**WASTES FINGERPRINTS IN SOILS: A STUDY OF INFLUENCE OF WASTES ON THE CONCENTRATIONS OF SELECTED HEAVY METALS IN SOILS UNDERLYING OPEN DUMPSITES**

**Abstract**

*Sustainable waste management and heavy metal pollution are among the most pressing environmental challenges worldwide. When waste becomes a source of heavy metals in soils, the issue grows more complex and calls for integrated management solutions. This study investigates the proportion of heavy metals released from automechanic (A), paint processing (P), and abattoir (AB) wastes into the underlying soils. Samples from the waste piles were collected from the dumpsites while soil samples were collected from the underlying soils and analyzed for levels of selected heavy metals: lead (Pb), cadmium (Cd), chromium (Cr), nickel (Ni) and vanadium (V) using standard laboratory procedures. Soil samples were digested using Aqua regia and analyzed for Pb, Cd, Cr, Ni, and V via atomic absorption spectrophotometry. The heavy metal release percentage (HMR) was calculated using the principle of mass balance. The result revealed that Pb (8,621.1 mg/kg), Cd (1,413.1 mg/kg), Ni (563.0 mg/kg), and V (507.0 mg/kg) were highest in automechanic wastes, whereas Cr (1,413.1 mg/kg) peaked in paint processing wastes. Similarly, the dumpsite of A had 4310.0, 179.0 and 303.0 as the highest concentrations (mg/kg) of Pb, Cd and Ni, respectively while P impacted soils had 600.0 and 240.0 for Cr and V, respectively. These represent HMR of 49.8, 41.7, 42.7, 51.8 and 48.6 for Pb, Cd, Cr, Ni and V, respectively. Transferring such levels of the dangerous substances from their laden-wastes to the soils is not healthy to the entire ecosystem. The levels of Pb, Cd, Cr, Ni and V were by 1437, 3480, 200, 160 and 1percentages higher than their respective limits set for residential zones by FAO. These has caused pedosphere contamination by offsetting its equilibrium. Hence there is need for timely intervention to curtail risks caused by this situation through sustainable wastes management policies and ecofriendly remedial strategies like phytoremediation.*

Keywords*: Open dumpsite soil; wastes fingerprints; pedosphere contamination; triple planetary crisis, heavy metal release percentage*

**1.0 INTRODUCTION**

Open dumpsites have gradually become an outstanding contributing factor causing soil degradation thereby threatening the much anticipated global food security and environmental sustainability (Alao, 2022 & 2023). In the study by Udo *et al*. (2025), open dumpsites have been identified as major driving force for triple planetary crisis. This has caused serious threats to ecosystem stability, human well-being and the natural ability for our planet to support life.

Open dumpsite is one of the traditional ways of wastes disposal; other forms of such outmoded methods of managing wastes are sanitary landfilling and incineration (Sharma and Jain, 2020). The major environmental hazards associated with these traditional wastes disposal methods are penetration of leachates into surface and underground water as well as release of greenhouse gases into the atmosphere (Zhao *et al.,* 2016). Apart from the fact that some of such emitted gases from can increase greenhouse effect, others pollute the surrounding air with characteristics offensive odours (Chen *et al*., 2016; FAO, 2018), constituting nuisance in the environment. Furthermore, Williams *et al*. (2019) reported that about 400,000 to 1 million people die annually due to diseases associated with poor wastes management. This is because open dumpsites are naturally breeding grounds for some disease carrying-vectors like flies, rat and mosquitoes. Direct contacts with wastes can cause deadly infections especially among scavengers and wastes pickers. Equally, heavy metals from the wastes can leach into water or soil and can get into humans through food chains ( Agbeshie *et al*., 2025). Long time exposure to heavy metals can damage organs like liver, kidney and brain leading to organ’s failure and deaths (Wuana Okieimen, 2011). The aforementioned are some of the health risks associated with open dumpsites . All these culminated in making open dumpsites major driver of triple planetary crisis driver as reported by Udo *et al*. (2025).

Wastes could be defined as unintended by-products of production and consumption. Sustainable wastes management is now becoming one of the greatest global challenges facing mankind. According to the report by Sharma and Jain (2020), it was projected that in the next twenty five (by 2050), the rate of global wastes generation will overtake that of population growth. Similarly, UNEP (2024) estimates that over 2 billion tonnes of municipal solid waste are generated annually—enough to circle the Earth’s equator 25 times if packed in shipping containers.

Unarguably, managing such enormous quantity of wastes sustainably would be one of the greatest problems facing global populace. Perhaps this is why ‘engineered landfills’ had been recommended as a better option since it requires less space and the wastes are disposed in a more secure manner that minimizes their negative impacts in the environment (Ghafourian *et al*., 2016; Ferronato *et al.,* 2018).

The negative impacts of indiscriminate dumping of wastes cannot be over emphasized. According to Omeiza *et al*. (2022 & 2023), incessant wastes dumping can alter soil pH, nutrient equilibrium, and overall fertility. By studying the impacts of dumpsite wastes on the properties of the underlying soils, it was observed by Udo *et al.* (2025) that there was congruence of chemical signatures of wastes and host soils; this indicated the existence of dynamic interactions between wastes and soil via leaching and infiltration. The authors opined that such negative impacts on soil health, water bodies, food security and ecosystem sustainability may not be erased within a reasonable time scale as such called for immediate intervention through ecofrienly and sustainable remedial strategies.

