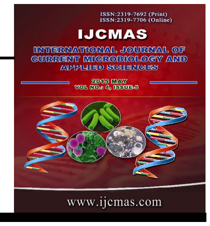


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**Original Research Article**

# Impact of Solid Waste Disposal System on Soil in Maradi City (Niger Republic): A Preliminary Study of Heavy Metal Contamination

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**A B S T R A C T**

Waste disposal system was assessed through an evaluation of heavy metal contamination in Maradi city. 68 composite soil samples were collected from three types of dumpsite and analyze for Zinc (Zn), Lead (Pb), Cadmium (Cd) and pH. A significant difference was found among the different dumpsites and their controls. This could indicate the beginning of contamination as further demonstrated by the calculated pollution index. The pH of these sites were mainly alkaline, indicator of active landfill/dumpsite. No significant difference was found between landfill site, official dumpsite and informal dumpsite. The result from this study showed that the management of waste disposal site is insufficient in terms of heavy metal contamination prevention. The inadequate use of soils from dumpsite as compost could contaminate crops and create health and environmental issues. The municipality has to sensitize the population about how to dispose of their wastes and the consequences of such activities, and also improve upon the waste management system.

**Keywords**

Waste disposal, dumpsite/ Landfill, Maradi, Niger, Zinc, Cadmium, Lead

## Introduction

Inadequate disposal of municipal solid waste and the increasing spatial and demographic growth constitute a great environmental challenge in many African cities (Salam, 2009).This is the case of Maradi city in which rapid urbanization and population growth have contributed to the increasing solid waste production. In fact, the Maradi population is estimated at 264,897 inhabitants with an annual growth rate of

4.3% (Institut National de la Statistique, 2013)and the daily waste production is estimated at 0.76 kg/ inhabitant(Concept SA and ERA International, 2007).The management of these wastes is however inadequate and based essentially on the use of open dumpsites or landfills. Only 37% of the produced waste are evacuated to the landfill (Concept SA and ERA International, 2007). Garbage is disposed of in containers, on the floor, or quarries without any precaution and often is encountered in gutters, green spaces, and farms. Children, and even adults venture there in search of toys and/or recyclable objects (Bruneau and Bontianti, 1994).

The unavailability of modern technologies and, more specifically waste accumulation in these open areas in relation to their contact with soil and the population have great environmental and health implications that could generate economic losses to people and government (Azeez et al., 2011). One specific threat resulting from inadequate wastes disposal is the contamination by heavy metals that have significant toxic potential for both the environment (soil, water, air), humans beings and the exposed biodiversity (Tankari Dan-Badjo et al., 2012). Several heavy metals (Al, Pb, Cd, Zn, Cu, Fe, As, Copper, Lead, etc ...) have been identified in urban landfills and dumps (Beyene and Banerjee, 2011; Kimani, 2007; Tankari Dan-Badjo et al., 2013a). They result from the incineration of wastes, their decomposition and transformation but also the combustion of fuel, firewood, and industrial residues. At high doses, they can for example contribute to environmental imbalance by disruption of the chemical composition of rivers with the consequent contamination of fish and hence impacting on their reproduction (Ebrahimi and Taherianfard, 2011). Indeed, many heavy metals are found to accumulate in fishes causing human contamination and related health issues. Heavy metals also affect agricultural products and their consumers (Asongweet al., 2014).

This environmental challenge arising from a failure in urban planning, unavailability of the basic amenities and lack of collective determination has raised government concern. To address this problem, the Nigerien government, supported by its technical and financial partners continue to supply containers (dumpers) for waste disposal to the population, and seeks to establish official and controlled landfill sites. However, no study has shown whether this waste management type has or has no impacts on soil contamination in Maradi city. It is in this context that the present study was undertaken to investigate the impact of solid waste disposal sites on soil in this city through an assessment of the effectiveness of different types of dump and landfill in the management of municipal solid waste. This is specifically: (1) to quantify the concentration levels of heavy metal in soil of dumps / landfill sites and (2) to evaluate the efficacy of garbage management system in the city of Maradi.

