**ANALYSIS AND CHARACTERISTICS OF SOILS UNDERLYING OPEN DUMPSITES**

**IN AKWA IBOM STATE, NIGERIA: THEIR AGRICULTURAL**

**AND ENVIRONMENTAL IMPLICATIONS**

**Abstract**

*Open dumpsites are naturally connected to climate change, soil pollution and loss of biodiversity, problems described as triple planetary crisis. Despite this, dumping of wastes in open dumpsites is a common practice in Akwa Ibom State and indeed in most developing parts of the world. This study evaluated the impacts of various dumpsite waste materials on the physicochemical characteristics of the underlying soils in Akwa Ibom State, Nigeria with the aim of determining their agricultural and environmental implications. Nine dumpsites were identified and sampled in Etinan, Uyo and Ikot Ekpene Local Government Areas (LGA) of the State: one each for automechanic, paints processing, and abattoir wastes per LGA. An area believed to have no history of any of the wastes’ contamination was used as the control in each of the LGAs. Wastes samples were collected from the wastes piles while soil samples were collected from predetermined depths (0-20, 20-40 and 40-60) cm underneath the wastes piles and analyzed using standard laboratory procedures. The results had revealed that the continuous dumping of the automechanic, paint-processing, and abattoir wastes over the years have greatly modified the physicochemical characteristics of soils beneath the dumpsites in Akwa Ibom State. The pH, electrical conductivity, organic carbon exchangeable cations, and nutrient changes showed a direct relationship between waste compositions and soil pollution. Abattoir wastes were found to have enriched the impacted soils with organic matter and basic cations; paints processing wastes were outstanding in causing alkalinity in the impacted soil which can interfere with nutrients uptake. These changes can have serious impact on soil health and the entire ecosystem. As such intervention strategies of sustainable segregation of wastes, controlled disposal, and bioremediation must be done as a matter of urgency to ameliorate the impact already caused by the open dumpsites.*

Keywords: Open dumpsite soils, sustainable wastes management, soil pollution, agricultural and environmental sustainability.

**INTRODUCTION**

Open dumpsites have insidiously crept in as soil-degrading drivers, exerting adverse effects on food security and environmental wellbeing, especially in developing countries such as Nigeria (Alao, 2022 & 2023). It is in light of the above that this study examines the physicochemical changes experienced in soils located beneath abattoir, automechanic, and paint-processing waste dumpsites in Akwa Ibom State. By comparative study with pure control plots, it discovers how incessant waste dumping traverses soil pH, nutrient equilibrium, and overall fertility Omeiza *et al*., 2022 & 2023). By drawing emphasis on site-specific effects and decisive connectivity to farmability, the research brings sharply into focus the imperative for sustainable waste management intervention to drive soil fertility and environmental integrity among exposed communities. According to UNEP (2024) some terms like refuse, discards, thrash or garbage have been used to describe wastes. Essentially, waste is the unintended by-products of consumption and production. Sustainable waste management has become one of the greatest challenges facing mankind as a global problem. A recent report by UNEP (2024) has revealed that the annual municipal solid wastes (MSW) generation is over two billion tonnes. The report further asserts that if the wastes are packed into regular shipping containers and lined side by side, the wastes would wrap around the earth’s equator by twenty-five times or may be farther than a to and fro journey to the moon; this is quite disheartening.

The MSW are produced from agricultural production, construction and demolition, industrial and commercial facilities or processes; as well as from healthcare services (Alao, 2024). Admittedly, the entire world is facing the problem of sustainable wastes management. However, Tolera and Alemu (2020) revealed that it is more serious in the developing nations than in the developed ones. This is as a result of incessant unwholesome or unregulated human activities in the former. Sharma and Jain (2020) attributed this to the less effective wastes management strategies in developing and poorer nations of the world.

The major consequence of improper wastes management is environmental pollution (Omeiza and Dary, 2018; Alao *et al*., 2025). In the remark of Dan *et al*. (2018) environmental pollution and its associated problems on land, air, and water qualities are presently more than they were noted in the past; this has been attributed to the ever rising human population which has resulted in undue pressure and unregulated use of our fixed natural resources like the land (Ibia, 2019).

Soil pollution, introduction of any substance or energy by anthropogenic means into the soil environment which can affect or cause harm to organisms living in that soil or such substance interferes with the use or reduce the intrinsic value or quality of resources in the soil environment or hinder the use of such resources. Incidentally, soil environment is very susceptible to contamination by wastes. The reason advanced for this is that soil is always in direct contact with waste materials. Its vulnerability lies on the fact that soil naturally allows pollutants to infiltrate through it thereby causing contamination (Winegardner, 2019). Another point is that soil is inherently weak in terms of its capacity to clean itself from pollution; in most cases soil relies on natural cleansing processes of weathering and microbial degradation.

Winegardner, (2019) described soil as a link connecting life to the geological world; when soil is polluted, lives depending on it are negatively affected. Apart from the hazards this has posed to the entire ecosystems, government at all levels as well as environmental and health experts have devoted immense energy and resources to combat the menace of environmental pollution. These could be from biological, geochemical and anthropogenic activities like agricultural and industrial related activities as well as the disposal of their indiscriminate disposal of wastes (Wuana and Okieimen, 2011).

