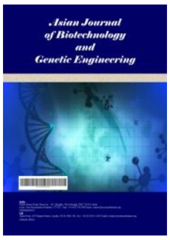

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Assessment of Seasonal Variation on Heavy Metal Concentration in the Soil of Ugwuaji Solid Waste Dump Sites

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Open dump site has become a major challenge in maintaining a pollution free environment in most rural and suburban areas. The present study was aimed toward investigating the effect of seasonal variation on metal (Pb, Cd, Cu, Cr, Hg, and Zn) concentration in soil obtained from Ugwuaji solid waste dump sites in Enugu state. Standard procedures and techniques were employed in the study. Using circular plot method, soil samples were collected from the study area at depth 0 to 15 cm, 15 to 30 cm, and 30 to 45 cm during the dry (November, December, January) and wet (April, May, June) season. The results of the findings showed reduction in soil pH, CEC, SOM and moisture content during the dry season [5.65 pH.H_2O, 11.8 cmol/kg, 388.2 g/kg, and 8.12 % respectively] compared to the wet season [6.75 pH.H_2O, 13.8 cmol/kg, 458.2 g/kg, 16.1 %]. The concentration of metals increased progressively during the period of assessment in the order: November> December>January>April>May>June. During the dry season metal concentration was highest in soil sample from depth 0 to 15 cm and least in soil sample from depth 30 to 45 cm. In contrast, during the wet season metal concentration was highest in soil sample from depth 30 to 45 cm and least in soil sample from depth 0 to 15 cm. The concentration of all the metals investigated were above WHO maximum permissible limit for both seasons. The concentrations of the metals

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investigated were observed in the following order Zn > Pb > Cu > Cr > Hg > Cd. The research study has indicated that soil from the study area (Ugwuaji waste dumpsite) are polluted by the heavy metals.

Keywords: Solid waste; open dumpsite; heavy metal; pollution; assessment; Ugwuaji; soil physicochemical properties.

1. INTRODUCTION

Soil pollution occurs as a result of introduction of contaminants in a concentration that is beyond the threshold limit which affects the soil quality [1]. It poses serious danger to man, plants and wildlife. For decades now, heavy metals have considerably damaged the soil quality and fertility as a consequence of increased environmental pollution from industrial, agricultural and municipal sources [1]. The major causes of soil pollution include improper waste disposal, chemicals like insecticides, pesticides, fertilizer application and herbicide [2]. Human activities such as improper dumping of municipal solid waste (MSW) often called “garbage” or “trash” has continuously aggravated environmental pollution [3]. This is worsened by geometric increase in human population and economic growth which leads to the generation of high quantity of solid waste [4].

Solid waste management strategy has been a universal problem. According to studies, it has been noted that the major problems in Enugu was the accumulation of tonnes of solid waste [5]. Enugu remains one of the most populous metropolitan areas in South Eastern Nigeria and its population is projected to be between 1,000,000 to 3,267,837 generating waste of more than 25,000 tonnes of refuse daily [6]. It is a common practice by residents all over the city to indiscriminately or improperly dispose domestic waste in the streets, markets, gutters, streams and any available plot of land leading to poor quality of the soil. Delay in evacuation of waste contribute to its accumulation and decay in any dump site. Improper waste management is harmful to the environment and health for it contaminates underground and surface water, polluting the air and land [7] by producing offensive odors and smells as well as poisonous chemicals (leachate).

Domestic solid wastes stand out as a serious hazard in Enugu urban areas, particularly neighborhood waste [8]. These wastes could be solid organic substance that are biodegradable (like cash crops, peels, grasses and vegetables) or inorganic substances that are non-biodegradable e.g. plastic, bottles and metals [9]. The problems of waste accumulation do not only end on heavy accumulation and its effects on soil or the environment. There are other related cases like household dumping of solid waste haphazardly which subsequently block water channels, leading to flooding. Some of the roads in the area have been partially covered by solid waste, since adequate space is not provided for refuse dump for the neighborhood [10]. Evidence has shown that the problem of domestic solid waste disposal and management in Enugu urban continued to worsen despite the monthly environmental sanitation exercise as wastes are seen littered all over the street [11].