## Materials and Methods

### Study site

The study was carried out in Maradi city, the economic center of Niger. Located between latitudes 13° 32' and 13° 26' North and longitude 7° 40 'and 7° 13' East, this city spans over an area of 8269 hectares (Figure 1).The Sahelo-sudanian climate characterized by a mean annual temperature of 27.26°C and an average relative humidity of 40.10% prevails in this area (Direction Nationale de la Méteorologie, 2013). The mean precipitation estimated over the past 30 years is 476.89 mm. The hydrographical network is dominated by the valley of Goulbi Maradi and a few temporary water ponds. Soil of Maradi is mainly sandy but is rich in silt around the Goulbi valley.

Maradi has a very cosmopolitan population estimated at 147,038 inhabitants (with an annual growth rate of 2.23%) in 2001 and 264,897 inhabitants with an annual growth rate of 4.3% in 2012 (Institut National de la Statistique, 2013).The availability of water during a major part of the year favored the development of rainfed and irrigated agriculture, an activity of about 40% of the population.

**Sampling sites**

Waste disposal is done in three stages. It starts from the production sites (houses, markets, hospitals, etc.) where they are temporality stocked in wheelbarrow or any unused container. Secondly the local population transfer these wastes to the dumping sites and finally the municipal services collect and stock them into the landfill sites.

Based on the information received from the municipality and observations conducted on the ground, two types of waste storage sites were identified namely, dumpsites and landfills.

Dumpsites can be characterized as follows in Maradi city (Figure 2): official and informal dumpsites. The official dumps are places equipped with dumpsters or garbage bins reserved for waste collection (Concept SA and ERA International, 2007). These dumpsters have a capacity of 5.5 $m^3$ and are more or less regularly removed and evacuated to landfills or other sites. Furthermore, two categories of official dumpsites are encountered: (i) "the official dumps platforms" that are equipped with a three-compartment system namely, a quay (dock) for easy access to the dumpsters, a terrace of about 5 $m^2$ in the downstream portion in contact with two or three containers and a small shack for on-site caretaker, and (ii)the "official dump without dock" which are the most abundant in the city and are also characterized by the presence of dumpsters. They are officially recognized by the municipality. Unlike official dumps, informal dumpsites are waste consolidation sites without official permission of the municipality, but created by the local population. This is usually caused by lack of dumpster container and the relatively long distance to the official dump that make it inaccessible (Concept SA and ERA International, 2007). They are located in inappropriate places, in the streets, often alongside educational or health infrastructures etc...

Landfills are quarries or areas adjacent to the city where waste is disposed of once collected from the dumpsites. At times, they result from very large uncontrolled dumpsites (Figure 2).

Soil sampling was carried out in six official dumpsites, six informal dumpsites and four landfill sites.

**Soil sampling**

Composite samples were collected from 16 sites (Figure 1) and the number of sample replicates varied according to the size of the sites: landfills are bigger than informal dumpsites that are bigger than official dumps. Thus, six replicates were collected from landfills, five in informal dumpsites and four composite samples in official dumps. Each composite sample was made up of five subsamples (four in the corners and one in the center of a plot) collected from the top 20 cm of the soil and mixed homogeneously as surfaces of the soil are better indicators of metallic burdens as suggested by Davies (1973). Control samples were collected at 100 m distance from hazard points.

In total, 68 composites samples were collected for laboratory analysis. Heavy metals assay analyzes including Zinc, Lead and Cadmium, and the evaluation of soil pH were performed. The extraction and determination of total heavy metal in soil samples were carried out at the laboratory of ICRISAT Soil Chemistry at Sadoré (Niger).

## Soil analysis

Soil samples were air-dried, grinded and sieved through a 2mm mesh size, then10 g of each soil sample was used for the analysis. Hence:

pH is an important environmental factor that determines the availability and solubility of heavy metals in soil. The pH estimation was carried out potentiometrically with direct reading from the pH meter.