Another major environmental concern associated open dumpsite is heavy metal pollution; this is because most heavy metals are inherent components of wastes (Ebong *et al*., 2020, Wuana and Okieimen, 2011; Kaparwan *et al*., 2020). It was estimated by He *et al*. (2015) that there are above 10 million pollution sites globally of which more than 50 % of that are associated with heavy metals and /or metalloids contaminations. Heavy metals are not easily degraded; they can persist in the soil for a long time (Ghaderi *et al*. 2012; Yang *et al*. 2012. This single factor makes heavy metals pollution one of the greatest environmental problems confronting human race (Asmoay *et al*., 2019).

Living organisms including humans can be exposed to heavy contaminations through air, water, food and most commercially manufactured products (Kaparwan *et al.,* 2020). Some authors have reported that heavy metals contamination have toxic and carcinogenic effects in the body and can damage internal and nervous system (Maas *et al*., 2010; Jyothi, 2020); enter animals including human beings through food chain (Kahkha *et al.,* 2017); affect children’s developmental processes (WHO, 2011; CAFÉ, 2024).

Sometime in the twentieth century, there was a bittersweet experience in Romania; as noted by Nescu *et al*. (2022) there was heightened progress in mining industry which provided over a million jobs to the populace. Though this was seen as a major economic breakthrough, it was not without serious environmental consequences. A few years later, about 138 million tons of pollutants were released into the environment annually. Those pollutants included some non-ferrous compounds and particles which posed severe harmful effects on the ecosystem. As further reported, the cause of these was mostly due to mismanagement and obsolete technologies and working facilities.

Similar to Romania’s mining waste scenario, mismanagement of dumpsite wastes in Akwa Ibom State and indeed in most other parts of the world may cause long-term soil contamination. The occurrence has strongly correlated with the findings of Udo (2025) and Udo *et al*. (2025) where properties of wastes materials (including the heavy metals concentrations) from dumpsites were seen to have significantly correlated with those of the underlying soils. This study investigates the proportion of heavy metals released from automechanic, paint processing, and abattoir wastes into surrounding soils, hypothesizing that waste type significantly influences metal release rates. It is believed that the outcome of the study will give an evident-based warning for environmental and agricultural managers to appropriately manage heavy metals laden wastes in eco-friendly ways for agricultural and environmental sustainability.

**2.0 MATERIALS AND METHODS**

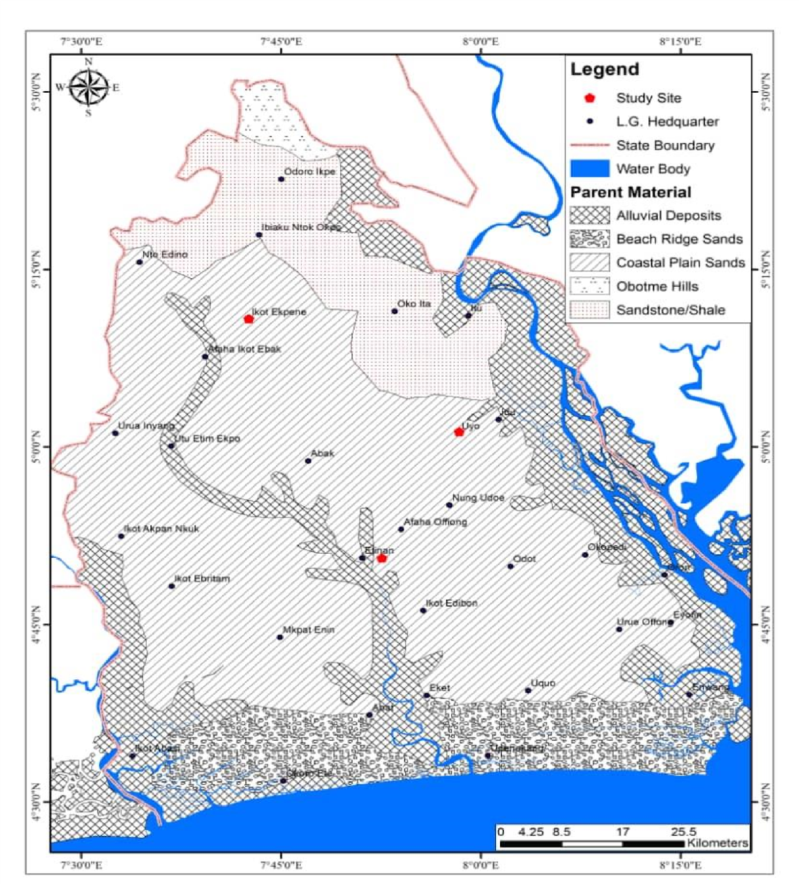
**2.1 Location, Climate and Soils of Akwa Ibom State**

#### Akwa Ibom State is one of the States in Nigeria lying between latitudes 40˚ 32’ and 50 ˚ 33’ N and longitudes 70 ˚ 25’ and 80 ˚ 25’ E (Ibia, 2019) covering an approximate land mass of 8,412 km2. The State experiences a bimodal rainfall pattern, having the major raining season covering the months of April to July, then a minor raining periods occurs between September to November, with a spell of dry period occurring between them. The mean annual rainfall of the State normally ranges between 2,500 and 3,000 mm. The annual mean temperature of the State is between 27 ˚C and 28 ˚C with relative humidity of 75-80 % (Petters *et al*. (1989). Rainfall as high as 3000 mm per annum could be experienced in the coastal areas of the State but decreasing hinterland to about 2000 mm annum in the northern part. Soils of Akwa Ibom State are formed mostly from parent materials grouped into coastal plain sands, beach ridge sands, sandstone/shales and alluvial deposits (Ibia, 2019). About 70% of the soils in Akwa Ibom State are formed from coastal plain sands. These parent materials determine the types of soil found in the State.

