GSC Advanced Research and Reviews
eISSN: 2582-4597 CODEN (USA): GARRC2
Cross Ref DOI: 10.30574/gscarr
Journal homepage: https://gsconlinepress.com/journals/gscarr/

(Research Article)

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Heavy metal content in dumpsite soils and vegetables: A case study of Ondo Town, Nigeria

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GSC Advanced Research and Reviews, 2024, 19(01), 097–104

Publication history: Received on 05 March 2024; revised on 15 April 2024; accepted on 18 April 2024

Article DOI: https://doi.org/10.30574/gscarr.2024.19.1.0141

Abstract

The investigation scrutinized the levels and distribution of five heavy metals (iron, cadmium, copper, lead, and nickel) at two dumpsites (Site A and Site B) and a control zone in Ondo Town, Nigeria. Moreover, the examination assessed the presence of these heavy metals in vegetable plants (*Talinum triangulare* and *Chromolaena odorata*) commonly encountered in these areas, employing atomic absorption spectrophotometry (Buck AAS 210 VGP). Conventional methodologies were utilized to evaluate specific soil physicochemical characteristics. In the control region, minimal levels of each metal were identified, with the exception of nickel. The quantities of metals varied, with lead at 0.02 mg/kg in the control area and iron at 3.54 mg/kg in Site A. The metal levels in both soil and vegetables investigated generally remained below the maximum thresholds established by the World Health Organization (WHO) for soil and vegetables, except for cadmium in Site A. The dumpsites and the associated vegetables displayed elevated levels of the heavy metals in comparison to the control area, suggesting a gradual accumulation of these metals in the vegetable flora. Hence, the consumption of vegetables cultivated near the examined sites and the use of these areas for agricultural activities should be discouraged.

Keywords: Dumpsites; Vegetables; *Talium triangulare*; bioaccumulation; Ondo Town

1. Introduction

Our environments have undergone a significant transformation, transitioning into either partially or fully open dumpsites. This change stems from a recent surge in waste generation, attributed to the establishment of additional industries, markets, hospitals, population growth, and unplanned urbanization (Alimba et al., 2006). The presence of dumpsites within residential areas in developing nations is exacerbated by lax enforcement of relevant regulations governing waste disposal, inadequate provision of organized landfill sites, and deficient urban planning.

The escalation in industrial activities, particularly in this era of technological advancement, has resulted in a higher discharge of industrial chemicals. Consequently, there's a mounting accumulation of untreated domestic waste containing heavy metals (Olajire, 1998). These toxic metals, including nickel, copper, iron, cadmium, manganese, mercury, zinc, and lead, originating from batteries, pesticides, insecticides, PVC containers, nail polish removers, and various products, are often present in industrial, commercial, and domestic wastes. They are released into the environment either directly or indirectly during usage or after their intended purposes. This phenomenon has become a persistent issue associated with human development, as evidenced by research studies (Ajah et al., 2015) emphasizing that a healthy environment is closely linked to human health.

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The detrimental impacts of waste disposal on the environment, local communities, and public health cannot be overstated (Pacyna, 2002). Dumpsites, as defined by (Abdul-Salam et al., 2011), serve as locations for the disposal of unwanted materials and represent one of the oldest waste management methods. Open dumpsites now pose significant concerns due to the myriad of dangers they pose to individuals who come into contact with the soils and plants within these areas. Much of the waste materials deposited in these dumpsites contain heavy metals, as the widespread industrial use of such metals has made them omnipresent. Leachate from these refuse dumps, containing heavy metals, poses extreme toxicity to both soil and aquatic environments due to their solubility in water (Odukoya et al., 2001). Heavy metals persist in the environment for extended periods once deposited in the soil because they do not readily degrade like organic wastes, thereby causing prolonged environmental pollution (Oyelola et al., 2009). The presence of heavy metals as metal ions in the environment hampers rapid detoxification and removal through metabolic activities, thus increasing their persistence in the soil environment.