The soil heavy metal analysis is performed by atomic absorption spectroscopy using a Perkin Elmer Model Analyst 400. The three stepped analysis was carried out according to the Lindsay and Norvell (1978) procedures. Firstly, a mixture in a fixed ratio of 1/2 (w / v) of the 0.1 mol/L triethanolamine (TEA), 0.01 mol/L of chloride calcium and 0.005 mol/L of diethylenetriaminepentaacetic acid (DTPA) was made at pH 7.3. Secondly, 20 ml of that solution were added to each 10 g of soil samples in a beaker. Each sealed beaker was placed in a vertical position on a shaker put in an insulated room at 20°C. After stirring for 2 hours, the suspensions were filtered by gravity with a filter paper (Whatman no. 42) and finally analyzed using the Perkin Elmer Model Analyst 400.

## Statistical test

The statistical package NADA in R was used for data analysis. The mean, standard deviation and the Wilcoxon test were calculated through the Kaplan-Meier survival method because of the nature of data in which are censored observations (Hesel and Lee, 2006; Hesel, 2012).

The pollution index (PI), a criterion for assessing the toxicity of a soil by metal assemblage, was calculated as follows (Smouni *et al*., 2010; Tankari Dan-Badjo, 2013b):

$$PI = \left[\frac{\frac{Cd}{3} + \frac{Pb}{100} + \frac{Zn}{300}}{3}\right]$$

It represents the ratio of metals concentration in soil based on the adjusted values corresponding to the tolerable levels of metal concentrations in the soil.

## Results and Discussion

A result summary of pH and three heavy metal concentrations from dumpsites, wastes landfill sites and their control samples is presented in Table 1. The soil of dumpsites and landfill sites are purely alkaline with respective mean value of 8.069 (±0.54) and 8.12 (±0.51). In fact, alkaline pH is an indicator of active dumpsite/landfill. These pH values corroborate findings of several researches carried out in Addis Ababa (Ethiopia), Lomé (Togo) and Maiduguri (Nigeria) (Beyene and Banerje, 2011; Bodjona et al., 2012 and Mshelia et al. 2014).They could result from the type of wastes present on site and their decomposition processes. Indeed, wastes in Maradi are composed of 59% of sand, 23% of organic matter, 11% stones and gravels, 2.3% plastics and 4.7% of others materials (metal, glass, leather and textile, paper, etc.). These wastes contain fermenticid which releases alkaline and earth alkaline elements that contribute to the increase in pH through their exchangeable basis such as $Ca^{2+}$, $Mg^{2+}$, $Na^+$ and $K^+$ (Martin et al., 1996; Bodjona et al., 2012). The anaerobic decomposition favorable to the decrease of free volatile acids, and the presence of bicarbonate and some oxides elements have great influence on the increase in pH (García et al., 2004).No significant difference was found among the sites and their control in terms of pH even though the mean pH of the landfill control sites is almost neutral (6.8±1.11).