**2.2 Soil Sampling and Laboratory Analyses**

Three LGAs (Etinan, Uyo and Ikot Ekpene) designated as Locations 1, 2 and 3, respectively were used for the study. These locations were selected based on statistics and historical facts. There was a paints production plants in Etinan, Peacock Paint Limited, Ikot Ekan, Etinan. The company was folded up some years ago though the State Government is trying to revive it. This is an impression that there should be some levels of paints wastes related contaminations in Etinan. Uyo is the State Capital; its fast growing population has increased pressure on land use for urbanization and industrialization. These activities are associated with soil pollution (Ibia, 2019; Sharma and Jain, 2020). Ikot Ekpene is also one the fastest growing LGAs in the State which is also witnessing accelerated demand for food production and industrial development with its attendant pollution tendencies. For instance, it was estimated that about 40 % of total animals consumed in the State are slaughtered in Uyo (Opara *et* *al*., 2005; Bello *et al*., 2023).).

The coordinates of the dumpsites are presented on Table 1; Fig. 1 presents the map of the State and the locations of the dumpsites. Three dumpsites each in the three LGAs were selected (each for abattoir, paints processing and automechanic wastes) and used for the study. An area believed to have no history of any of these wastes contamination was chosen as a control in the respective location (Dan *et al*., 2018; Udo *et al*., 2025). A total of 12 locations [9 for waste dumpsites (3x3) and 3 controls (3x1)] were used for the study. Three sections within each dumpsite were randomly designated (augering points); wastes were cleared from the portions and soil samples collected with soil auger at from the top soil (0-20) cm. At the control locations, bulk samples were equally collected from three portions from the top soil (0-20 cm). A total of 36 composite samples (3 auger points from 12 locations) were collected from (each location comprised of 3 dumpsites and 1 control). Samples from the three auger points were combined to form a bulk sample which gave a total of 12 bulk samples.



**Figure 1: Map of Akwa Ibom State showing the different parent materials and the Local Government Areas used for the study  
Source: Udo *et al*. (2025)**

**2.3 Samples processing and laboratory analyses**

Soil samples were air-dried, and sieved (<2 mm). Samples of wastes from each of the nine dumpsites were taken in sample bottles for laboratory analyses. The soil and *waste samples* were subjected to laboratory analyses.

**2.4 Heavy metals analyses in the soil**

**Extraction with Aqua Regia [Conc. Hydrochloric and Nitric Acids (HCl/HNO3) in the Ratio of 3:1:** This procedure is outlined by Abegunde *et al*. (2018). 1 g of soil sample was weighed into digestion flask. Then 20 ml of aqua regia was added into the flask; the digestion was done on a heating mantle in the fume cupboard. The temperature was gradually increased while it was occasionally agitated till the volume of the content decreased to about 5 ml. The flask was covered with watch class to prevent excessive evaporation. The remaining solution was then filtered, washed with deionized and double distilled water before being turned into a 50 ml volumetric flask, then some distilled water was added up to the mark then analyzed with atomic absorption spectrophotometer (AA500 model manufactured by PG Instruments)

**Table 1: Locations of dumpsites and their coordinates used for the study**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **No.** | **LGA** | **Dumpsite** | **Latitude** | **Longitude** |
| 1 | Etinan | A1 | 4˚49’52”N | 7˚51’9"E |
| P1 | 4˚48’33”N | 7˚53’1”E |
| AB1 | 4˚52’14”N | 7˚50’40”E |
| C1 | 4˚56’8” N | 7˚50’29”E |
| 2 | Uyo | A2 | 5˚1’24”N | 7˚53’52”E |
| P2 | 5˚1’39” N | 7˚56’33”E |
| AB2 | 5˚3’23”N | 7˚53’4”E |
| C2 | 4˚58’1”N | 7˚58’46”E |
| 3 | Ikot Ekpene | A3 | 5˚9’43”N | 7˚43’54”E |
| P3 | 5˚9’47”N | 7˚43’57”E |
| AB3 | 5˚6’49”N | 7˚47’16”E |
| C3 | 5˚9’25”E | 7˚44’41”E |

**Keys: A1, A2, A3 = Auto mechanic wastes dumpsites; P1, P2, P3 = Paints processing wastes dumpsites; AB1, AB2, AB3 =Abattoir wastes dumpsites; C1, C2, C3 = Controls; LGA = Local Government Area**

**Source: Udo *et al*. (2025)**

**2.5 Heavy metals analyses in the waste materials**

The method of Novozamsky *et al*. (1983) was used in the wastes analyses. 0.2g of the waste materials was weighed into a 50 cl conical flask; then 10 ml of H2SO4 and Salicylic solution was added, the mixture was then allowed to stand for overnight (18 hours). The mixture was heated on a digestion block at 100˚C for 2 hours in a fume cupboard. After being allowed to cool, 5 ml of perchloric acid was added to the mixture and was heated continuously until the sample was fully digested (with clear colour). The sample was allowed to cool and then the volumetric flask was filled to the mark with deionized water. The extract was analyzed for Pb, Cd, Cr, Ni and V using atomic absorption spectrophotometer (AA500 model manufactured by PG Instruments) under optimal condition with air acetylene flame.

