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Physico Chemical Characterization and Pollution Risk Assessment

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Abstract

This study evaluates the physico- chemical properties of soils in the vicinity of the Nekede open waste dumpsite, southeastern Nigeria, to determine their quality status and potential environmental risks. After the removal of the overlying waste, soil samples were collected from seven different location points within the dumpsite with two points serving as controls.100m away from each other and Soil samples were collected at a depth of three different depths (surface,15cm, 30cm) on an open waste landfill using a Dutch soil auger. The physicochemical parameters of the soil were determined using standard laboratory methods, while, EDXRF was used for heavy metal determination. The soils were observed to have a PH value of averaging 5.7 to 8.3 indicating slightly acidic to moderately alkaline, Nitrate levels up to 101.60 ppm and nitrate–nitrogen up to 22.80 ppm exceed WHO safety limits (50 mg/L nitrate; 10 mg/L nitrate–nitrogen), Elevated EC and salinity values surpass agricultural tolerance thresholds, potentially leading to soil structure degradation, reduced infiltration, and diminished crop yields. Nickel (Ni) levels ranged from 540 mg/kg at the surface to 437 mg/kg at 35 cm depth, remaining consistently above permissible limits. Lead was highest at the surface (211 mg/kg) and decreased slightly with depth, indicating partial retention in upper layers. Zinc was extremely elevated, with 1162 mg/kg at the surface, suggesting strong contamination from metallic and electronic waste. Iron, while naturally abundant, reached an exceptionally high 492,855 mg/kg at the surface, likely from corroded ferrous materials. The control site showed much lower values across all metals, confirming anthropogenic input as the primary contamination source. The soils under study are severely contaminated with Nickel, Copper, lead, and Zinc, which show values far above pollution thresholds. The geo accumulation factor reveals extreme levels of accumulation for these metals in this order copper >Zinc>Ni>Lead >Iron while enrichment factor suggests minimal to moderate enrichment. High value of PLI obtained shows the severe ecological risk posed by these contaminants, thereby confirming the presence of strong anthropogenic influences such as waste dumping, industrial discharges, and other pollution sources.

Keywords: Leachate, Physicochemicals Tatus, Enrichment Factor, Soils, Dumpsite, Nekede

1.1 INTRODUCTION

Effective solid waste disposal has continued to be a major global challenge, especially in developing nations like Nigeria. Environmental pollution by heavy metals is one of the most dangerous elements of contamination due to improper disposal of solid wastes. A comparison between the developed nations of the world and the developing ones shows a sharp variation in the methods employed in the disposal of solid wastes. While the developed countries have established regulatory programs for effective and efficient disposal, developing nations have generally continued to use unsophisticated methods such as open dumps or unlined land filling (Kocasoy, 2002). This entails that dumping of wastes in an uncontrolled manner with no provision for lining in the top soil will have adverse effect on the soil.

Natural constituent of the earth's crust such as heavy metals are non-degradable and sometimes, they find their way in our bodies through drink, food, water and air. Some heavy metals for instance, iron (Fe) and zinc (Zn) are essential for metabolic maintenance in humans. However, if not regulated at higher concentrations heavy metals have been shown to have negative effects and impact on the environment and humans (Sia Su, 2008). Heavy metal is any metallic substance that has a relatively high density and a low concentration, it is toxic. Some of such heavy metals include mercury (Hg), cadmium (Cd), arsenic (As), chromium (Cr), titanium (Ti) and lead (Pb), etc. An open waste dump site is defined as a land disposal site whereby solid wastes are disposed of in a manner that does not protect the people and environment; it is vulnerable to open burning. Open waste dumping includes the solid waste of this different sort which when disposed poses reasonable possibility of adverse effects on the health of the environment (Adelekan and Alawode, 2011).

In developing countries such as Nigeria, open dumpsites are common practice due to low budget for waste disposal and lack of political will. Nigeria is generally faced with rapid deterioration of environmental conditions due to the conventional system of collection and dumping of solid wastes. Therefore, waste management has become a major concern in cities. Little efforts have been made in order to improve the waste collection and disposal facilities.

Sources of soil contamination with heavy metals and metalloids include emission from the rapidly expanding industrial areas, mine tailings, disposal of high metal wastes in improperly protected landfills, leaded gasoline and paints, land application of fertilizers, animal manures, sewage sludge, pesticides, waste water irrigation, coal combustion residues, spillage of petrochemicals and atmospheric deposition (Khan et. al, 2008). Solid waste disposals (open dumps, landfills, sanitary landfills or incinerators) however represent a significant source of metals released into the environment (Iwegbue et al, 2013; Bretzel and Calderisi, 2011; Rizo et. al, 2012). Heavy metals are the most toxic and environmentally dangerous pollutants in leachates and they can contaminate soil and water due to their leach ability and mobility (Samuding, 2009).