Municipal wastes are intrinsically connected to climate change, pollution and loss of biodiversity, problems described as triple planetary crisis. Some greenhouse gases and air borne pollutants are released through transporting, processing and disposing of some wastes; these increase the incidence of climate change. The practice of indiscriminate disposal of wastes can introduce some hazardous chemicals into the environment (soil, water bodies and air), this has the potential to cause irreversible damage to local flora and fauna which has adverse impacts on diversity, destroy the entire ecosystems and also enter the food chain (UNEP 2024). It has also been established by Williams *et al*. (2019) that about 400,000 to 1 million people die per annum because of diseases caused by poor wastes management. Such diseases could be diarrhea, malaria, heart disease or cancer.

Furthermore, Abdallah and Danyaya (2025) noted in their study that the concentrations of some heavy metals in the dumpsite soils and in plants growing on them were higher than in the control soil and WHO permissible limits. The implication of this is that if such soil is used for farming, it could impure the quality of the farm produce. Similarly, a study by Udo (2025) revealed that wastes materials had imposed a substantial influence on the soil properties with a potential for causing soil degradation and tampering with the soil health.

The problems associated with improper wastes management tend to be more severe in the developing or poorer countries of the world; this might continue if adequate efforts are not used to curtail this. For instance, it has been reported that the developed countries of the world have effectively implemented the solid waste management strategies. They are now trying to reduce wastes production, reusing and recycling of municipal soil wastes. Conversely, in the low and middle income countries, most of the wastes are disposed into open dumpsites (Jain and Sharma, 2020) thereby exposing the ecosystem to its attendant risks.

Activities like abattoir operations are noted for their high waste generation capacity; wastes are produced in every stage of meat production. In most abattoirs in Nigeria, wastes are not well managed; either they are indiscriminately dumped or buried within the area of the abattoir or they are channeled into the surrounding water bodies. Abattoir wastes are mixtures of animal dung, blood, animal trimmings, fat, paunch contents as well as other unwanted products (Bandaw and Herago, 2017).

Wastes are also produced from paint industries related activities. Though the volume of the wastes might not be as much as in the case of abattoir, wastes from paints industries have high polluting tendencies in our environment. It has been revealed from the study of Kulkarmi (2016) that paints industry related wastes are classified as hazardous wastes. The United States Environmental Protection Agency (EPA) defines hazardous wastes as those which have been established to exhibit either one or more of hazardous traits like toxicity, reactivity, explosivity, ignitability and corrosivity EPA (2024). Paint sludge, a mixture of over sprayed paint and water is a highly multifarious material. The constituents of the paints components are uncured polymer resins, surfactants, pigment, curing agents and other components. Lead materials are suitable components used for different functions in paints industries (EPA, 2020). Porwal (2015) opined that high levels of lead in the soils of old residential areas could be as a result of lead laden wastes from the area. Environmental lead exposure could be very damaging especially to growing children as this can cause developmental defects and reduced intelligent quotient in some cases.

Another type of dumpsites which attract highly persistent compound (like heavy metals) in the wastes are those of automobile related activities like repairs, maintenances, and sites for using and dumping scraps of automobiles (Abiaziem *et al*., 2013). In auto mechanic workshops, these wastes materials and other liquid wastes are constantly generated (Kulkarmi, 2016). As noted by Sutherland (2010) waste materials dumped in automechanic dumpsites could be brake fluid, motor oil and contaminated soil. Other waste materials are used diesel, petrol and grease.

In Akwa Ibom State, there is preponderance of open dumpsites where wastes from abattoir operations, automechanic, paints processing related activities and other sources are indiscriminately dumped with their attendant risks. This study intends to assess the impacts of such open dumpsites on some characteristics of the soil with a view of assessing their agricultural and environmental implications.

**MATERIALS AND METHODS**

#### Location and Spatial Extent of Akwa Ibom State

Akwa Ibom State is located in the Southeastern part of Nigeria along the Coast of Guinea. The State is being wedged between Abia, Cross River and Rivers States; on the southern margin of the State which stretches from Oron to Ikot Abasi is the Atlantic Ocean. The State is triangular in shape with Ini Local Government Area at the apex while Ikot Abasi, Onna, Eket, Uquo Ibeno and Oron form the base (Ekpoh, 1994). The State lies between latitudes 40˚ 32’and 50 ˚ 33’ N and longitudes 70 ˚ 25’ and 80 ˚ 25’ E (Ibia, 2019). It is estimated that the State covers an approximate land mass of 8,412 km2.