**2.6 Heavy metals released percentage (HMR)**

The heavy metals released percentage (from the wastes to soil) was estimated using the mass balance principle (de Vries and Bakker, 1996). It was calculated from the equation bellow:

Where HMR (%) = heavy metal release percentage from the wastes into the soil; S = concentration of heavy metal in the impacted soil; B = background concentration of the heavy metal in the soil (location-specific control value); W = concentration of heavy metal in the waste materials

**2.7 Physicochemical properties of the soil**

This is just for mentioning, the physicochemical properties of the dumpsite soils had already been determined.

**3.0 RESULTS AND DISCUSSION**

**3.1 Physicochemical properties of the soil**

The results for physicochemical properties of the studied soils are presented on Table 2. According to the results, the soils were generally sandy without any significant difference in the proportions of their separates (sand, silt and clay). This could be attributed to their parent materials as all the dumpsites were situated within the coastal plain sands part of the State (Akpan-Idiok, 2012; Obi *et al*., 2020; Udoh and Ibia, 2022). The soils showed varying pH values ranging from strongly acidic (4.63) for the control soil; slightly acidic (6.49) for abattoir soil; neutral to alkaline (7.37) for automechanic dumpsite soil and slightly alkaline (7.99) for paints wastes impacted soil. The values are significantly different from each other indicating that the various waste materials had significantly impacted on the soil pH and at varying degrees (Udo, 2025). Equally, the wastes had also significantly impacted on the soil organic carbon levels of the soils. The abattoir soil had the highest (37.10 g/kg) followed by automechanic with 21.31 g/kg, the control soil had 13.57 k/kg while the least was paint wastes impacted soil with 4.98g/kg.The order is expected, abattoir wastes are mainly from organic sources as such was able to raise the organic carbon in the soils higher than those of other soils. The higher content of organic carbon in automechanic soil could be as a result of used hydrocarbon compounds dumped on the soil (Johnbosco *et al*., 2020). The control soil was under fallow so had accumulated a certain level of organic matter. The paint wastes were mostly chemicals with no or little material of organic origin, so there should be no doubt if its impacted soil had the least level of organic carbon.

**Table 2: Physicochemical properties of different dumpsite soils**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Soil property** |  | **Dumpsite** | |  |
| **Control** | **Automechanic** | **Paints** | **Abattoir** |
| **Sand (k/kg)** | 739.00a | 795.66a | 795.88a | 826.33a |
| **Silt (k/kg)** | 63.33a | 65.56a | 66.44a | 73.00a |
| **Clay (k/kg)** | 187.67a | 138.78ab | 139.67ab | 107.89b |
| **pH (H2O)** | 4.63d | 7.36b | 7.99a | 6.49c |
| **EC (µS/cm)** | 56.73b | 146.01b | 166.40b | 536.42a |
| **OC (g/kg)** | 13.57c | 21.31b | 4.98d | 37.10a |
| **OM (g/kg)** | 23.37c | 36.74b | 8.58d | 63.96a |
| **TN (k/kg)** | 1.77b | 1.31b | 0.67b | 13.22a |
| **Available P. (mg/kg)** | 20.53b | 24.58b | 39.79b | 48.30a |
| **Ca (Cmol/kg)** | 2.49d | 20.47b | 7.20c | 32.53a |
| **mg (cmol/kg)** | 1.20c | 8.47b | 4.00c | 12.71a |
| **K (Cmol/kg)** | 0.10c | 2.77b | 0.58c | 4.80a |
| **Na (Cmol/kg)** | 0.07c | 2.35b | 0.48c | 3.06a |
| **EA (Cmol/kg)** | 1.68a | 0.41c | 0.42c | 0.68b |
| **ECEC (Cmol/kg)** | 5.43c | 33.30b | 12.54c | 53.78a |
| **BS (%)** | 67.91c | 98.63a | 96.21b | 98.69a |

*Note: a, b, c and d indicate means which are statistically different and are compared horizontally across the table*

*Source: Udo et al. (2025)*

**3.2 Concentrations of heavy metals in the various waste materials**

The results of the analyses for the concentrations of the heavy metals in various wastes materials from the dumpsites are presented on Table 3. The concentrations (mg/kg) of Pb in the wastes could be arranged in decreasing order as follows: 8621.1, 4359.0 and 166.0 for automechanic, paints processing and abattoir wastes, respectively with LSD (0.05) value of 1329.8. These values are significantly different from each other in that order, meaning automechanic wastes had the highest level of Pb while abattoir wastes had the least. Cadmium had its values in the order of increasing statistical order as 393.2, 270.0 and 60.2 for automechanic, paint processing and abattoir wastes, respectively with LSD value of 50.8 which also indicated that automechanic wastes had the highest level of Cd while abattoir had the least. The concentrations (mg/kg) of Cr were 1413.1, 1051.0 and 243.0 (decreasing order) for paints processing, automechanic and abattoir wastes, respectively with LSD (0.05) of 309.0.