Municipal solid waste management is an important part of the urban infrastructure that ensures the protection of human environment and human health [12]. Solid waste generated in Enugu urban are regularly throw off in dumpsite, gutters and behind houses by residents that generates them [3]. Enugu State government through Enugu state waste management authority (ESWAMA) has employed several methods to manage their waste but all to no avail as waste is seen littered along streets and gutters of Enugu town. This study examines the effect of seasonal variation in the accumulation heavy metals in soil from solid waste dumpsite in Ugwuaji, Enugu State. Generally, two seasons are experienced in Enugu State; the rainy season and the dry season. The rainy season is usually experienced from the month of February to August; while the dry season is experienced from September to January. The average temperature of the rainy season is around 15.86 ^{o}C with an average rainfall of 35.7 cm^3. Rainfall is usually not experienced during the dry season and the average temperature for this period is about 30.64 ^{o}C. This study will help in environmental monitoring and further enlighten the general public of the need to practice good waste management strategy.

2. MATERIALS AND METHODS

2.1 Study Area

Ugwuaji is a town in Southern part of Enugu state, Nigeria. The state is one of the five Southeastern states of Nigeria, located between latitude 6°.00’N and 7°.00’N and longitude 7°.00’E and 7°.45’E. It falls within the humid tropical rainforest belt of the Southeastern Nigeria [13]. There are two distinct seasons experienced in the state: the dry and rainy seasons. The annual rainfall ranges between 937.2 mm to 2243.3 mm and the temperature between 20.3°C to 32.16°C [13,6]. The estimated population of Enugu inhabitants is around 722, 664 (2006 census) [6].

The geographic position system (GPS) coordinates of Ugwuaji is: Elevation 186 m; North 6°26.27’; and East: 7°32.831 as originally mapped out by Enugu State Waste Management Authority (ESWAMA) municipal solid waste (MSW). It is used by the establishment (ESWAMA) as the final disposal site of all municipal solid waste generated in Enugu metropolis. The area is approximately 7.878 ha of land space [13]. The dump site is about 1.6 kilometers off Enugu-Port Harcourt expressway. The dumpsite was originally conceived as a landfill but has degenerated to a massive open dump due to poor management, inadequate manpower and lack of requisite technology. The bottom of the landfill was not lined for leachate containment, and no compaction was undertaken. There is no perimeter fencing, hence scavengers and stray animals roam the dumpsite unrestricted [13].

2.2 Experimental Design

A randomized complete block design was adopted for the study. The site was partitioned into units through the circular plot method. Soil samples were collected for dry and wet season within the months of November, December, January; and April, May, June respectively.

2.3 Sample Collection

Soil sampling will be conducted using circular plot method. In this method, the open landfill was used as the central point, and a rope marked at 2 m intervals was pivoted to determine the edges of the circular plot. Through this means, three circles 2 m apart were created. Soil samples were collected within the circumferences of the circles [14]. Soil samples were collected from the study area at depth 0 to 15 cm, 15 to 30 cm, and 30 to 45 cm using a calibrated soil auger. Each sample was immediately placed in sterilized bags and tightly sealed. After which, the samples were taken to the laboratory for preparation and analysis. Control soil samples were also be collected from uncontaminated (pollution free) area for comparison purpose.

2.4 Sample Preparation and Digestion

All the samples were dried at 100 – 110 ^{o}C to drive out moisture. On cooling, each sample was sieved through a nylon sieve of 0.2 mm diameter to remove stones, plant residues and to obtain a uniform particle size.

Soil samples were digested using dry-ash method according to [15]. One gram of the representative soil sample was weighed into a porcelain crucible and heated on heating mantle to volatilize all organic matter. Two millilitre of concentrated nitric acid was added and evaporate to dryness using a heating mantle. The sample was introduced into a muffle furnace and ashed at 450 ^{o}C for four hours. After ashing, the dish was removed from the muffle furnace and 50 ml of 50 % aqueous hydrochloric acid solution was used to wash out the sample into a 100 ml beaker. The solution was heated gently for 30 minutes for complete de-solution. The solution was allowed to cool and filtered into a 100 ml volumetric flask. The digest was made up to the mark using distilled water. Metals in the sample were determined by Atomic Absorption Spectrophotometry (AAS).

2.4.1 Determination of soil Ph

The soil pH was determined using the procedure according to [15]. About 10 g of each air-dry soil sample, passed through 2 mm sieve, was added to 20 ml 0.01M $CaCl_2$ solution to form some suspension. The suspensions were allowed to stand for 30 min with occasional stirring using a glass rod. The pH of each sample was then measured using pH meter.