#### Soil Sampling and Laboratory Analyses

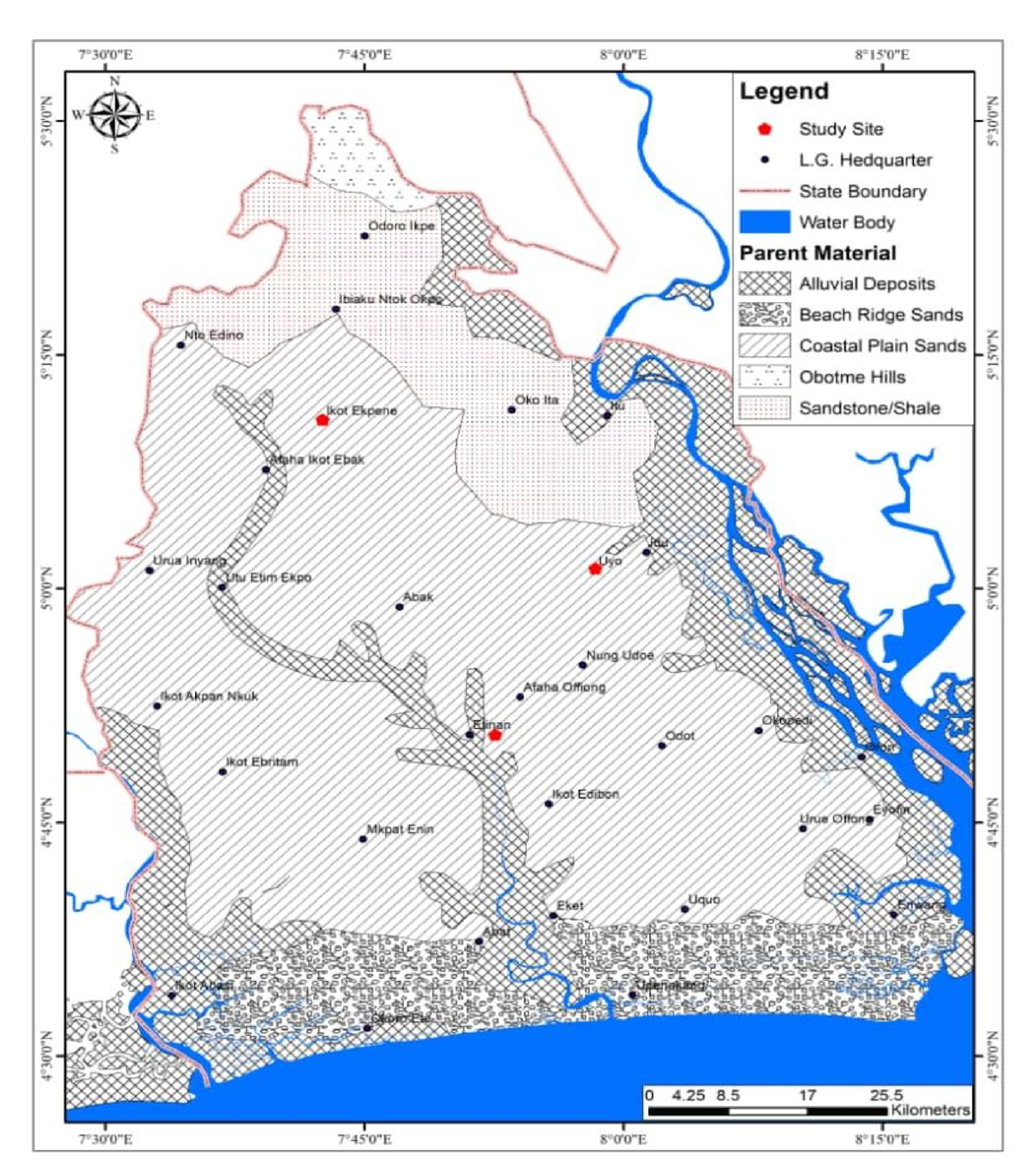
The coordinates of the dumpsites are presented on Table 1; Figure 1 presents the map of the State and the locations of the dumpsites.

**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: Field Data**

These LGAs were designated as locations 1, 2 and 3 for Etinan, Uyo and Ikot Ekpene, respectively. In each of the locations, three dumpsites (each for abattoir, paints processing and



**Figure 1: Map of Akwa Ibom State showing the Different Parent Materials and the Local Government Areas Used for the Study.**

**Adapted from Udoh and Ibia (2022).**

automechanic wastes) were picked. 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). These gave a total of 12 locations: 9 for waste dumpsites (3x3) and 3 controls (3x1). Three sections within each dumpsite were randomly designated; wastes were cleared from the portions and soil samples collected with soil auger at predetermined depths (0-20, 20-40 and 40-60) cm. At the control locations, bulk samples were equally collected from three portions at the same three depths. A total of 96 bulk samples were collected from the 12 locations (9 dumpsites and 3 controls).

The 9 soil samples [(3 auger points) x 3 depths] in each location were mixed according to their depths to form 3 composite samples from each location (1 from each depth). Samples of wastes from each of the nine dumpsites were taken in sample bottles for laboratory analyses. The soil and wastes samples were subjected to laboratory analyses.

**Laboratory analyses**

Particle size analysis was determined using Bouyoucous hydrometer method of 1951 as described by Gee and Or, (2002) and Udo *et al*. (2009a). Soil pH was measured in 1:2.5 soil-water ratio using pH meter as described in Udo *et al.* (2009a). Electrical Conductivity was measured in an extract obtained from 1:2.5 soil-water suspensions using method of Rhoades (1982) as described by Udo *et al*. (2009a). The Organic carbon was determined using the Walkley and Black Wet Oxidation Method (1934). Organic matter was obtained by multiplying organic carbon with the conventional Van Bennelar factor (OM = OC x 1.724). Total nitrogen was determined using Macro-Kjeldahl Digestion and Distillation Method as was described by Bremner and Mulvaney (1996). Available phosphorus was determined by Bray P- 2 method as described by Udo *et al*. (2009a). Exchangeable Cations: (Ca, and Mg): The Exchangeable were determined using Versanate EDTA Complexiometric Titration Method of James (1995). The cations (K and Na) were determined using flame photometry method as described by James (1995). The exchangeable Acidity was obtained using the method of IITA (1979) was described by Udo *et al*. (2009a). Effective Cation Exchange Capacity (ECEC) was determined by the summation of the values of all exchangeable bases (Ca2+ + Mg2+ + K+ + Na+) and the exchangeable acidity (Al3+ + H+). Percentage Base Saturation was determined by dividing total exchangeable bases by ECEC then multiply by 100.