**Table 3: Mean concentrations of the heavy metals in the wastes from different dumpsites**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Dumpsite** | **Pb** | **Cd** | **Cr** | **Ni** | **V** |
|  | **mg/kg** | | | | |
| **Automechanic** | 8621.1 | 393.2 | 1051.0 | 563.0 | 507.0 |
| **Paints** | 4359.0 | 270.0 | 1413.1 | 345.0 | 487.0 |
| **Abattoir** | 166.0 | 60.2 | 243.0 | 262.0 | 226.0 |
| **LSD (0.05)** | **1329.8** | **50.8** | **309.0** | **164.8** | **121.3** |

**Key: LSD = Least significance difference**

This has revealed that the highest concentration of Cr was found in the paints processing wastes. The concentrations of Ni obtained were 563.0, 345.0 and 262.0 for automechanic, paints processing and abattoir wastes, respectively with LSD (0.05) value of 164.8. Though there was no significant difference between the values for paints processing wastes and abattoir wastes, both of them were significantly smaller than that of A. This also indicated that automechanic wastes had the highest level of Ni. The values for the concentrations (mg/kg) of V obtained from automechanic, paints processing and abattoir wastes were 507.0, 487.0 and 226.0, respectively with LSD (0.05) value of 121.0. This has revealed that the values for automechanic wastes and paint processing wastes are statistically the same but are all greater than that of abattoir wastes.

Generally, the concentrations of Pb, Cd, Ni and V in the wastes materials followed this order: automechanic > paints processing > abattoir wastes while that of Cr is paints processing > automechanic > abattoir wastes. The possibly reason for having the highest levels of Pb and Cd in the automechanic wastes could be from the different sources of the wastes. For instance, Pb can come from lead-acid batteries (WHO, 2011); Pb added to gasoline during production (OECD, 1999; Angrand *et al*., 2022). It was observed by Akpoveta and Osakwe (2014) that unused petroleum products contained high level of lead. Other reports by Kaparwan *et al*. (2020) and Nwakife *et al*. (2022) made a similar obsrvation that used petroleum products can increase the concentration of Pb as was evident in the impacted soils.

High level of cadmium in the wastes could be from the used lubricating oils, vehicle metallic parts and metal alloys used for hardening the engine parts. Angerville *et al*. (2005) and Nascimento *et al*. (2011**)** had reported the presence of lead and cadmium in paints effluents. Nickel is a natural component of hydrocarbon compounds (Kabata-Pendias and Pendias, 2001) so there should not be any doubt if a high level of the metal detected in the waste materials. In their reports, Bencheng *et al*. (2014) noted that used petroleum products could increase Ni level in the soil.

Kabata-Pendias and Pendias (2001) and Olaolorun *et al*. (2021) reported that V is also contained in hydrocarbon compounds naturally. In related developments, high concentration of V was detected in automechanic wastes polluted soils which the cause was attributed to the used petroleum products (Zharskiy *et al*., 2015; Orjiakor *et al*., 2020). It could most probably be concluded that the high contents of Ni and V came as natural components of the waste materials or the metals were added to some products during production.

The highest of chromium in paints wastes could be traceable to some chromic compounds used as raw materials in paints production. For instance, chromic acids are used as paint pigments. Some authors had given reports of detecting chromium in paint effluents (Okafor *et al*., 2015; Ahenda *et al*., 2020). Udo (2025) equally recorded a higher chromium concentration in paints wastes impacted soils than as was obtained from automechanic and abattoir dumpsite soils; this was attributed to the high contents of the metal in the wastes materials.

The implication of having these elevated levels of the heavy metals in the wastes is that these contaminants could be released into the environment (Ji *et al*., 2012; Udo, 2025). This was also the view of Winegardner (2019) that soil is vulnerable to contamination because it naturally allows pollutants to infiltrate through it thereby causing contaminations. Unfortunately most of these wastes are dumped indiscriminately especially in the less developed world (Sharma and Jain (2020); polluting the environment to create one of the most challenging problem facing mankind (Tolera and Alemu, 2020). It is also more disturbing that almost all the studied dumpsites were located within the residential areas; this makes the possibility of human exposure to these contaminations so high.

**3.3 Concentrations of the heavy metals in the top soil (0-20 cm) of different dumpsite soil**

The results on the concentrations of the heavy metals in the top soil of the dumpsite are presented on Table 4. This shows that cadmium concentrations (mg/kg) were 26.5, 179.0, 122.9 and 0.8 for abattoir (ABS), automechanic (AS) and paints processing (PS) wastes dumpsites soils and the control soil (CS), respectively with LSD value of 31.5. These indicate that the values were significantly different from each other and in the increasing order as: CS, ABS, and PS and AS. In all the dumpsite soils, their concentrations of Cd are significantly higher than in the CS. While the level of Cd in the CS could be described as the natural background of the metal in the soil which could be due to natural process; those of the dumpsites are deemed to be caused by the released of the metals from their respective materials (Angerville *et al*., 2005; Igwe and Nwachukwu, 2016; Ebong *et al*., 2020; Nwakife *et al*., 2022). This fact can be exemplified by Figure 2 which has illustrated similar trends exhibited by the concentrations of the metal in the wastes and that of the soils (Borgese *et al*., 2013; Udo *et al*., 2025). Also, it should be noted that the concentration of Cd in all the dumpsites are higher than 5 mg/kg maximum limit for dangerous substances in residential zones established by FAO (2004). In their study, Amos-Tautua *et al*. (2014) observed higher concentrations of lead and chromium in the soils of municipal dumpsites than in the control soil. But they reported a trace level of cadmium which was far below from the metal’s critical limit. This does not totally agree with the findings of this work as all the tested metals have high levels in all the dumpsite soils (as compared to their FAO acceptable limits) and also significantly higher than the control values as was observed by Udo (2025). With these submissions, a conclusion could be drawn that the nature of the wastes, sources, and the concentrations of analytes in the wastes among other things could determine the concentration of the analytes in the tested soil.