In Nigeria and most African countries, dumpsites are commonplace across cities, towns, and villages. Many dumpsites, owing to their fertile soil, have been repurposed into farmland for cultivating plants such as vegetables and fruits. While farmers may rejoice in the high productivity of dumpsite farming, the elevated concentrations of heavy metals associated with exposed crops raise significant concerns. Bioaccumulation of heavy metals in plants occurs via their rhizospheres and transfers into the food chain upon consumption by animals and humans (Segura-Munoz et al., 2006). At times, when heavy metals accumulate in plants, they adversely affect physiological processes such as photosynthesis, nutrient absorption, and gas exchange, resulting in diminished plant growth and dry matter accumulation (Fagbote, 2010). The rate of metal uptake by crop plants can be influenced by various factors including metal species, plant species, plant age, and plant part, warranting attention due to their speciation (Amusan et al., 2005). Accumulation of heavy metals in the tissues and organs of living organisms can lead to severe health effects (Rotich et al., 2006).

Due to the deposition of diverse types of waste, soils in municipal waste dumps are typically rich in organic matter once decomposition occurs (Anikwe, 2001). Consequently, in Ondo Town, many dumpsite soils are being utilized for cultivating edible vegetables and other food crops due to their high fertility, without prior comprehensive assessment for potential ecological and health-related concerns. Bioaccumulation of metals occurs in the plant tissues of crops grown around dumpsites due to the uptake of metals by plants from soils with increased metal ion content or soils polluted by leachates (Grant, 1997). Heavy metals pose significant health risks when they accumulate in the tissues and organs of living organisms, even at low concentrations, as there is no efficient mechanism for their elimination from the body (Rotich et al., 2006). In an effort to raise awareness of the health risks associated with improper and indiscriminate waste disposal and their subsequent effects on the ecosystem, this research endeavors to evaluate the soil heavy metal loads of two dumpsites (Ondo-Ife road dumpsite and Okelaje dumpsite in Ondo Town) and vegetables grown in their vicinity, compared to a control site directly opposite the University of Medical Sciences in Ondo Town, Nigeria.

2. Material and methods

The first dumpsite (Site A), is physically located along old Ondo-Ife road closed to the boundary between Ondo Town and Okeigbo. This lies on Latitude 07^{o} 07.661$'$ N and Longitude 004^{o} 47.030$'$ E. This dumpsite serves as a major dumping site for many residential houses (figure 2). The dumpsite was dated over six (6) years of age with some cultivated farmlands around it. The second dumpsite (Site B) is located along Okelaje-Ondo Road, also of Ondo town. This lies on Latitude 07^{o} 03.865^{1} and Longitude 004^{o} 47.709$'$. This dumpsite also serves as a major dumpsite for many residential homes (figure 3). Its age was dated to be over six (6) years also with some subsistence farming activities going on around it. A control site (Site C), directly opposite the University of Medical Sciences lies on Latitude 07^{o} 04.395$'$ N and Longitude 004^{o} 47.870$'$ E where reference samples were taken, is an area considered to be free from the influence anthropogenic induced pollution. The most available vegetable in all the site is water leaf *(Talinum triangulare)*, its grows naturally and is widely consumed by residents around these sites except for the control site where *Chromolaena odorata* (triffid weed) is the most available plant which grows naturally and is widely used for medicinal purposes by residents around the site.

2.1. Sample collection and preparation:

Random system of soil collection was used to collect a total of seventeen (17) soil samples from each sampling site at the depth of 0-15 cm with the aid of a soil auger. Composite samples of the collected soil samples were obtained via thorough mixing in cleaned flat stainless trays to obtain, air dried for seven (7) days, crushed with mortar, sieved through 2 mm mesh sieve and then stored in laboratory analysis. *Talium triangulare and Chromolaena odrota* common to each sampling site were collected, rinsed with water to remove entangled soil particles. The vegetable plant samples were weighed and oven-dried at 70 °C for 48 h to constant weights. Each oven-dried sample was pulverized, sieved through 0.18 mm mesh sieve, and then stored for laboratory analysis.