**RESULTS AND DISCUSSION**

The particle size analyses for the control soil (C) showed the mean of 739.00 g/kg for sand, 63.33 g/kg for silt and 187.67 g/kg for clay (Table 2). This represents a soil with sand as dominant fraction (73.9 %); relative low silt (6.33 %) and significant but not dominant clay (18.77 %). These particles distributions make the C soil fits into sandy clay loam (SCL) textural class. The soil of automechanic wastes dumpsite (A) had particles size distribution of (795.66, 65.56 and 138.78) g/kg representing percentage distributions of 79.57, 6.57 and 13.88, for sand, silt and clay, respectively. This equally showed that the soil is SCL. Similarly, the soil of paints processing wastes dumpsite (P) with particle size distributions of (795.88, 66.44 and 139.67) g/kg had the percentage distribution of 79.59, 6.64, and 13.79, for sand, silt and clay, respectively. This soil could also be classified as SCL. The abattoir wastes dumpsite (AB) soil had particle size distributions of [826.33 g/kg (82.63 %), 73.00 g/kg (7.3%), and 107 g/kg (10.7 %)] for sand, silt and clay, respectively. By these, the AB soil is loamy sand (LS). Other related works by Udo, (1994), Udo *et al.* (2009b), Akpan-idiok (2012) and Obi *et* *al*. (2020) have consistently confirmed the sandy nature of soils derived from coastal plain sands as in the cases of these dumpsites.

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

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Soil property** | **Range** |  | Dumpsite | |  |
| **Control** | **Automechanic** | **Paints** | **Abattoir** |
| **Sand (k/kg)** | Min  Max | 719.00  779.00 | 645.00  899.00 | 603.00  875.00 | 693.00  883.00 |
|  | **Mean** | **739.00a** | **795.66a** | **795.88a** | **826.33a** |
| **Silt (k/kg)** | Min  Max | 30.00  90.00 | 30.00  98.00 | 28.00  118.00 | 34.00  114.00 |
|  | **Mean** | **63.33a** | **65.56a** | **66.44a** | **73.00a** |
| **Clay (k/kg)** | Min  Max | 131.00  251.00 | 71.00  287.00 | 67.00  323.00 | 73.00  267.00 |
|  | **Mean** | **187.67a** | **138.78ab** | **139.67ab** | **107.89b** |
| **pH (H2O)** | Min  Max | 4.50  4.80 | 6.70  8.20 | 7.30  8.40 | 5.70  7.30 |
|  | **Mean** | **4.63d** | **7.36b** | **7.99a** | **6.49c** |
| **EC (µS/cm)** | Min  Max | 27.00 99.10 | 40.30  337.00 | 82.02  352.32 | 167.80  1259.00 |
|  | **Mean** | **56.73b** | **146.01b** | **166.40b** | **536.42a** |
| **OC (g/kg)** | Min  Max | 10.73  18.13 | 10.15  33.95 | 2.43  7.35 | 26.25  46.25 |
|  | **Mean** | **13.57c** | **21.31b** | **4.98d** | **37.10a** |
| **OM (g/kg)** | Min  Max | 18.46  31.26 | 17.49  58.23 | 4.22  12.67 | 45.26  79.74 |
|  | **Mean** | **23.37c** | **36.74b** | **8.58d** | **63.96a** |
| **TN (k/kg)** | Min  Max | 0.98  3.22 | 0.56  3.64 | 0.56  0.84 | 0.98  21.98 |
|  | **Mean** | **1.77b** | **1.31b** | **0.67b** | **13.22a** |
| **Available P. (mg/kg)** | Min  Max | 16.37  22.28 | 16.34  42.77 | 24.92  58.39 | 33.62  63.15 |
|  | **Mean** | **20.53b** | **24.58b** | **39.79b** | **48.30a** |
|  | Min | 1.60 | 1.60 | 3.60 | 25.20 |
| **Ca (Cmol/kg)** | Max | 3.20 | 27.00 | 11.60 | 40.00 |
|  | **Mean** | **2.49d** | **20.47b** | **7.20c** | **32.53a** |
| **Mg (Cmol/kg)** | Min  Max | 0.80  1.60 | 5.20  12.20 | 2.00  7.60 | 6.40  18.40 |
|  | **Mean** | **1.20c** | **8.47b** | **4.00c** | **12.71a** |
| **K (Cmol/kg)** | Min  Max | 0.06 0.15 | 0.95 4.69 | 0.33 0.90 | 3.16 6.58 |
|  | **Mean** | **0.10c** | **2.77b** | **0.58c** | **4.80a** |
| **Na (Cmol/kg)** | Min  Max | 0.04 0.10 | 0.31 2.35 | 0.13 0.64 | 0.04 4.61 |
|  | **Mean** | **0.07c** | **2.35b** | **0.48c** | **3.06a** |
| **EA (Cmol/kg)** | Min  Max | 0.24  2.00 | 0.24  0.56 | 0.32  0.48 | 0.56  0.80 |
|  | **Mean** | **1.68a** | **0.41c** | **0.42c** | **0.68b** |
| **ECEC (Cmol/kg)** | Min  Max | 4.51  70.23 | 19.82  47.04 | 6.53  21.13 | 36.53  70.23 |
|  | **Mean** | **5.43c** | **33.30b** | **12.54c** | **53.78a** |
| **BS (%)** | Min | 55.60 | 97.17 | 93.69 | 98.02 |
|  | Max | 99.40 | 99.40 | 98.11 | 99.09 |
|  | **Mean** | **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.**

