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Studies on Heavy Metal Accumulation in Plant, Insect and Soil in a Public Dumpsite in Ado-Ekiti, Ekiti State

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Abstract

Studies on heavy metals' accumulation in plants, insects and soil was carried out in a municipal dumpsite located in Ado-Ekiti. The concentrations of five heavy metals, cadmium (Cd), cobalt (Co), lead (Pb), nickel (Ni), and copper (Cu) in the samples was evaluated for the bio-assessment of environmental heavy metal pollution. The concentration of heavy metals in the plants, soil and grasshoppers from the waste dumpsite in Ado-Ekiti was found to be proportional in the order Cu > Co > Ni >Pb>Cd. It was noticed that Lead and Cadmium were undetected in all the samples of soil, insect and plant screened hence suggesting no immediate threat of poisoning. However, there were considerable levels of Copper, Nickel and Cobalt in the plants, insects and soil with the soil having the highest amount of cobalt and the grasshopper having high amounts of copper detected. Heavy metal pollution of the environment, even at low levels, and their resultant long-term amassed health effects are among the leading public health concerns all over the world. This study therefore recommends the prevention of any form of farming on dumpsite soils, wastes' segregation at the point of generation and the use of geo-synthetic clay liners as protectors so as to prevent leachate percolation into underground soils.

Keywords: Copper; Dumpsite; Heavy metals; Insects; Lead; Plant; Soil.

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1. Introduction

Rapid and relatively unorganized urban expansion, industrial developments coupled with inadequate waste management causes significant alterations in the physical environment and increases accumulation of municipal waste. In Africa, some cities lack proper solid waste regulations and proper disposal facilities, for harmful waste. Such waste may be toxic or radioactive [1, 2, 3, 4]. These cities reveal aspects of waste-management problem such as heaps of uncontrolled garbage, roadsides littered with refuse; streams blocked with rubbish and inappropriately disposed toxic waste and disposal sites that constitute a health hazard to residential areas.

Abandoned waste dumpsites have been used extensively as fertile grounds for cultivating vegetables though research has indicated that the vegetables are capable of accumulating high levels of heavy metals from contaminated and polluted soils [8, 9, 10, 11]. Heavy metal pollution of the environment, even at low levels, and their resulting long-term cumulative health effects are among the leading health concerns all over the world [12]. In Nigeria, the most important sources of such contamination of urban agricultural sites are derived from industrial processing plants or leachates from solid waste dumpsites [13]. Modern farming, industrialization, and increased vehicular use have led to high concentrations of heavy metals such as lead, nickel, chromium, cadmium, aluminum, mercury, and zinc in the environment [14]. These toxic heavy metals are regularly getting into air, water, and soil, thereby becoming part of natural biogeochemical cycle [15]. It is suspected that in most cases, the heavy metals in these soils are taken up by plants via the roots and later accumulated in the stem and other edible portions of plants which eventually lead to poisoning when consumed [16]. The higher the concentration of these metals in soils, the higher the uptake by plant. Apart from uptake by plant, they can also be leached into underground water sources [17].

Insects have strong relationship with ecology and are popularly used as bio indicators of heavy metal pollution [18]. Acute and chronic effects of heavy metals on various insects are frequently reported in the form of growth inhibition, developmental abnormalities, reduced reproduction, and decreased hatchability [19]. Generally higher metal concentrations have been reported in invertebrates collected from more contaminated sites and considerable differences have been observed between the metal concentrations of the various group of invertebrates [20,21,22,].

It is very alarming today, considering the nature and composition of waste we generate that little attention is given to the proper treatment and care of the disposal sites. It is obvious that solid waste problem has become a number one serious environmental problem facing the country, because of its consequent effects on the pollution of soil, water and air. Heavy metals toxicity can result in damaged or reduced mental and central nervous function, lower energy level and damage to blood composition, lungs, kidney, liver and other neurological organs among others[23] .

This study aims to describe the patterns of metal accumulation in soil, plants and herbivorous insects - grasshoppers, (Orthoptera, Acrididae) at selected sites in the vicinity of the waste dumpsite in Ado-Ekiti.

The heavy metals analyzed in municipal dumpsite environment assessed in this study are Cadmium (Cd), Lead

(Pb), Copper (Cu), Nickel (Ni) and Cobalt (Co).