2.4.2 Determination of soil moisture

Moisture was determined by oven-drying method [15]. A clean dried crucible was weighed (W_1). One and a half gram (1.5 g) of well-mixed soil sample was accurately weighed in clean, dried crucible (W_3). The crucible was allowed in an oven at 105 ^{o}C for 6 hrs until a constant weight of the crucible was obtained. Then the crucible was placed in the desiccator for 30 min to cool. After cooling, it was weighed again (W_2) [15]. The percent moisture was calculated using the following formula:

$$MC = \frac{W2 - W3}{W1}$$

Where: W_1 = Initial weight of crucible, W_2 = intial weight of crucible + soil sample, W_3 = final weight of crucible + soil sample

$$\% \text{ Moisture} = \frac{Loss\ in\ weight}{Weight\ of\ Sample}\ x\ 100 \text{ [15]}$$

Note: Moisture free soil samples were used for future analysis.

2.4.3 Determination of Cation Exchange Capacity (CEC)

The CEC of each soil sample was determined from the calculated readings of the different concentrations of Na^+, Ca^{2+}, Mg^{2+} and K^+ in each sample using AAS [15].

2.4.4 Metal determination

Heavy metals (Pb, Cd, Cu, Cr, Hg, Zn) were analysed by atomic absorption spectroscopy. The concentration of heavy metal in the soil was determined using the formula

$$\text{Metal concentration (mg/kg)} = \frac{Reading\ (mg/L) \times Final\ volume\ (ml)}{Initial\ sample\ weight\ (g)}$$

3. RESULT

3.1 Comparison between the Soil Properties and Metal Concentration Observed in Soil Samples from Dry and Rainy Season

The Fig. 1 showed lower level of pH (5.65 pH.H_2O), cation exchange capacity (CEC) (11.8 cmol/kg), soil organic matter (388.2 g/kg) and soil moisture content (8.12 %) in soil samples collected during the dry season compared to soil samples collected during the wet season [6.75 pH.H_2O, 13.8 cmol/kg, 458.2 g/kg, and 16.1 % respectively]. The concentrations of the metals investigated were observed to be higher in soil samples collected during the wet season [Pb (157.2 mg/kg), Cd (6.5 mg/kg), Cu (119.1 mg/kg), Hg (8.91 mg/kg), Zn (374.2 mg/kg)] than in soil samples collected during the dry season [Pb (129.9 mg/kg), Cd (5.7 mg/kg), Cu (98.8 mg/kg), Hg (8.23 mg/kg), Zn (360.2 mg/kg)]; except for Cr which was observed to be higher in soil samples collected during the dry season (72.0 mg/kg) than in soil samples collected during the wet season (61.2 mg/kg).

3.2 Comparison of Heavy Metal Concentration Across Different Soil Depths Observed During the Dry and Rainy Season

The concentration of heavy metals (Pb, Cd, Cu, Cr, Hg, and Zn) were investigated across different soil depths within the dumpsite; to assesses the rate of heavy metal infiltration into the ground water table. The results are represented in the graphs below.

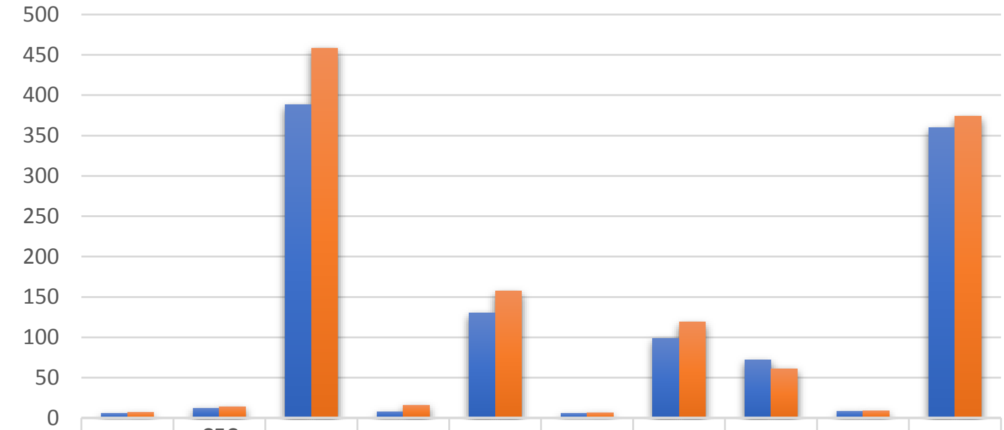
The concentration of metals in soil were higher at depth 0 to 15 cm during the dry season and lesser at depth 30 to 45 cm. during the rainy season, the concentration of heavy metals was higher at depth 40 to 45 cm but lesser at depth 0 to 15 cm. this can be attributed to the increase in soil moisture content during the rainy season (Fig. 2). The highest concentration of all the heavy metals investigated during the dry season were observed at depth 15 to 30 cm. The soil samples from depth 0-15 cm showed similar concentration of Pb and Zn as soil samples from depth 15-30 during the dry season. This can be due to the high soil organic matter and decrease in soil pH [16,17,18]. The concentrations of Cd, Cu, Cr, and Hg in soil samples from depth 0-15 cm were lesser than what was observed in soil samples from the soil depth of 15-30 cm during the dry season. Also, soil samples from depth 30 to 45 cm showed the least concentration of all the metals investigated during the dry season (Fig. 2).