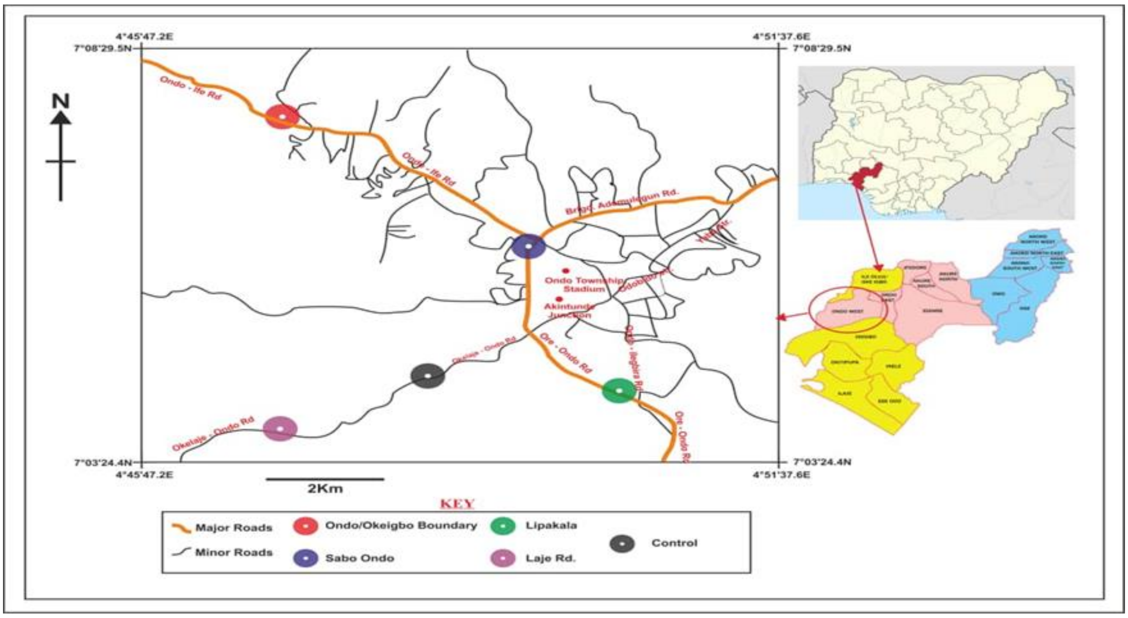

Figure 1 Map of Ondo town showing the sampling sites. Adapted from Goggle Map of Ondo street guide map.

Figure 2 Site A (Ondo-Ife Rd dumpsite)

Figure 3 Site B (Laje dumpsite)

2.2. Physicochemical analysis

2.2.1. Determination of Soil pH:

The pH of the soil samples was determined with the aid of a handheld Hanna pH meter (model H12211). 5 g of the fine soil sample was weighed into a 50 mL beaker, 10 mL of distilled water was then added. The mixture was stirred with a glass rod and allowed to stand for 30 minutes at room temperature. HANNA pH meter pre-calibrated in pH 6.86 and 4.00 buffer was inserted into the slurry and the pH reading was recorded immediately the meter got stabilized (Kumar *et al*., 2008).

2.2.2. Soil organic matter determination

The soils organic carbons were determined by Walkley – Black method for soil organic carbon determination. 1 g of fine soil sample was weighed into 250 mL conical flask and 10 ml of 0.2 M $K_2Cr_2O_7$ solution was added, the flask was swirled gently to disperse the soil in the solution, after which 20 mL of concentrated H_2SO_4 was added quickly and then mixed thoroughly. The mixture was allowed to cool for 30 minute after which 100 mL of water was added, followed by adding of 3-4 drops of Ferroin indicator. The solution was titrated against 0.5 M ferrous ammonium sulphate solution. A colour change from bluish green to brilliant green being observed indicated the end point (Kumar *et al*., 2008). Blank titration was carried out using deionized water without the soil sample. The percentage organic carbon was calculated using the titration readings (Walkey *et al*., 1937).

$$\text{Organic carbon} = \frac{(B - T) \times M \times 0.003 \times 1.33 \times 100}{\text{Weight of soil sample taken}}$$