2. Methodology

2.1 Study Area

Ado-Ekiti, the state capital of Ekiti State is a city in Southwestern Nigeria. The city has long been a commercial and industrial centre among cities, towns and villages in Ekiti State. According to the 2006 National Census figureure, Ado-Ekiti is the largest city in Ekiti State with estimated population of about 2.3 million people [24]. Ado-Ekiti is situated at latitude 7° 15' - 8°05'N, longitude 4° 45'-5° 45'E and 456 meters' elevation above the sea level. It is situated along Ado-Iworoko road and it has a good accessibility. There is an Ebira community within the study area. The composition of Ilokun dumpsite are organic materials, polythene and plastic materials, metal scraps, animal wastes etc.

2.2 Sample collection

2.2.1 Soil Samples

Soil samples were collected by grab sampling at various points in each direction in east, west, north and south of the sampling sites. These were then mixed to form composite samples; the center of the waste dumpsite was taken as zero point. The Dutch Auger was used to collect soil samples at 0 – 20 cm depth of the sampling site. Samples were air-dried, ground to fine dust, sieved to pass through a 2 mm sieve [25].

2.2.2 Insects

Using insect nets, males and females, ten grasshoppers *Zonocerus variegatus* were collected from the sampling site. They were then transported to the Department of Zoology laboratory, Ekiti State University, Ado-Ekiti. The grasshoppers were fed the same grass [19].

2.2.3 Plants

Plants found growing on the refuse dump was randomly uprooted, packed into plastic bags, and washed with distilled water to remove debris and insects, and partitioned into parts (leaf, stem, fruit, and root) prior to analysis in the laboratory [26].

2.2.4 Sample Analysis

- **Soil**

10 g of each soil sample was weighed into a 100 mL conical flask which had already been washed with deionized water followed by the addition of 6 mL $HNO_3/HClO_4$ acid in ratio 2:1 and left overnight. Each sample was digested at 150°C for about 90 minutes and the temperature was increased to 230°C for 30 minutes and HCl solution was added in ratio 1:1 to the digested sample and re-digested again for another 30 minutes. The

digested sample was washed into 100 mL volumetric flask. Mixture obtained was cooled down to room temperature to avoid formation of insoluble per chloric compounds and was made up to mark with deionized water. Heavy metals in this digest were determined using atomic absorption spectrophotometer (BUCK 210 VGP) and the amount of each heavy metal was extrapolated from the calibration graph prepared. The amounts of heavy metal obtained were reported as mg/kg heavy metal [27].

- **Insects and plants**

Insects were mechanically dried in oven, prior to grounding were ground into homogenous powder and weighed on microbalance. This was followed by digestion using 10 ml of 1M HNO_3 and mild heat until brown fumes appeared. The samples were cooled off, made up to 50ml in a standard volumetric flask which have been subjected to acid wash to remove any trace of residual metals and then filtered prior to analysis. The already partitioned plant was dried in the oven at 60ºC for 10 hours, then ground and powdered with a mortar.

The powdered sample (1 g) was digested using a mixture of concentrated nitric and perchloric acids [17]. Digests of the three samples were analyzed for metal contents.

Determination of heavy metals (Cd, Co, Ni, Pb, and Zn) in the soil, insect, and vegetable samples were performed using the atomic absorption spectrometer (AAS) [17, 19, 28].

3. Results

The heavy metal analysis of soil samples collected from the waste dumpsite location was evaluated and the result is presented in figure 1. It was observed that Lead (Pb) and cadmium (Cd) were undetected in the soil samples while cobalt (Co) had the highest value in sample A at levels of 0.856mg/100g, copper (Cu) in sample B and C at levels 0.163mg/100g and 0.709mg/100g respectively. Nickel was also detected in the soil samples at various levels of 0.264, 0.045 and 0.24 mg/100g in all the soil samples respectively. Figure 2 showed the heavy metal levels in the sampled insects (grasshopper) found at the waste dumpsite environment. The insects were used as biomarkers of heavy metal pollution as they tend to accumulate heavy metals. It was observed that copper had the highest values detected in the insect with a level of 6.568 mg/100g in sample A and 2.632 mg/100g in sample 2. Nickel also was detected at a level of 0.624 and 0.116 mg/100g in samples A and B respectively. However, Lead (Pb), cadmium and cobalt were undetected in both samples analyzed for their heavy metal bioaccumulation levels.

The concentration of heavy metals in plants growing around the dumpsite was also determined and the result is shown in Figure 3. Three samples were analyzed and it was observed that Lead (Pb), cadmium and cobalt were undetected in sample A and C respectively but cadmium was detected in sample B at concentration of 0.043 mg/100g. Copper was the highest detected heavy metal in the samples at concentrations of 0.83, 1.014 and 0.624 mg/100g in samples A, B, and C respectively. Also, Nickel was detected in all the samples too at concentrations of 0.252 mg/100g in sample A, 0.34 mg/100g in sample B and 0.225 mg/100g in sample C.