**Table 3: Mean values of the properties of wastes from the dumpsites**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Dumpsite** | **pH**  **(H2O)** | **EC (µs/cm)** | **OC** | | **OM** | | **TN** | **Av. P.**  **m/kg** | **Ca** | | **Mg** | | **K** | | **Na** |
| **g/kg** | | | | | **cmol/kg** | | | | | | |
| **A** | 8.77a | 431.37a | 94.60b | 163.12b | | 5.88a | | 63.34b | 42.40b | 18.80b | | 6.7b | | 2.8a | |
| **P** | 9.4b | 498.27a | 12.95 | 22.66a | | 1.91a | | 87.76c | 16.81a | 10.00a | | 1.6a | | 1.2a | |
| **AB** | 8.1a | 1088.13b | 220.73c | 380.53c | | 33.69b | | 106.61 | 51.73c | 29.33c | | 11.4c | | 8.0b | |

**Keys: A = automchanic wastes dumpsite, P = paints processing wastes dumpsite, AB = abattoir wastes dumpsite. Note: Note: a, b, c and d indicate means which are statistically different and are compared vertically across the table.**

The soil pH values obtained were 4.63, 7.36, 7.99 and 6.49 for C, A, P and AB, respectively. The pH values of the three dumpsites soils were significantly different from each other (p< 0.05) and in this sequence: (A<P<AB); they were also significantly greater than the control. The pH of C soil (4.63) is acidic and is likely due to natural processes associated with coastal plains sands as reported by Akpan-Idiok, (2012). The pH value of 7.36 for A soil indicates neutral to slightly alkaline soil condition. The higher pH value in A soil than in C could be attributed to the contamination of A by automechanic wastes which raised the soil pH in A higher than the natural background value. But in the work of Johnbosco *et al*. (2020), it was reported that a pH value obtained from automechanic wastes impacted soil was lower than that of the control. Anapuwa (2014) also observed a similar result in which the pH value of the control soil was slightly higher than that of automechanic workshop waste impacted soil. This was attributed by the author to some of the workshop activities related wastes like the acids from motor batteries.

Similarly, pH value of 7.99 obtained from P soil higher than that of the control (4.63) could be attributed to the impact of paint waste material suggesting a high contamination. In the work of Orjiakor *et al*. (2020), the same observation was made as paints wastes impacted soil had higher pH value than the control. But according to the work of Igwe and Nwachukwu (2016), a pH value of 5.50 was obtained in the control soils; this was lower than the value (6.30) that was gotten from the paint effluent impacted soil. The slightly acidic pH of 6.49 was recorded for AB soil in this work could be caused by the influence of abattoir wastes in the impacted soil. In their findings on the impacts of abattoir wastes on trace elements accumulation in soil of Akwa Ibom State, Ebong *et al.* (2020) reported a mean pH value of 6.41 against the lower value of 4.77 in the control soil. This agrees with the result of Dan *et al*. (2018) who did similar studies in the State and found out that the control soils were more acidic than waste impacted soils. A similar observation was equally made by Akintola (2021) as a higher mean pH value of 7.35 was recorded for a dumpsite soil (actually dumping point) as against 7.85 for downslope and 7.37 for upslope.

Table 3 has revealed that the mean pH value for the sample from paints wastes dumpsite was 9.43, the pH for automechanic wastes was 8.77 while the least was that of abattoir wastes with value of 8.13. In the increasing order of pH values of the wastes is 8.13, 8.77 and 9, for abattoir, automechanic and paints processing wastes, respectively. The increasing order of the pH values of soils impacted by the wastes is 6.49, 7.36 and 7.99 for AB, A and P soils, respectively; this follows the same distribution pattern like that of the wastes. This is well explained on Figure 2 where the pH values of both the soils and the wastes have similar trend. It could therefore be deduced that the cause of the differences in pH values between C soil and those of A, P and AB is the impacts of the wastes; implying that wastes had imposed significant chemical and environmental impacts on the dumpsite soil. Since soil pH plays important role in heavy metals mobility and bioavailability (Kabata-Pendias and Pendias, 2001), moderating the pH of soil by the various wastes then has a huge environmental and agricultural implications.

Figure 2: pH values of the dumpsite soils and the waste materials

The electrical conductivity (EC) values obtained were (56.73, 146.01, 166.40 and 536. 42) µS/cm, for C, A, P and AB soil. The EC values for the dumpsites (A, P, and AB) were significantly higher (< 0.05) than that of the C. This was in line with earlier observation by Johnbosco *et al*. (2020) that EC in automechanic contaminated soil was higher than in the control; they recorded EC values ranging from 108 to 127 μS/cm from auto mechanic wastes impacted soils while those of control soils were below 100 μS/cm. They attributed these variations to some metallic materials in the dumped wastes which could have possibly increased some ions like Na+, Ca2+ and others. According to the study of Anapuwa (2014), automechanic wastes impacted soils had mean EC value of 306.23 μS/cm while the control soil had 26.07 μS/cm. Also from automechanic impacted soil, Osayande *et al*. (2022) reported that the EC values from the impacted soils had a range between 238.0 and 330.8 μS/cm far higher (< 0.05) than the control’s values ranging from 90.3 to 149 μS/cm.