Where,

B = Blank Titre Value

T = Sample Titre Value

M = Molarity of ferrous sulphate (Inengite *et al*., 2015)

$$\% \text{ organic matter} = \% \text{ organic carbon} \times 1.724$$

2.3. Determination of Heavy metals (Pb, Cd, Cu, Fe and Ni) in soil and vegetable plant

Soil samples were digested according to (Allen *et al.*, 1974). 1.0 g of soil sample was weighed into a 100 mL kjeldahl digestion tube and 20 mL of mixture of HCl and HNO_3 (aqua regia) was added. A thermostat hot plate at 150 ^oC placed in a fume cupboard was used to heat the solution until a slightly clear colour solution was obtained. It was cooled and filtered using Whatman filter paper into a 100 mL standard flask and made up to mark with distilled water. Triplicate samples of pulverized *Talinum triangulare* and *Chromolaena odorata* plant samples were equally digested according to method described by (Pequerul *et al*., 1993). 0.5 g amount of the vegetable samples were weighed into a 100 mL beaker, followed by the addition of 5 mL concentrated HNO_3. In a fume cupboard, the solution was heated on a thermostat hot plate at 120 ^oC with occasional addition of 4 mL H_2O_2 to avoid dryness. The solution was cooled and filtered. The filtrate obtained into 100 mL standard flask and was made up to mark with distilled water. Background contamination by the reagents used was duly checked by preparing blanks.

2.4. Metal analysis:

Atomic absorption spectrophotometer (Buck AAS 210 VGP) in Sustainable laboratory services limited, Ondo state, Nigeria, was used to analyzed for five heavy metals (Cu, Cd, Pb, Ni, and Fe) in the digested soil samples. The manufacturers' specifications for the instrument setting and operational conditions were strictly adhered to.

2.5. Statistical analysis:

Statistical Programmed for Social Sciences (SPSS) version 13.0 was used to analyze the mean concentrations of heavy metals in soils and vegetable plants.

3. Results and discussion

The result of the physicochemical properties and the percentage organic matter of the soil samples determined are presented in table 1. The first dumpsite that it is physically located along old Ondo-Ife road closed to the boundary between Ondo Town and Okeigbo is represented as **Site A** while the second dumpsite (Site B) that it is located along Okelaje-Ondo Road is represented as **Site B**.

Table 1 Soil samples physicochemical properties

Sites	Site A	Site B	Control
pH	$7.37^{b} \pm 0.06$	$7.50^{c} \pm 0.10$	$6.87^{a} \pm 0.06$
% TOM	$4.99^{b} \pm 0.55$	$7.13^{c} \pm 0.17$	$3.59^{a} \pm 0.17$

Values are mean ± SD (n=3), TOM = Total Organic Matter. Superscript with different letters across the row show significant variation, while those with same letter does not at $p<0.05$

The mean pH value of the soils ranged from 7.37 in site C to 7.50 in site D as against that of the control site with pH of 6.87. This shows that the control soil is slightly acidic while site A and B soils are slightly alkaline. The mean pH values obtained are similar research works reported by (Victoria, 2014) for Akure dumpsites, Nigeria and for Oke-Ese dumpsite, Ilesa, Osun state, Nigeria reported by (Awokunmi *et al*., 2015). The mean pH values of site A, and B were greater than the value obtained for the control. The higher value of pH may be linked to mineral build-up by wastes on the dumpsites. Soil pH plays significant role in regulating the solubility and mobility of heavy metals. According to the research reported (Wang *et al*., 2007), most metals in soils with pH range of 6.0 - 9.0 have metals that are not likely to be bioavailable because they are always not in their free states. The metals examined in this research work may possibly not be bioavailable to plant until when favourable conditions like acidic precipitation prevailed in the soils because the soil samples investigated in this research work have pH values within this range.

Organic matter supplies important nutrients and also enhances and controls microbial activities as it serves as a source of food to the soil microbes (Brady, 1996). The mean percentage organic matter of soil samples ranged from 3.59 to 7.13, and follows the order; control < site A < site B. The percentage organic matter of the of the control site was lower the two dumpsites. The higher percentage organic matter recorded for site A and site B could be attributed to the decomposition and composting processes of organic wastes. This result is higher than the 0.1 to 1.34 percentage organic matter reported by (Akinnusotu, 2016) for dumpsites in Rufus Giwa Polythenic, Owo, Ondo state, Nigeria but lower than the 7.62 to 8.60 reported by (Victoria, 2014) for Oke-Esa dumpsite in Ilesa, Osun state, Nigeria.

