.58±1.15	0.19±0.02	1.19±0.07	1.28±0.06
	20-40	0.11±0.02	13.37±0.12	0.03±0.01	0.35±0.02	0.51±0.03
	40-60	ND	4.01±0.09	ND	0.11±0.01	ND
Amoutivé	0-20	0.48±0.02	90.15±1.80	0.23±0.02	1.81±0.08	2.26±0.08
	20-40	0.14±0.01	27.04±1.10	ND	0.54±0.04	0.53±0.02
	40-60	ND	8.11±0.15	ND	0.15±0.02	ND
Akodesséwa	0-20	0.69±0.05	129.14±2.9	0.29±0.03	2.35±0.09	2.30±0.09
	20-40	0.21±0.02	38.75±1.12	ND	0.70±0.05	0.55±0.03
	40-60	ND	11.10±0.11	ND	0.22±0.03	ND

ND: stands for Not Detectable.

Table 3: Heavy metal concentrations in soil (mg kg^{-1}) at different depths in a radius of 10 to 20 m around solid waste landfills in three districts in Lomé city

Districts	Soil layer (cm)	Cd	Pb	Hg	Ni	As
Nyékonakpoè	0-20	0.04±0.01	14.06±1.10	0.05±0.02	0.53±0.03	0.31±0.07
	20-40	ND	3.89±0.17	ND	0.16±0.02	0.06±0.01
	40-60	ND	1.17±0.02	ND	ND	ND
Amoutivé	0-20	0.05±0.02	28.56±1.15	0.06±0.01	0.82±0.04	0.52±0.02
	20-40	ND	8.33±0.13	ND	0.25±0.01	0.15±0.01
	40-60	ND	2.49±0.08	ND	ND	ND
Akodesséwa	0-20	0.09±0.03	39.09±1.14	0.06±0.01	1.05±0.09	0.55±0.02
	20-40	ND	11.72±0.19	ND	0.31±0.02	0.16±0.01
	40-60	ND	3.51±0.11	ND	ND	ND

ND: stands for Not Detectable.

For Ni, the mean concentrations in soil around Akodesséwa landfill (0.09 – 2.35 mg kg^{-1}) and Amoutivé landfill (0.07 – 1.81 mg kg^{-1}) were approximately and respectively about 2 and 1.5 times greater than that recorded around Nyékonakpoè landfill (0.05 – 1.19 mg kg^{-1}). The relative highest presence of Ni in soil around Akodesséwa landfill could indicate that this landfill received some industrial wastes, especially since Akodesséwa district is an industrial port area. The Ni in soil may be from municipal waste and nickel-cadmium batteries. The mean value concentrations of Ni found in this study were below those of various standards [12, 13, 14]. The variation of Ni concentration in soil depending to depth and radius around the landfill (Tables 2 to 4) were similar to what has been reported by Makuleke and Ngole-Jeme [3] and Olafisoye *et al*. [17] who concluded that the heavy metal concentration levels were affected by soil depth and sampling point distance from landfill.

Table 4: Heavy metal concentrations in soil (mg kg^{-1}) at different depths in a radius of 20 to 30 m around solid waste landfills in three districts in Lomé city

Districts	Soil layer (cm)	Cd	Pb	Hg	Ni	As

Nyékonakpoè	0-20	0.04±0.01	5.79±0.18	0.05±0.02	0.05±0.01	0.05±0.02
	20-40	ND	1.73±0.11	ND	ND	ND
	40-60	ND	0.51±0.02	ND	ND	ND
Amoutivé	0-20	0.07±0.01	12.10±0.13	0.05±0.02	0.07±0.03	0.06±0.02
	20-40	ND	3.63±0.14	ND	ND	ND
	40-60	ND	1.09±0.10	ND	ND	ND
Akodesséwa	0-20	0.09±0.02	20.59±1.02	0.06±0.03	0.09±0.04	0.06±0.03
	20-40	ND	6.17±0.15	ND	ND	ND
	40-60	ND	2.01±0.12	ND	ND	ND

ND: stands for Not Detectable.

The concentrations of cadmium (Cd) were found low in soil at all sampling points around landfills. The levels of Cd recorded in this study (0.04 - 0.69 mg kg^{-1}) were below those (1.86 - 2.87 mg kg^{-1}) found in soil from dump sites in Kumasi suburbs at Ayigya, Buokrom and Abrepo [21]. It may indicate naturally low concentrations of this heavy metal in the soil. The concentrations of Cd found in soil around Akodesséwa landfill (0.69 mg kg^{-1}) were higher than the WHO permissible limits (0.35 mg kg^{-1}) but below Dutch standard (0.8 mg kg^{-1}) (Tables 1 to 4). The absence of Cd in soil horizon 40 - 60 cm indicates the low mobility of this heavy metal [22]. The highest average concentration of arsenic (2.30 mg kg^{-1}) was recorded in topsoil at radius of 0 to 10 m around Akodesséwa landfill. This value was about 2 times, 12 times and 17 times less than Finland, Dutch and WHO standard limits respectively. The mean values of mercury (Hg) ranged from 0.05 to 0.29 mg kg^{-1} in soil around Akodesséwa landfill, from 0.05 to 0.23 mg kg^{-1} in soil around Amoutivé landfill and from 0.03 to 0.19 mg kg^{-1} in soil around Nyékonakpoè landfill. These values were below the various reference limits set by [12, 13,14] (Tables 1 to 4). Based on the limit values of reference, there are no health risks related to the concentrations of arsenic and mercury in soil around the landfills in the study area.

4. CONCLUSION

Five heavy metals have been determined in soil at different depths and radiuses around landfills. Their concentrations varied with soil depth and distance away from the landfill. The mechanisms of their distribution and accumulation in soil remain poorly understood. The identification of key factors controlling their distribution and accumulation in soil around landfills will be greater preoccupation in the future researches to understand the mechanism of soil contamination around landfill in response to interactions with environmental factors.

5. ACKNOWLEDGEMENTS

Authors thank Laboratory of Management, Treatment and Value of Waste, University of Lomé (GTVD/UL) for its kind support and cooperation in carrying out soil samples analysis.

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