Figure 3 has revealed quite an interesting fact about this study which is that the EC values of both the dumpsite soils and the waste materials have the same trend. This indicates strong correlations between the EC contents in the wastes and those of the underlying soils.

In the abattoir wastes impacted soil in Akwa Ibom State, Ebong *et al*, (2020) made a similar finding having recorded 46.61 μS/cm as a mean value of EC from abattoir wastes impacted soil which was higher than the control value of 23.43 μS/cm. Equally, the work of Ogunlade *et al*. (2021) revealed EC value of 1692 μS/cm from dumpsite against 114 μS/cm of the control. In this study, the EC values of the impacted soils in an increasing order is (146.01, 166.40, 536.4) µS/cm for A, P and AB soils; that of the wastes is (431.37, 498.27 and 1087.13) µS/cm for automechanic, paints processing and abattoir wastes, respectively. The values follow the same distribution pattern; as it happened with pH values, it could then be concluded that the levels of EC in the impacted soils are determined or influenced by the EC of the respective waste materials. The report of the work of Orjiakor *et al*. (2020) can confirm this; they found out that the EC of the paints wastes materials was higher than those of the wastes impacted soils while that of the control soil was the least.

Figure 3: Electrical conductivity of the dumpsite soils and the waste materials

The implication of higher values of EC in all the impacted soils than in the control is that there is a higher presence of ions in the impacted soils than in the control soils. Anapuwa (2014) opined that this could be as a result of some reactions in the soil involving some components of the wastes which can form some soluble and ionizable inorganic salts within the soil system. The organic carbon (OC) contents have the means of (13.57, 21.98, 4.98 and 37.10) g/kg for C, A. P and AB soils, respectively. The values are significantly different from each other, the P soil has the lowest (4.98 g/kg) followed by C (13.57 g/kg), then P (21.98 g/kg) and the highest AB (37.10 g/kg). The order is expected, C was under fallow so had accumulated organic matter. The higher content of OC in A soil than the control could be as a result of used hydrocarbon compounds dumped on the soil; this can be confirmed from Table 3 showing the OC values of 94.60, 12.95 and 220.73 g/kg for automechanic, paint processing, and abattoir wastes, respectively. This was in line with the observation of Johnbosco *et al*. (2020) that the content of OC in automechanic wastes impacted soil was higher than in the control. They attributed this to the presence of carbonaceous materials presence in the used hydrocarbons which were dumped on the site. Anapuwa (2014) reported a mean value of 77.15 % in the automechanic contaminated soil while 25.21 % was for the control.

Similarly, Orjiakor *et al*. (2020) had noticed that the OC contents in paints wastes impacted soil was lower than in the control soil. Undoubtedly, accumulation of abattoirs wastes over the years on AB soil has contributed to OC in the soil; hence AB recorded the highest OC. This can as well be explained in Figure 4 where OC values in both the wastes and impacted soils showed a strong correlation given their similar trends.

In a related development while studying abattoir wastes polluted soil, Ebong *et al*. (2020) observed that the contaminated soil had a higher mean value of 6.29 % for OM while the control had 4.94 %. Soil organic carbon can act both as the sink and source for nutrients as such it has important role to play in maintaining soil fertility (Bationo *et al*., 2007); any condition that can alter the OC levels in the soil can have significant impact on such soil. The OC is the measurable component of OM in the soil so the OM levels follow the same pattern of OC. The mean values of OM are (23.37, 36.74, 8.58, and 63.96) g/kg, for C, A, P and AB, respectively.

Figure 4: Organic carbon contents of the dumpsite soils and the waste materials

The mean values of total nitrogen (TN) were as follows: (1.77, 1.31, 0.67 and 13.22) g/kg for the C, A, P and AB soils. Another author (Anapuwa, 2014) recorded TN mean value of 4.19 g/kg for automechanic wastes impacted soil against 0.31 % gotten from the control soil. Jolly *et al*. (2008) observed that in treating soil with paint industry effluent, the contents of TN increased at the concentrations of 2.5, 5 and 10 % of the effluent but decreased at 25 and 50 %. On their parts Chukwuma *et al*. (2022) noticed a decrease in the level of TN after six months of treating soil with some wastes effluent from paints industry.

The TN value for AB soil is significantly higher than the values of the other soils; the reason for this could be due to the presence of the protein components in the abattoir wastes. Being majorly from animal source (blood, tissue, urine, bones and other parts), they are rich in proteins. As they decompose, nitrogenous compounds are released into the soil. Also animal wastes are habitations of a great population of microbes which break down organic matter to release N. Equally, through the process of ammonification, microbes can convert organic form of nitrogen into ammonium (NH4+) to increase its availability. Dan *et al*. (2018) in their studies reported TN values of 0.04 and 0.06 % for the abattoir soils while the control soil had 0.01%.

The contents of available phosphorus (Av. P.) were 20.53, 24.58, 39.79 and 48.30) mg/kg for C, A, P and AB, respectively, this follows the pattern of TN. In the work of Igwe and Nwachukwu (2016), paints wastes impacted soil had available phosphorus contents of 1.79 while the uncontaminated soil had a higher content level of 2.05 mg/kg. It is also good to observe that while the Av. P sequence in the wastes materials was automechanic < paints processing<abattoir, that of the soil was A<P<AB (in the same sequence).