Table 2 shows the concentrations of each of the heavy metals investigated in the soil samples of the two dumpsites and the control site. Results obtained indicated that, apart from Ni and Fe in site B, the dumpsite soils contained higher concentrations of metals than their corresponding metals level at the control site. The result is in agreement with similar research studies reported by Asaolu *et al*. on a dumpsite in Ilesha. The metal concentrations could be linked to gradual leaching of metals into the sub-soils from wastes containing metals in the dumpsites. The investigated heavy metals (Pb, Cu, Ni, Cd and Fe) concentrations in the soil samples were lower than the maximum permissible limit standard set by the WHO for metals in soil except for Cd in site A and B.

Table 2 Soil heavy metal concentration (mg/kg)

Sites	Site A	Site B	Control	WHO MPL soil (mg/kg)
Pb	$0.54^{b} \pm 0.00$	$0.83^{c} \pm 0.00$	$0.02^{a} \pm 0.00$	85.00
Cu	$2.15^{c} \pm 0.00$	$0.46^{b} \pm 0.01$	$0.28^{a} \pm 0.02$	36.00
Ni	$0.63^{b} \pm 0.00$	$0.39^{a} \pm 0.00$	$1.04^{c} \pm 0.00$	35.00
Cd	$0.95^{b} \pm 0.00$	$0.13^{a} \pm 0.00$	$0.08^{a} \pm 0.00$	0.80
Fe	$3.54^{c} \pm 0.00$	$2.32^{a} \pm 0.00$	$3.13^{b} \pm 0.00$	50,000

Values are mean ± SD (n=3); WHO MPL: World Health Organization maximum permissible level
At p<0.05, superscript with same letters across the row show no significant variation while those with different letters do.
Source: (FAO/WHO, 2011)

Lead (Pb) is one of the toxic elements that are ubiquitously in the soil. The mean concentrations of lead in the various sites were higher than the control site and were significantly different across the sites. The soil of site B had the maximum concentration of lead with 0.83 mg/kg and the control site had the minimum concentration of lead with 0.02 mg/kg. This result is of similar trend with the result reported by (Victoria, 2014) on dumpsite in Akure. The presence of lead in the soils may be due to the disposal of material wastes such as paint, textiles, lead acid batteries and other automobile parts. Copper (Cu) is one of the essential elements for plants, microorganisms, animals and humans. The mean concentrations of copper across the various sites were significantly different, it ranged from 0.28 mg/kg in the control site to 2.15 mg/kg in site A. This is in agreement with the research work reported by (Onder *et al*., 2007) that Cu content differ according to soil type and pollution source. The results obtained for copper in this study were also similar to the research reported for copper concentration of waste dumpsites soils (Osakwe, 2008). The presence of copper in the soils can be linked to anthropogenic activities such dumping of copper containing wastes like electrical wires, fertilizers, textile and plumbing materials. Nickel (Ni) has been considered to be an essential trace element for plant, human and animal health. The mean concentrations of nickel were significantly different across the sites with the control site having the highest values than the two dumpsite soil samples. The presence of nickel in the soils can be attributed to sandy nature of the soils and anthropogenic activities like the disposal of material wastes such as nickel batteries (Osakwe, 2008). Cadmium is a heavy metal toxicant. Cadmium mean concentrations ranged from 0.13 mg/kg in site B to 0.95 mg/kg in site A which are considerably higher than that of the control with 0.08 mg/kg. The results obtained in this study were lower than the 0.25 – 13.42 mg/kg reported by (Ilori *et al*., 2018) on the study on selected dumpsites. The presence of cadmium determined in the site soils could be attributed to contamination from material wastes such as Ni-Cd batteries, detergents, plastics, phosphate fertilizers and pesticides disposed on the sites. Cadmium is one of toxic metals which negatively affect soil functions and other environmental media when their presence exceed maximum allowable limits (Carter, 1993, Ademoroti, 1996). Iron (Fe) is regarded as one of the essential elements for humans but can also be toxic to cellular constituents when present in excess. The concentrations of iron across all the sites were higher than the concentrations of other metals investigated in this research work. The soil of site A had the maximum concentration of iron with mean concentration value of 3.54 mg/kg and site B had the minimum concentration value of 2.32 mg/kg while the control site had a mean value of 3.13 mg/kg. This result is far below higher value concentrations of iron in Nigeria soil earlier reported by some researchers (Adefemi, 2009, Awokunmi *et al*, 2010).