During the rainy season, the sampling depth 30-45 showed the highest concentration of the metals investigated compared to the other depths. The sampling depth 15-30 showed concentration of metals higher than depth 0-15, but lesser than depth 30-45. The heavy metals Pb, Cd, Hg, and Zn were observed to be above the WHO maximum allowable concentration in all the sampling depth. However, the heavy metals Cu and Cr were observed to be below the WHO maximum allowable concentration for soil samples collected during the dry and rainy season. The metal Zn was observed to show the highest concentration amongst other metals investigated, in all the sampling depth. Whereas, Cd had the least concentration amongst other metals investigated, in all sampling depth.

4. DISCUSSION

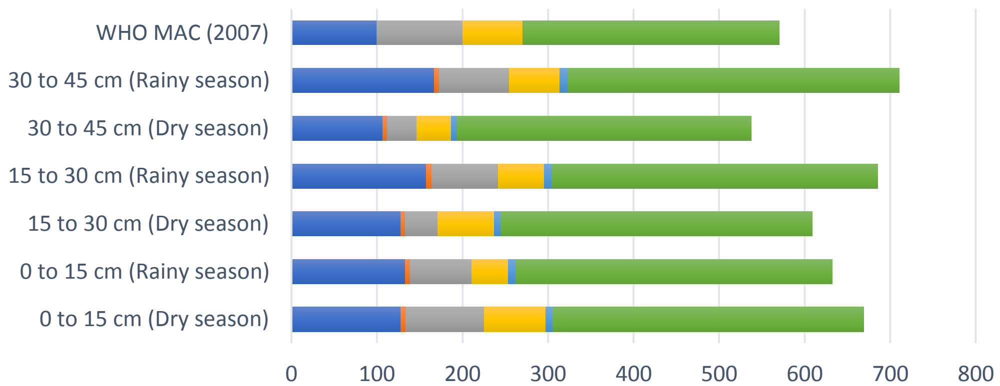
The present study was conducted to assess the effect of seasonal variation on the concentration of heavy metals in soil samples collected from a waste dumpsite. The physicochemical properties of the soil during dry and wet season were investigated to determine how seasonal variation affect the polluted soil samples. From the result of the physicochemical analysis, it was observed that during the dry season, the pH of the soil samples from the dumpsite were slightly acidic (5.65 – 6.76). There was also reduction in the soil cation exchange capacity (11.8 cmol/kg) compared to the control sample (28.9 cmol/kg). The soil organic matter (SOM) was observed to be very high (ranging from 388.2 g/kg to 234.3

g/kg) compared to the control. The high level of SOM may be attributed to the reduction of the pH of the soil. This is in line with Kekane et al. [19], that the presence of higher content of organic matter in the soil can be a possible reason for lowering of the pH of that soil. The textural class of the soil was observed to be sandy-loam which is not usually suitable for agricultural crop production.



	pH	CEC (cmol/kg)	SOM (g/kg)	Moisture (%)	Pb (mg/kg)	Cd (mg/kg)	Cu (mg/kg)	Cr (mg/kg)	Hg (mg/kg)	Zn (mg/kg)
Dry	5.65	11.8	388.2	8.12	129.9	5.7	98.8	72	8.23	360.2
Wet	6.75	13.8	458.2	16.1	157.2	6.5	119.1	61.2	8.91	374.2

Fig. 1. Soil properties and average concentration of heavy metals observed in soil samples during dry and wet season



	0 to 15 cm (Dry season)	0 to 15 cm (Rainy season)	15 to 30 cm (Dry season)	15 to 30 cm (Rainy season)	30 to 45 cm (Dry season)	30 to 45 cm (Rainy season)	WHO MAC (2007)
Pb	128	133	128	158	107	167	100
Cd	5.43	5.75	5.01	5.73	4.82	5.91	0.35
Cu	92	72	38	78	35	82	100
Cr	72	43	66	54	40	59	70
Hg	8.02	8.4	7.73	8.58	6.89	8.79	0.03
Zn	364	370	364	381	344	388	300