The Ca contents across the studied dumpsite were as follows: (2.49, 20.47, 7.20 and 32.53) cmol/kg for C, A, P and AB soils, respectively with all the values significantly different (p< 0.05) from each other. This is a clear indication that the all the wastes dumped on these dumpsites by one way or the other had added to Ca level of the soil. In the top soil of automechanic impacted soils, Osayande *et al*. (2022) had reported 3.80 to 21.02 cmol/kg of Ca while the values from the control soil were 19.5 to 30.66 cmol/kg. This signifies a higher Ca content in the control soils than in impacted soil.

According to work of Igwe and Nwachukwu, (2016) the Ca values of 32.80 and 5.20 cmol/kg were noted for paints wastes contaminated and uncontaminated soils, respectively. This agrees with the result of this study where the contaminated soils had higher contents of Ca than in the control. In the study on the impacts of paints wastes on soils, Jolly *et al*. (2008) reported that when the effluent of paint industry was applied to the soil, the level of Ca increased at the concentrations of 2.5, 5 and 10 % but decreased at the concentrations of 25 and 50 %. But in the abattoir wastes contaminated soils, Alu *et al*. (2018) noticed that the contents of Ca was 3.20 cmol/kg for the control soil and ranged from 3.60 to 6.40 cmol/kg in the impacted soil. In this study Ca has a value of 2.49 cmol/kg in the C soil; this could probably be the natural Ca level in the soil, perhaps from the weathering of parent materials. The P soil has the value of 7.20 cmol/kg for Ca, some paints pigments like Ca-based compounds can add to the Ca levels in the soil. Also paints contain some CaCO3 used as fillers, these can add to the Ca levels in the P soil. The next higher value of Ca is 20.47 cmol/kg which wasobtained from A; this elevated value might be caused by lime-rich materials contain in some wastes like battery acid neutralizers. The highest level of Ca (32.53 cmol/kg) came from AB soil. There should be no doubt if it could be assumed that this high level of Ca is from the animal related wastes. Bones for instance contain high levels of calcium phosphate (Ca3(PO4)2, through decomposition this compound can release Ca into the soil. Similarly, animal blood and tissues are good sources of Ca which could be released into the soil.

The values for Mg were (1.20, 8.47, 4.00 and 12.71) cmol/kg for C, A, P and AB, respectively. There was no significant difference between the values for C and P, the values for A and AB were significantly (p< 0.05) different from each other, indicating a sequence of (C, P) <A<AB. A study by Jolly *et al*. (2008) revealed that the contents of Mg increased while the soil was impacted with 2.5, 5, and 10 % effluent from paints industry but got decreased at higher concentrations of 25 and 50 %. Also, in the study of paints wastes impacted soils, Igwe and Nwachukwu (2016) recorded 8.40 and 2.40 cmol/kg for impacted and non-impacted soils, respectively. Alu *et al*. (2018) noticed in their study that the contents of Mg had values that ranged from 2.40 to 3.20 cmol/kg and were lower than 1.65 cmol/kg of the control.

The values obtained for K in the studied soils were (0.10, 2.77, 0.58, and 4.80) cmol/kg for C, A, P and AB soil respectively. As in the case of Mg, the values for C and P were statistically the same but A was significantly different from AB value. In another work by Osayande *et al*. (2022) recorded values ranging from 15.0 to 16.2 cmol/kg were obtained from the top soil of automechanic wastes impacted soil while 16.12 to 16.62 cmol/kg were recorded from the control soil. According to the work of Igwe and Nwachukwu (2016), in paints wastes impacted soils, there was no difference in the level in K contents as 0.30 cmol/kg was obtained in both contaminated and uncontaminated soils. A similar study from abattoir wastes impacted soil revealed Mg levels of 0.13 to 0.17 cmol/kg in the contaminated soils (at the top soil) while 1.65 cmol/kg was obtained from the control soil (Alu *et al*., 2018). The results of this study agrees with those of Igwe and Nwachukwu (2016) and Alu *et al*. (2018) where it was indicated that the respective wastes materials had caused increases in the values of Mg of the impacted soils.

Sodium had the values (0.07, 2.35, 0.48 and 3.06) cmol/kg for C, A, P and AB, respectively. These followed the same trend of Mg and K, the mean values for C and P were the same while there was a significant difference between those of A and AB; the value for AB was the highest. This implies that abattoir wastes exhibit the highest capacity to raise the level of Na in the soil. According to the report on the study of the impacts of automechanic wastes on the soils by Osayande *et al*. (2022), the Na values in the impacted soils had values ranging from 0.98 to 1.88 cmol/kg at the top soil while the control soils had 1.22 to 1.86 cmol/kg. In the paints effluents impacted soils by Jolly *et al*. (2008) they noticed that the contents of Na increased with the wastes levels (2.5, 5 and 10 %) but started to decrease from 25 % of the wastes. In the findings of Alu *et al*. (2018) from the impacts of abattoir wastes on soils properties, Na values ranging between 0.26 and 0.32 cmol/kg were observed for the impacted soils while the control had 0.18 cmol/kg. Though the nature of wastes was not specify, Akintola *et al*. (2021) reported the values of (234.89, 121.85, 54.56 and 189.09) cmol/kg for Ca, Mg, K and Na from dumpsites soils and that the values were higher at the actual dumpsite spot receiving the direct impacts of the wastes than at farther locations.