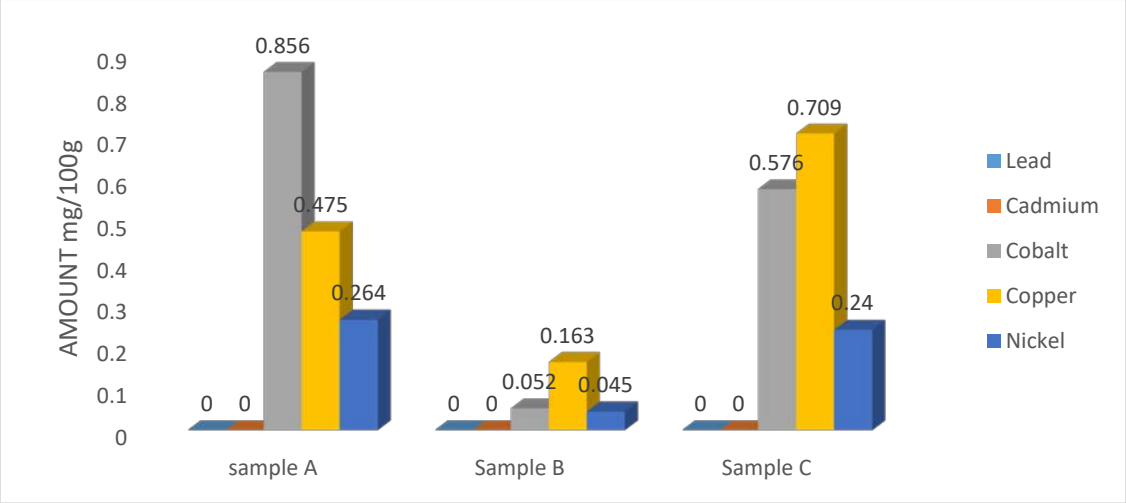

Figure 1: Heavy metal concentration in soil samples collected from municipal dumpsite in Ado-Ekiti

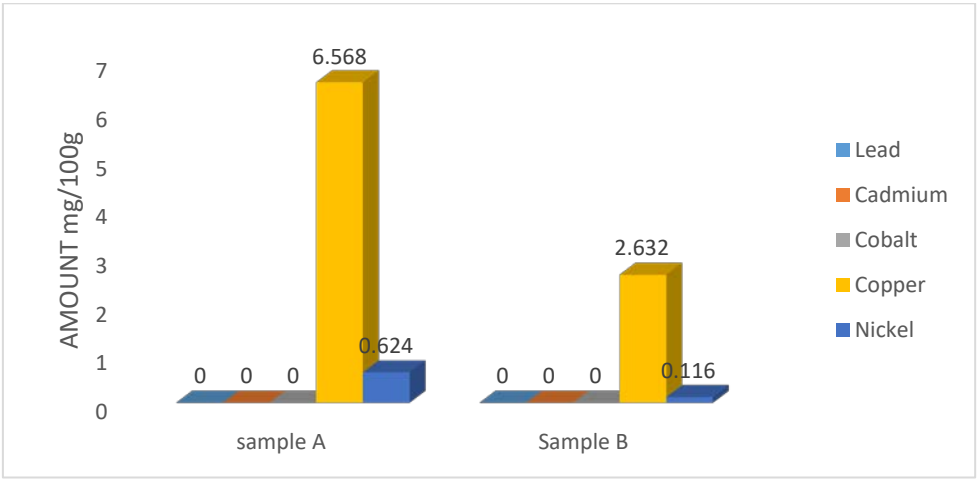

Figure 2: Heavy metal concentration in Grasshopper samples collected from the municipal dumpsite in Ado-Ekiti