**Table 4: Heavy metals in the top soil (0-20 cm) of different dumpsites**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Heavy metal** | **Abattoir Automechanic Paints**  **mg/kg** | | | **Control** | **LSD** |
| Cadmium | 26.5 | 179.0 | 122.9 | 0.8 | **28.7** |
| Chromium | 109.3 | 467.5 | 600.7 | 1.5 | **65.1** |
| Nickel | 129.0 | 303.0 | 195.0 | 6.0 | **93.5** |
| Lead | 73.0 | 4310.0 | 1745.0 | 10.0 | **954.7** |
| Vanadium | 99.5 | 227.6 | 240.0 | 2.2 | **58.5** |

**Key: LSD = Least significance difference**

**Figure 2: Concentrations of Cadmium in waste material and top soil (0-20 cm) of different dumpsite soils.**

Table 2 has also revealed that level of contamination of the dumpsite soils by chromium. In the increasing order, the levels of chromium recorded in the studied soils are 1.5, 109.3, 467.5 and 600.7 (mg/kg) for CS, ABS, AS and PS; indicating chromium as the greatest contaminants in PS. A similar observation was made by Udo (2025). The results have clearly shown that all the wastes had contaminated the soils by raising the background level (1.5 mg/kg) of chromium (being that of the control soil) to the present levels (Igwe and Nwachukwu, 2016; Ebong *et al*., 2020; Nwakife *et al*., 2022). The levels of contaminations in the PS and AS soils are beyond the limits (300 mg/kg) for residential zone set by FAO (2004). Figure 3 has shown similar trend established for the concentrations of chromium both in the wastes and in the top soil. This positive correlation can attest to the fact that elevated levels of Cr in the soils are the consequences of wastes dumped on the soil (Angerville *et al*., 2005; Borgese *et al*., 2013).

**Figure 3: Concentrations of chromium in waste material and the top soil (0-20 cm) of different dumpsite soils.**

The concentrations of nickel present in the top soils of the dumpsite are equally indicated in Table 3. The values as arranged in increasing order is 6.0, 129.0, 195.0 and 303.0 for CS, ABS, PS and AS, respectively with LSD value of 93.5. It has been shown from the result that the levels of nickel in all the impacted soils are significantly higher than that of CS (6.0 mg/kg) which can be acknowledged as the natural background level. This has proven the fact that various wastes have significantly contributed to the levels of the metal’s contaminations in the soils (Igwe and Nwachukwu , 2016; Tang and Goh, 2022). Apart from in ABS, all others have nickel levels higher than 150 mg/kg being a safe limit for dangerous substances in residential zone (FAO, 2004). Figure 4 has served as an additional evidence corroborating this fact; this figure has highlighted correlations between the levels of nickel in the both wastes and the impacted soils as earlier observed by Udo (2025) and Udo *et al*. (2025).

**Figure 4: Concentrations of nickel in waste material and the top soil (0-20 cm) of different dumpsite soils.**

The concentrations of lead in the top soil of the dumpsite are also on Table 4; this has revealed concentrations (mg/kg) in an increase order as 10.0, 73.0, 1745.0 and 4310.0 for CS, ABS, PS and AS, respectively with LSD value of 954.7. This has indicated the there was no significant difference between levels of the metal in CS and ABS but those of PS and AS were significantly higher than the levels in CS and ABS. Also, it is good to note that the value of AS was higher than those of all other soils. This has shown that all the wastes had contributed to the higher levels of lead in the impacted soils (Okafor *et al*., 2015; Igwe and Nwachukwu, 2016; Ebong *et al*. 2020; Johnbosco *et* *al*., 2020; Tang and Goh, 2022). Figure 5 has furthered substantiated this fact as it has indicated a similar trend and by implication, a correlation between the concentrations of lead in the wastes and in the soils. Similar observations had already been made (Borgese *et al*., 2013).

**Figure 5: Concentrations of lead in waste material and the top soil (0-20 cm) of different dumpsite soils**

Table 4 equally has highlighted the results of the concentrations of vanadium in the top soils of the dumpsites. From the results and in an increasing order, (2.2, 99.5, 227.6, 240.0) mg/kg were noted for CS, ABS, AS and PS, respectively with 58.5 as LSD value. Vanadium is natural component of hydrocarbons (Pawlak, 1980; Kabata-Pendias and Pendias, 2001; Olaolorun *et al*., 2021). This can be affirmed by these results; values of the impacted soils are all significantly different from that of the CS indicating that the wastes had enriched the soil with the metal (Zharskiy *et al*., 2015; Orjiakor *et al.,* 2022). It is equally revealed that PS was the highest vanadium contaminated soil followed by AS. Correlations between the concentrations of the metal in the wastes and in the soils (Figure 6) can attest to the fact that the wastes had influenced the metal contents in the soils.