Results of this study also demonstrate that the mean concentration levels of heavy metals decrease in the following sequence: Pb>Zn>Cd in landfill and Zn>Pb>Cd in dumpsites (Table 1). The concentration of Lead (Pb) is the highest of all three heavy metals and cadmium the lowest. Lead (Pb) is identified as one of the most common contaminant in the environment (Ajmone-Marsan and Biasioli, 2010) and its presence could be attributed to natural and anthropogenic sources such as the use of some pesticides in agricultural zone and atmospheric deposition in urban zones derived from high vehicular traffic and industrial activities. The low levels of cadmium contamination recorded in this study could be explained by its presence in wastes that are low sources of this metal (Ajmone-Marsan and Biasioli, 2010).Apart of the Zinc in landfill and Lead in dumpsite for which the concentration is greater in control sites, all the rests are lower in the control. The highest level of Lead recorded in the control dumpsites could be explained by their proximity to the road (Ajmone-Marsan and Biasioli, 2010, Ekwere et al., 2014).There is a significant difference (P-value =0.009 (Zn), $8.03*10^{-8}$ (Cd) and 0.0001 (Pb)) in the concentration of these metals in both sites and their control values (Table 2). This could suggest the beginning of soil contamination by Zn, Pb and Cd as further demonstrated by the Pollution Index (PI) lower than 1 in 14 sites (Table 2). The remaining two sites, SiteS11 (an informal dumpsite) and Site15 (a landfill) characterized by a Pollution Index greater than one are polluted. In fact, the Site S11is located in the area called Sourabildi found in the industrial zone of the city and close to a wetland to which sewage waters (domestic and industrial) are discharged. It is well known that the utilization of untreated sewage water contributes considerably to the increase of heavy metals in soil and crops (Mapanda et al., 2005).Meanwhile, Site S15 is located close to the Zinder road, which is a high traffic axis. This landfill is the oldest of the city, hence the accumulation of these heavy metals.

**Assessment of waste disposal system**

The concentration levels of zinc, cadmium and lead are heterogeneous as shown by the obtained range values (Table 3). The records also show that zinc is higher in informal dumpsite, cadmium in official dumpsite and lead in landfill site.

The generalized Wilcoxon statistical test performed on raw values shows that there is no significant difference among these values. This could imply that the use of official, informal dumpsites, or landfills site for solid waste disposal has no impact difference in terms of metal pollution. Hence, the management of wastes is insufficient in terms of heavy metal contamination prevention.

**Table.1** Summary statistics and comparison of mean concentration (mg.kg-1) of Zinc (Zn), Lead (Pb) and Cadmium (Cd) and pH in soil of dumpsites, landfill sites and their controls

| | Zinc (Zn) | Cadmium (Cd) | Lead (Pb) | pH |
|---|---|---|---|---|
| **Landfill sites** | 58.58 (± 44.48) | 0.03 (±0.04) | 139.059(±167.635) | 8.069 (±0.54) |
| **Control L** | 106.5(±DL-N) | DL | 92.96 (±14.47) | 6.8 (±1.11) |
| **Dumpsites** | 97.98 (±114.98) | 0.028 (±0.028) | 79.133 (±93.065) | 8.12 (±0.51) |
| **Control D** | 34.64 (±16.66) | 0.005 (±0.002) | 130.1 (±153.46) | 8.075 (±0.97) |
| **P-value** | 0.0092 | $8.13*10^{-5}$ | 0.0001 | 0.1360 |

Control L: control for landfill; Control D: control for dumpsite. P-value: Probability at $\alpha$ = 0.05. DL: below detection limit

**Table.2** Estimated Pollution Index (PI) values of the 16 sampling wastes disposal sites

| **Official dumpsites** | **S1** | **S2** | **S3** | **S4** | **S5** | **S6** |
|---|---|---|---|---|---|---|
| PI | 0.27 | 0.18 | 0.39 | 0.22 | 0.58 | 0.25 |
| **Informal dumpsites** | **S7** | **S8** | **S9** | **S10** | **S11** | **S12** |
| PI | 0.33 | 0.22 | 0.36 | 0.19 | 1.15 | 0.36 |
| **Landfill sites** | **S13** | **S14** | **S15** | **S16** | | |
| PI | 0.37 | 0.30 | 1.11 | 0.32 | | |