The mean concentrations of the selected metals in the vegetable plants; *Talinum triangulare* obtained from sites A, B and *Chromolaena odorata* obtained from the control site are shown in table 3.

Table 3 Heavy metal concentration in vegetables (mg/kg)

Sites	Site A	Site B	Control	WHO MPL Vegetable/plant (mg/kg)
Pb	0.13 ^{b} ± 0.00	0.17 ^{c} ± 0.00	0.01 ^{a} ± 0.00	0.30
Cu	0.37 ^{c} ± 0.06	0.30 ^{b} ± 0.00	0.09 ^{a} ± 0.00	73.00
Ni	0.08 ^{b} ± 0.06	0.05 ^{a} ± 0.00	0.53 ^{c}± 0.00	67.00
Cd	0.20 ^{c} ± 0.00	0.03 ^{b} ± 0.00	0.02 ^{a} ± 0.00	0.10
Fe	1.93 ^{a} ± 0.01	2.08 ^{b} ± 0.01	2.13 ^{c} ± 0.01	500

Values are mean ± SD (n=3); Source: (FAO/WHO, 2011)
At $p<0.05$, superscript with same letters across the row show no significant variation while those with different letters do

The concentrations of the different metals assimilated by the vegetable flora exhibited notable significance at the diverse locations. The uptake of metals by a plant is regulated by various factors such as: (i) the concentration and speciation of the metal in the soil solution, (ii) the metal's movement to the root surface from the soil, (iii) the metal's transportation into the root from the root surface, and (iv) the translocation of the metal to the shoot from the root (Barber, 1984, Wild, 1988). Nevertheless, it is crucial to acknowledge that the inherent characteristics of a metallic element and its interaction with a specific plant system can significantly impact the metal's distribution within the plant. A study conducted by Barber (1984) also indicates that the metal plant uptake is greatly influenced by the concentration and bioavailability of the metal in the bulk soil. Thus, the assessment of metal concentrations in vegetable plants predominantly mirrors their respective levels in the soil. The levels of heavy metals absorbed by the vegetable plants examined in the vicinity of the disposal sites surpassed those at the control site, with the exception of nickel and iron. They remained below the maximum permissible levels for metals in plants set by the World Health Organization, except for cadmium at site A. This suggests that the consumption of these vegetable plants is deemed safe, although the continuous accumulation of metals in the vegetables poses a significant risk with sustained consumption.

4. Conclusion

The heavy metals concentration examined in this investigation followed the sequence Fe > Cu > Cd > Ni > Pb for soil from locations A, and Fe > Pb > Cu > Ni > Cd for soil from sites B. These metals were detected in vegetable plants cultivated near the landfill sites under analysis, with iron (Fe) and Cadmium (Cd) displaying the highest and lowest levels in the vegetable flora, respectively. While the soil and plants scrutinized were deemed safe at present due to most metals falling below WHO-authorized thresholds, the continual accumulation noted in their respective concentrations at the dumpsites and control area raises significant concerns. Moreover, the inevitable bioaccumulation of these metals and their subsequent integration into the food chain, posing associated health hazards, will occur if the ongoing cultivation of edible produce around the dumpsites is not promptly discouraged.

Compliance with ethical standards

Acknowledgments

Mr J.O Adunbi, was responsible for the financial burden involved in carrying out this research work. Prof. O.O Ajayi and Dr. E.O. Abata supervise the work, while Mr. R.B. Babafemi provide advice that were useful at the course of the research. We are grateful to the laboratory technologist Mr. O.A. Ajayi who assisted in the research work.

Disclosure of conflict of interest

Authors have declared that no competing interest exist.

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