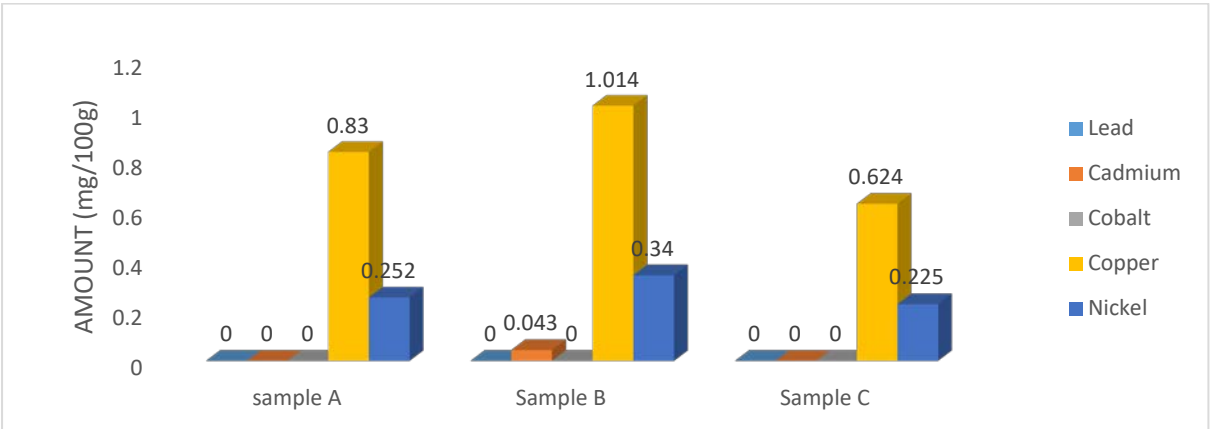

Figure 3: Heavy metal concentration in plant samples collected from the municipal dumpsite in Ado-Ekiti

4. Discussion

The heavy metal concentration in soil, plant and insects from a municipal dumpsite in Ado-Ekiti was evaluated for the bio assessment of heavy metal pollution. The concentration of heavy metals in the plants, soil and grasshoppers from the waste dumpsite in Ado-Ekiti was proportional in the order Cu > Ni > Cd>Pb>Co. [29]. A study of characteristics of soils and crop uptake of heavy metal in municipal waste dumpsite in Nigeria established that soil of municipal waste dumpsites are higher in heavy metal concentration and that crops growing on the dumpsites bio-accumulate considerably higher metal content than those on normal agricultural soils.

The presence of heavy metals on the dumpsite could be attributed to the disposal of solid wastes on the site which over time biodegrade and adds their metallic content to the soil. Metals and metal containing wastes are known to constitute a significant proportion of the wastes dumped at the site – about 25% [30]. Majority of heavy metals are toxic to living organisms and when retained in the soil, interfere with biochemical processes and alter the ecological balance [31]. These heavy metals do not biodegrade rather they bio accumulate and these may have adverse effects on the biodiversity of the area if the organisms do not develop a mechanism of adaptation to it.

It was also noted that the copper levels was highest in the plant samples collected than soil. Although plant uptake is very slow, it can accumulate to toxic level in some perennial plant [17]. In order for root uptake to occur, a soluble species must exist adjacent to the root membrane for some finite period. Once metal-containing materials are deposited, they are subjected to chemical and microbial modification with metal solubility ultimately approaching thermodynamic equilibrium with nature soil mineral and organic matter. The rate and extent of solubilisation are governed by the physicochemical properties of the deposited material, soil processes and soil properties, therefore solubility might be responsible for the slow uptake of heavy metal by plant.

It was observed that copper was the most abundant metal amongst the heavy metals tested in the plant and grasshopper and was also relatively high in the soil samples, second to cobalt in one of the soil samples while lead and cadmium were rarely detected in most of the samples. This was similar to the findings of [25].

The values of all metals determined were below the tolerable limits recommended by World Health Organization (WHO) and European Union (EU) except for copper. [32] also observed that the heavy metals tested for in soil samples from farmlands in the vicinity of the refuse dump site of Obafemi Awolowo University, Ile-Ife, Nigeria were also below the standards set except for lead. The absence of high amounts of lead and cadmium in this study indicates a reduced risk of pollution of underground water and resulting poisoning from leachate contamination.

Also. he levels of Cd, Cu, Fe, Ni, Pb in the plants studied were below the levels recommended by WHO/FAO and NAFDAC for metals in foods and vegetables and are also within the normal range of metals in plants as also observed in the study by [32].

Although the levels of these metals are within normal range for plants, however continual consumption could

lead to accumulation and adverse health implication [33]

5. Conclusion

The study has shown that heavy metals pollution of grasshoppers, soil, and plants is an issue of environmental concern, especially when e-waste is involved. The concentration levels of heavy metals were noted to be affected by change in season, depth of soil, sampling distance, and plant part. The results from this study revealed the presence of significant concentrations of Cu, and Ni in soils, grasshoppers and plants in the dumpsite environment. Frequent monitoring of the quality of dumpsites will be necessary to know the changes in chemistry of the environment and possibly initiate remedial measures. Modern waste disposal facilities should be acquired by relevant authorities and appropriate waste disposal sites be chosen to avoid the injurious effects of indiscriminate disposal of wastes, and residential buildings should be sited farther away from areas of pollution.

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