**Table.3** Comparison of concentration mean values (mg.kg-1) of Zinc (Zn), Cadmium (Cd), Lead (Pb) and pH and standard deviation (±SD), concentration range in three different waste disposal sites

| | Zinc (Zn) | Cadmium (Cd) | Lead (Pb) | pH |
|---|---|---|---|---|
| **Landfill** | 58.58 (±44.48) | 0.03(±0.04) | 139.059(±167.63) | 8.069 (±0.54) |
| **Range** | DL-133.95 | DL-0.113 | 58.65-610.80 | 7.2-8.8 |
| **Dumpsites Of** | 81.43 (±119.24) | 0.036(±0.035) | 39.056(±35.17) | 8.167 (±0.50) |
| **Range** | DL-379.35 | DL-0.113 | 29.85-125.25 | 7.7-9.2 |
| **Dumpsites In** | 117.76 (±109.13) | 0.021(±0.018) | 20.722(±18.05) | 8.072 (±0.52) |
| **Range** | DL-381.60 | DL-0.059 | 42-610.50 | 7.5-9.1 |
| **P-value** | 0.227 | 0.329 | 0.342 | 0.639 |

Dumpsites Of: Official dumpsites; Dumpsites In: informal dumpsites. P-value: Probability at $\alpha$ = 0.05. DL: Values below Detection Limit. Range value (minima – maxima) obtained during this study

**Figure.1** Location of Maradi city and sampling sites

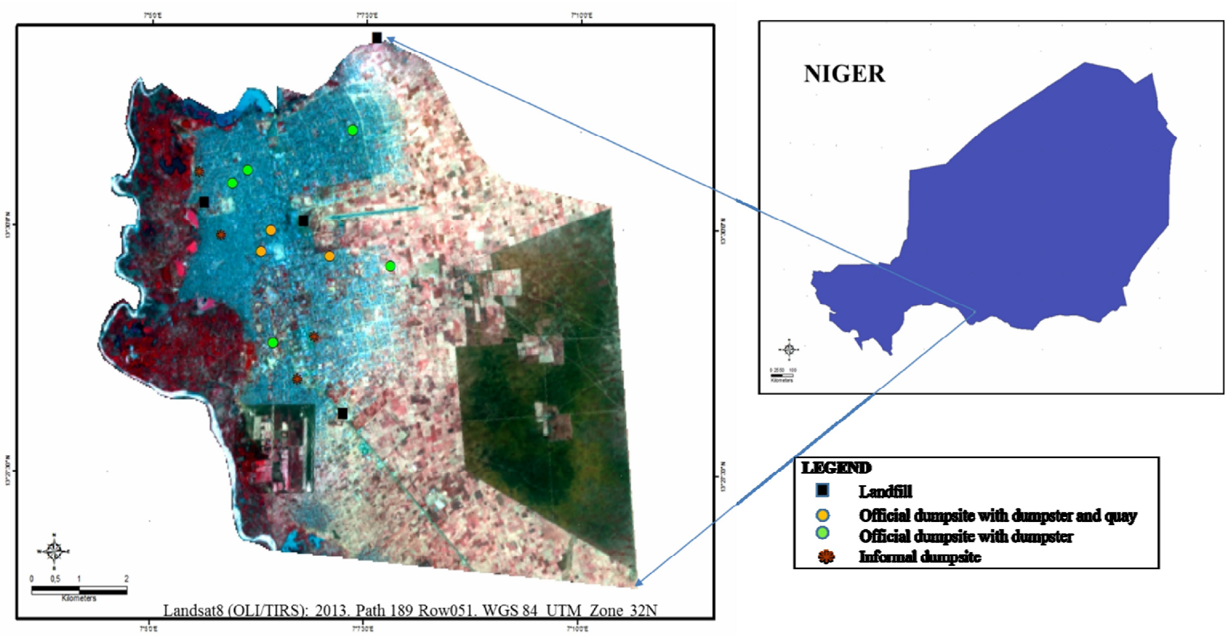
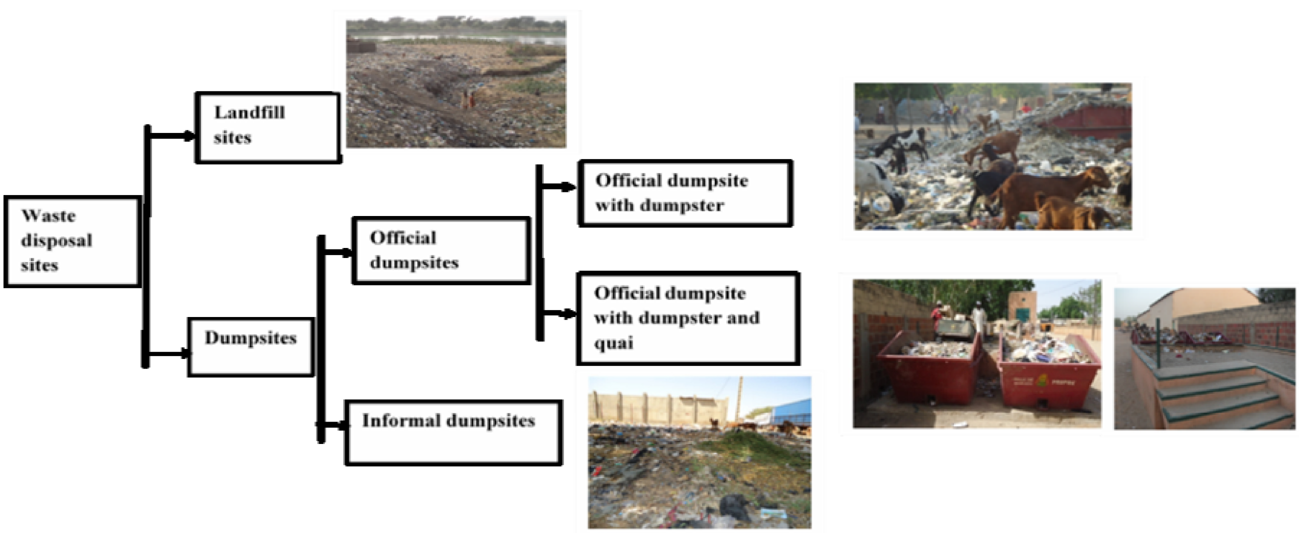