EA mean values were (1.68, 0.41, 0.42, and 0.68) cmol/kg for C, A, P and AB, respectively. The values for A and P soils were statistically the same (p< 0.05); that of C was higher than that of AB with that of C as the highest. This result shows that the EA followed a reverse trend of soil pH and those of the basic cations. The implication of this is that acidic conditions will cause release of H+ and Al3+ while alkaline conditions favours the neutralization or precipitation of these ions. In a related work by Igwe and Nwachukwu (2016) recorded EA values of 0.88 and 0.80 mg/kg for the contaminated and the uncontaminated soil, respectively. In the study of abattoir wastes impacted soils, Alu *et al*. (2018) noted EA values that ranged from 0.42 to 1.92 cmol/kg for the impacted soils and 0.18 cmol/kg for the control. These results align with the outcome of this work indicating that the wastes had raised the EA contents of the impacted soils. There are a number of possible mechanisms through which wastes contaminations can increase the EA of the impacted soils. These may include hydrolysis of toxic compounds, release of nitrogen and sulphur compounds, or disruption of the buffering capacity of the soils by the contaminants.

The ECEC mean values for C, A, P and AB were (5.43, 33.30, 12.54, and 53.78) cmol/kg, respectively. From the results, values for C and P are not significantly different from each other (p <0.05); value for A is higher than those of C and P while that of AB is higher than all of them. In the work of Igwe and Nwachukwa (2016), the contents of ECEC were 42.78 and 9.10 cmol/kg for the contaminated and the uncontaminated soils, respectively. In another related work, values of ECEC ranging from 8.49 to 10.65 cmol/kg were reported in the contaminated soil (Alu *et al*., 2018) while the control soil had 6.24 cmol/kg.

Base saturation (BS) values were (67.91, 98.63, 96.21 and 98.69) % for C, A, P and AB soils, respectively. Igwe and Nwachukwu (2016) reported a slightly higher BS in the contaminated soils than in the uncontaminated soils with the values of 97.94 and 91.21 %, respectively. In another abattoir wastes impacted soils, the BS values which ranged from 78.02 to 95.52 % were recorded while that of the control was 82.13 % (Alu *et al*., 2018).

1. **The agricultural implications of dumping wastes on the studied soils**

As established by the results, there were positive correlations between the properties of the wastes and those of the impacted soil. This could be attested to by the properties like pH, electrical conductivity, organic carbons and the basic cations in both waste materials and the impacted soils following the same trends. This has serious agricultural implications viz:

1. **Soil degradation or impact on soil health**: The similarity in trends is a pointer to the fact that the wastes materials have imposed a substantial influence on the soil properties with a potential for causing soil degradation and tampering with the soil health.
2. **Nutrient imbalance:** The imposed changes of the soil properties caused by the wastes can affect nutrients availability, while the levels of some elements may be excessive; some may be deficient. In some cases when some nutrient elements could be raised above the optimal level; nutrients antagonism may set in. This is a situation whereby one element interferes with the intake, utilization and function of another element in the soil. For instance, excessive level of potassium in the soil can interfere with absorption of magnesium in the soil; high intake of zinc can interfere with the absorption of copper.
3. **Reduced soil productivity**: It is obvious from the study that dumping of the wastes on soil can reduce soil productivity. Any condition which can cause soil degradation and nutrients imbalance would eventually cause low productivity as this will result in poor plant growth, low yield and poor quality products.
4. **The environmental implications of dumping wastes on the studied soils**
5. **Impacts on mobility and bioavailability of certain pollutants**: The results have shown that the wastes had significantly caused changes in the pH levels of the impacted soils. This can affect the mobility and bioavailability of some pollutants like heavy metals in the soil and potentially raise their contamination risks in the soil and water bodies (both surface and underground).
6. **Impacts on the activities and the population of microbial organisms**: Microbes in the soil play significant roles in the decompositions of organic matter and nutrient cycling for enhanced soil productivity. Changes in soil pH beyond the optimal level or tolerable range would potentially affect the diversity and the performance of microbes; these can disrupt optimal functioning of the soil ecosystem.

**Conclusion**

The research confirms that automechanic, paint-processing, and abattoir wastes dumped for years have greatly modified the physicochemical characteristics of soils in Akwa Ibom State open dumpsites. The pH, electrical conductivity, organic carbon, exchangeable cations, and nutrient changes show a direct relationship between waste composition and soil pollution. Abattoir wastewaters particularly contributed most to the enrichment of organic matter and base-forming cations, and paint-processing wastes contributed alkalinity, which can interfere with nutrient uptake. All of these changes detract from the productivity of soils by initiating nutrient imbalances, microbial disturbance, and prolonged degradation, inflicting considerable damage to agriculture and the environment. Additionally, the congruence of chemical signatures of wastes and host soils indicates the existence of dynamic interactions between waste and soil via leaching and infiltration. This has a critical impact on soil health, as well as groundwater vulnerability, food safety, and ecosystem stability. Since agriculture depends on soil for sustenance, the results form a timely notice of warning. Hence, intervention strategies of sustainable segregation of wastes, controlled disposal, and bioremediation must be taken on an emergency basis. Policy-based implementation of sustainable interventions for waste management, public outreach, and research on remediation technology, significant milestones toward restoration of soil health and environmental integrity in vulnerable tropical ecosystems are advocated in this paper.

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