**Figure 6: Concentrations of vanadium in waste material and the top soil (0-20 cm) of different dumpsite soils**

**3.4 Heavy metals release percentage (HMR)**

The results of the heavy metals release percentage from the waste materials to the soil are presented on Table 5. The HMR was estimated using the principle of mass balance. Some authors (de Vries and Bakker, 1996; Michaud *et al*., 2020; Carne *et al*., 2021) had used this method to asses some polluting agents in the soils.

The HMR of cadmium in the increasing order is 43.1, 43.1 and 44.9 for AS, ABS and PS soils, respectively with LSD value of 10.5.Interestingly, there was no significantly different in the values. This might be due to the fact that all the three dumpsite soils have equivalent abilities in regulating the amount of pollutants they can absorb or allowed to infiltrate through them. For instance all the soils are relatively sandy having originated from coastal plain sands (Udo *et al*., 2009a&b; Akpan-Idiok, 2012; Obi *et al*., 2020; Udoh and Ibia, 2022); there is no significantly different in the amount of clay contents in the soils (Table 5). It was observed that soil texture is an important property that regulates the amount of solutes in the soil (de Vries and Bakker, 1996).

**TABLE 5: Percentages of release of heavy metals into the top soil (0-20 cm) of different dumpsites**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Heavy metal** | **Abattoir Automechanic Paints**  **%** | | | **LSD** |
| Cadmium | 43.1 | 41.7 | 44.9 | **10.5** |
| Chromium | 44.3 | 44.8 | 42.7 | **5.8** |
| Nickel | 46.2 | 51.8 | 56.0 | **14.7** |
| Lead | 38.2 | 49.8 | 38.5 | **12.6** |
| Vanadium | 43.5 | 45.3 | 48.6 | **8.3** |

**Key: LSD = Least significance difference**

The HMR for chromium as indicated on Table 5 has these values: 42.7, 44.3 and 44.8 for PS, ABS and AS, respectively when arranged in increasing order with LSD value of 5.8. As it was in the case of cadmium, there was no significant different among the values. The reason could also be attributed to the sandy nature of the soils as they originate from coastal plain sands as their parent materials. The percentage of nickel released from the wastes to the soils: ABS, AS, and PS could be arranged as 46.2, 51.8 and 56.0, respectively with LSD value of 14.7. Equally, there was no significant difference existing among these values. This has suggested that there is a degree of similarity existing amongst the soils; these give them equivalent abilities in regulating themselves by controlling the amount of pollutants that can infiltrate or absorbed within their systems.

Table 5 has also presented the HMR of lead as 38.2, 38.5 and 49.8 for ABS, PS and AS, respectively in an increasing order having the LSD value of 12.6. Just as in the cases of other metals, there was no significant difference existing amongst the values; this suggests that the soils had similar capacities to regulate the amount of pollutants or solutes passing through or being absorbed by them. In the case of vanadium, its HMR for ABS, AS and PS are 43.5, 45.3 and 48.6, respectively when arranged in an increasing order with LSD value of 8.3; this does not reflect any significant difference amongst the values.

Overall, the values for HMR for the five metals ranged from 38.2 (for lead) and 56.0 (for nickel). Though there was no significant difference in all the values of HMR across all the impacted soils, PS had highest values for Cadmium, nickel and vanadium while lead had its highest mean value in AS.

**3.4 Mean concentrations of heavy metals in top soils of the dumpsite at different locations**

The results of the concentrations of heavy metals present in top soils of the dumpsites at different locations are presented on Table 6. According to the results, the concentrations of cadmium were 89.8, 114.3 and 124.0 for Etinan, Ikot Ekpene and Uyo, respectively when arranged in an increasing order and with LSD value of 31.5. This reveals that the concentration of cadmium in the dumpsites of Uyo was higher than that of Etinan but it was not significantly different from that of Etinan. In the Uyo dumpsites, especially in one of the automechanic wastes dumpsite (Mechanic Village), the soil was visibly seen to have been contaminated with the used hydrocarbon compounds more than in anywhere else. Probably this could be the reason for the high cadmium contamination (Daniel *et al*, 2025). Cadmium as well as its compounds is classified in Group ‘1’ among carcinogenic substances (IARC, 2012). The concentrations of cadmium in the entire impacted soils are by far higher than 5 mg/kg permissible limit by FAO, (2004) for residential zone. The implication of this is that these dumpsite soils have constituted themselves as serious threats to humans having direct or indirectly having links with those soils. As reported by EFSA (2009) cadmium can easily get distributed in the body and accumulated over a long time having gotten biological half-life that ranged between 10 to 30 years.

The chromium concentrations (mg/kg) of the soils as presented on Table 6 are 358.0, 373.0 and 432 in the increasing order for Etinan, Ikot Ekpene and Uyo, respectively with LSD value of 77.8. This means that there was no significant difference among these values. However all the values are higher than the limit (300 mg/kg) for residential zone (FAO, 2004). Sharma *et al*. (2021) opined that the toxic nature of chromium makes it to be classified as a class ‘A’ carcinogen. Shanker *et* *al*. (2005) noted that a long term exposure to chromium can cause kidney and liver damage; mutation and gastrointestinal and respiratory related problems.