Fig. 2. Heavy mental concentration across different soil depths for rainy and dry season

Table 1. WHO permissible limit for metal concentration in the soil (2007)

	Pb	Cd	Cu	Cr	Hg	Zn
WHO limits (mg/kg)	100	0.35	100	70	0.03	300

During the wet season it was observed that the soil pH was slightly increased (ranging from 6.24 to 7.16) compared to the dry season. According to Kekane et al. [19], the normal soil pH ranges from 6 to 8.5. Also, the CEC, SOM, and moisture content were observed to be higher than the values observed during the dry season. The soil textural class was observed to be sandy-loam as in the case of during the dry season. All agricultural productions and development depend upon physicochemical parameters of the soil used for it [20]. Maintenance of soil quality is critical for ensuring the sustainability of the environment and the biosphere [21].

The concentration of metals (Pb, Cd, Cu, Cr, Hg and Zn) across varying soil depth (0-15, 15-30, 30-45 cm) within the dumpsite was also investigated in the study. This is to assess the rate of infiltration of these metals into the soil and how seasonal variation influence the infiltration. The result for the dry season showed higher level of the test metals in soil samples from depth 0-15 cm; while soil samples from depth 30-45 cm showed the lowest concentrations of these metals (Fig. 2). Although, the concentration of some of the metals like Pb and Zn were similar in soil samples from depth 0-15 cm and 15-30 cm. This can be due to the high soil organic matter and decrease in soil pH. According to Nabulo et al. [16], Zn appears to be less available in soils with high pH. Low pH reduces Zn adsorption more for the sandy soils than for soil high in colloidal size materials [17]. Based on Lorenz et al. [18], soil high in organic matter have higher adsorption capacities and higher bonding energies for Zn. The result from Fig. 2 implies that the concentrations of these metals are highest at the top soil strata of the soil profile, and that the infiltration rate during the dry season is slow. This lends support to the findings of Demie and Degefa [14], who observed higher level of Mn, Cd, Co, Cr, Ni, and Pb at the top soil strata (0-15 cm) compared to the other soil depths. For the wet season, the concentration of the test metals was highest in soil samples from soil depth 30-45 cm, and lowest in soil samples from soil depth 0-15 cm (Fig. 2). This implies that the rate of metal infiltration as opposed to the dry season, is faster. This can be attributed to the increase in moisture content of the soil. According to Kekane et al. [19], the absorption of the nutrient by soil is largely depends on moisture content of the soil which also shows its effect on the texture of soil. The concentrations of these metals were observed to decrease during the dry season (from November to January); but during the wet season the concentration of these metals increased progressively (from April to June). This can be attributed to the rainfall capacity and water flow during these months. That is to say, that higher concentrations of these metals were observed during the wet season compared to the samples collected during the dry season. Furthermore, the concentration of the heavy metals was observed in the following order Zn > Pb > Cu > Cr > Hg > Cd.

Based on reviewed literatures, much attention has been given to waste management problems in Nigeria. These literatures have pointed out that solid waste problems have been intractable and appear to defy all the policies suggested for improvement. The two major approaches to waste management in Ugwuaji are private and public [22]. The private system is a contractual arrangement between households and waste disposal companies. The public system which is more conventional, involves the government waste disposal agencies tasked with the responsibility of waste management [23].

According to Uwadiegwu and Chukwu [22], the strategies employed by the government in waste pollution eradication in Ugwuaji include; citizen mobilization and environmental education on the effect and damages of improper waste disposal on human and environmental health. The Enugu State Waste Management Authority (ESWAMA) provided dumpsters for effective and efficient waste disposal [22]. Waste management legislation have been implemented to guide the waste management behaviour of people. It is advised that science and technology be involved in waste management to facilitate waste recycling; since currently, waste management programs involve simply moving waste from one place to another.

5. CONCLUSION

The research study has indicated that soil from the study area (Ugwuaji waste dumpsite) are polluted by the heavy metals under investigation. The major pollutants are Zinc, Lead, Copper, Chromium, Mercury, and Cadmium following their order of concentration. These heavy metals have also been observed to influence the soil physicochemical properties, reducing the soil quality. The concentration and seepage of these metals into the soil is shown to be affected by seasonal variation; as higher concentration of these metals was observed during the wet season. The soil around the study area is at risk of contamination by these heavy metals given the high total concentration of the metals gradually being released into the soil and subsequently, into the ground water table.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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