**Figure.2** The different waste disposal sites in Maradi city




The municipal management of these dump sites on one hand, and the behavior of local populations which is the continuous disposal of waste onto the ground despite the presence of dumpster on the other hand could explain this fact. In reality, the municipality has not the financial and technical capacity to collect and replace dumpsters overloaded with waste on a regular basis. This also contributes to the dumping of waste onto to the soil.

In order to reduce the quantity of waste, the population and even the municipality often set fire on these sites. The combustion of wastes is an important sources of heavy metal. Furthermore, some official dumpsites have originated from the informal ones and the concentration levels found in this study could have been the results of earlier management and accumulation of heavy metals in soil.

**Impacts of waste storage system**

The presence of heavy metals in urban soils has an impact on the environment and human health (Azeez et al., 2011). Indeed, in cities of Niger and specifically in Maradi, dumpsite soils are often used as compost without any treatment. The standard limits of compost for Lead is 100 mg/kg which is lower than the values obtained for certain sites, especially at the landfill. This practice could therefore become a source of metal contamination that could alter crop yields and quality and could cause illness among consumers (Tankari Dan-Dadjo et al., 2012, 2013b).

The location of dumpsites and landfill nearby stream or wetland could significantly affect the ecological balance and quality of seasonal crop. In contact with water, the latter becomes polluted. Contamination of stream can affect the biodiversity. They impede on the reproduction of some fishes for example (Ebrahimi and Taherianfard, 2011). Nevertheless, animals are threatened because they feed on these dumps and landfills, eating plastic, cardboard and other wastes.

The aesthetics of the city is disturbed by these wastes which emit foul odors of decomposition and gases that are notorious (Ashraf et al., 2014). They also attract mice and rats that are carriers of some diseases.

The municipality has to improve upon these methods in other to avoid all possible consequences. They should first sensitized the population, reduce the quantity of waste produced and then find adequate disposal system. Composting, when adequately done could be a viable solution (Compaore and Nanema, 2010). The utilization of these contaminated soils as it is done in Maradi is a threat unknown by farmers and neglected by authority.

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