The impacted soils in all the three locations (Etinan, Uyo and Ikot Ekpene) have the concentrations of nickel as (174.0, 215.0 and 236.0) mg/kg, respectively when arranged in an increasing order with 123.0 as the LSD value. This signifies that there was no significant difference among the values. However the values were all above 150 mg/kg limit established for residential areas by FAO (2004). This is not healthy for the environment the metal can be inhaled by animals and humans into their bodies. Nickel poisoning as reported by Cavani (2005) can kill or damage cells by oxidative reaction especially in lung, kidney and bone marrow. According to Wuana and Okieimen (2011), in acidic soils, the mobility of nickel increases making it leached into both surface and underground water bodies.

The concentrations (mg/kg) of lead in the soils were 1682.0, 2152.0 and 2293.0 when arranged in an increasing order for Etinan, Uyo and Ikot Ekpene, respectively with LSD value of 1251.1. These values were extremely high when compared to 300 mg/kg regulatory limit for residential areas (FAO, 2004). According to the report of CAFÉ (2024), when a soil has these levels of lead contamination (400 to 1000 mg/kg), it is classified as medium risk and children should be restricted from having access to such places. Perhaps, this was why Wuana and Okiemen (2011) said that exposing children to lead poisoning can impair their developments, reduce their intelligent quotient (IQ), shortened their attention span, cause mental deterioration and hyperactivity; children under six years may face greater risks of such exposure.

The dumpsites in Ikot Ekpene were seen to have been the highest contaminated soil with vanadium having had the highest concentration (230.8 mg/kg). This was followed by Uyo (177.1 mg/kg) then Etinan (159.2 mg/kg) in a decreasing order with LSD value of 63.2. The value from Ikot Ekpene was significantly higher than that of Etinan. Vanadium toxicity has been observed in various organ and systems in the body like central nervous system (Olaolorun *et al*., 2021)

**Table 6: Heavy metals in the top soil (0-20 cm) of dumpsites at different locations**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Heavy metal** | **Etinan Ikot Ekpene Uyo**  **mg/kg** | | | **LSD** |
| Cadmium | 89.8 | 114.3 | 124.0 | **31.5** |
| Chromium | 358.0 | 373.0 | 432.0 | **77.8** |
| Nickel | 174.0 | 236.0 | 215.0 | **123.0** |
| Lead | 1682.0 | 2293.0 | 2152.0 | **1251.1** |
| Vanadium | 159.2 | 230.8 | 177.1 | **63.2** |

**Key: LSD = Least significance difference**

Overall, Uyo and Ikot Ekpene were more highly contaminated with the metals than Etinan. Uyo is the Capital City of Akwa Ibom State and of course the most populous. Ikot Ekpene Urban is one the fast growing cities in the State. It is expected that there are more wastes generating activities as well as higher volume of heavy metals laden-wastes generated; these might have contributed to the high contamination in dumpsite soils of Uyo and Ikot Ekpene as similar observation had been made by Johnbosco *et al*. (2020) and Sharma *et al*., (2021). This is also in line with the opinion of Daniel *et al*. (2025) that certain factors which can influence the level of contamination in automechanic dumpsite soils are volume of work done, type of automobile service or repairs, types of lubricants used, the method of wastes disposal as well as the type of soil. The findings of this work have agreed with those of Umoh and Etim (2013); from their findings on impact of dumpsites on heavy metals concentrations in soil within Ikot Ekpene, they noted an increase in heavy metals levels in dumpsite soil as compared to control. They opined that the level of soil contamination is directly proportional to distance away from the source of contamination.

**4.0 CONCLUSION**

This research has confirmed that waste materials generated from automechanic workshop related activities, paints processing and abattoir have contaminated the host soils to the levels that might be difficult to reclaim within a reasonable timescale. The wastes materials especially those of automechanic had raised the levels of cadmium in the soil above FAO’s permissible limits for residential zones by 3480 % and lead by 1437 % while paints related wastes had raised that of chromium by 100 %. This has caused pedosphere contamination by offsetting its equilibrium. Strong positive correlations existed between the levels of these hazardous elements in the wastes and in the soils, suggesting that the wastes as the prinicipal sources of these pollutants in their host soils. It was found that automechanic and paints processing wastes had higher polluting tendencies than those of abattoir in terms of these heavy metals capacities into the soils. While lead, cadmium and nickel were the highest detectable ones in automechanic wastes polluted soils, chromium and vanadium constituted the highest contaminants in paints processing wastes polluted soils. The congruence of heavy metals signatures of the wastes and the host soils indicates existence of dynamic interactions between wastes and soils through leaching and infiltration. This has created a serious environmental concern considering the impacts these might have on soil health, water quality, food safety, agriculture and the entire ecosystem. In the light of this, multifaceted approached should be employed in curtailing this risks associated with the contaminations. There is urgent need to intervene in sustainable wastes management strategies like segregation of wastes, controlled disposal, recycling or reuse of reusable ones. The already degraded soils have to be remediated using eco-friendly techniques like phytoremediation. Also, engineered landfill could be used in wastes disposal as this can can minimize environmental and health risks as compared to the traditional open dumpsites. Furthermore, protection of our environment is sacrosanct; there should be strategic policies with legal frameworks to empower them for sustainable wastes management in line with international best practices.

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1.

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3.

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