Municipal Dumpsites have thus been identified as potential contributors to heavy metal contamination on soils. The sources of the contamination may include; incinerator ashes, mine waters, household hazardous materials such as batteries, paints, dyes, inks etc. (Erses and Onay, 2003).

Soils are regarded as the ultimate sink for heavy metals discharged into the environment by anthropogenic activities as many heavy metals are bound to soils (Obianjuwa et. al, 2002). The fate and transport in soil depends significantly on the chemical form and speciation of the metal (Wuana and Okiemen, 2011). Although heavy metals occur naturally in the soil environment from the pedogenetic processes of weathering of parent materials, they are usually found at levels that are regarded as trace (<1000 mgkg-1) and rarely toxic (Kabata-Pendias and Pendias; 2001; Pierzynski et. al, 2000). Unlike organic contaminants, which are oxidized to carbon (IV) oxide by microbial action, most metals do not undergo microbial or chemical degradation and their total concentration in soils persist for a long time after their introduction (Kirpichtchikov et. al, 2006). Changes in their chemical forms (speciation) and bioavailability are also possible (Kanmani and Gandhimathi, 2013). The presence of toxic metals in soil can severely inhibit the biodegradation of organic contaminants. Heavy metals in the soil are capable of decreasing crop production because of the risk of bioaccumulation and bioaccumulation in food chain. There is also a risk of superficial and ground water contamination. Thus, heavy metal contamination of soil may pose risks and hazards to humans and the ecosystem through direct ingestion or contact with contaminated soil, the food chain (soil-plant-human or soil-plant-animal-human), drinking of contaminated ground water, reduction of food quality (safety and marketability) via phytotoxicity, reduction in land usability for agricultural production causing food insecurity, and land tenure problems (McLaughlin et. al, 2000).

Bacud et al. (1994) pointed out that the pollution soil and ground water system could be as result of a poorly designed waste water tanks. Soil and ground water acidification and nitrification have been linked to waste dumps as well as microbial contamination of soil and ground water system (Awomeso et al., 2010). According to Sia Su (2008), solid waste dumps through leachate seeps to the groundwater, thereby causing abnormalities, such as cancer of the body and heart diseases. Rapid urbanization due to population increase laid to higher waste generation and improper waste management gives rise to both health and environmental concerns.

Adelekan and Alawode (2011) noted that waste from municipal dumpsites bear soils that are satisfactorily rich in organic matter that would be acceptable for surface feeder plants.

Subsequently, Brady (1996) and Helmore and Ratta (1995) reported concurrently, that an open dump siteperforms a twofold purpose of a safe disposal of waste and simultaneously approved chemical properties of soils that constitute productive agricultural fields. Nigeria a Western African country has a comparatively very poor waste management approach. Thus, the inadequate waste management approach has the potential of increasing soil metal concentration in and around the Nekede open dumpsite. Soil metal contamination increases health risks and deteriorates agricultural lands. In Imo state, the Ministry of Environment is saddled with the responsibility of checkmating solid waste and other waste disposal. The ministry has verse land allocated along old Nekede road for disposal of wastes both solid and others collected from different parts in Owerri town and its environments.

Owerri a non-industrial area that, refuses generated within the city comprise largely of degradable and non-degradable materials from the shopping malls, local markets, offices, hospitals and households such as garbage, plastics, textiles, sludge from sewage, dead animals, ashes, wood, disposed of food, stationaries and farm waste produce. However, damaged metallic materials from vehicle parts, electronics, computers, can drinks, etc. are also disposed of in the same way as the other non-metal contaminants. Methane and other gases are released into the surrounding air and micro-organisms decays loosening the solid waste and numerous volatile liquids that discharge; which seeps through the solid waste pile ultimately reaches the soil, shallow water and ground water. The harmful materials which include heavy metallic concentration, pesticides, herbicides and hydrocarbons consequently dissolves to form liquids that contaminate both soil and water (Adelekan and Alwaode, 2011).

Anikwe and Nwobodo (2001) postulated that disposal of municipal waste on soils may cause an increment in heavy metals composition in the soil and shallow water that would be amicable to deep feeding crops. Therefore, this study seeks to access the physicochemical properties of some selected soil samples of municipal open waste dumpsite Nekede Owerri West Local Government Area, Imo State of Nigeria. Specifically, the main aim of this study is to assess the physico chemical properties of soils around the Nekede dumpsite and evaluate their pollution risk potential. objectives are to, determine the soil pH, electrical conductivity, salinity etc., their composition with respect to its amount that will be favorable to plants growth around the dumpsite, determine the composition of selected heavy metals (Pb, Cd,Zn,Cu,Fe) contents and fertility position of the soils around the dumpsite. The study focuses on understanding how the continuous disposal of degradable municipal waste from various locations across the state such as markets, offices (especially the Polytechnique located close the dumpsite), hospitals and households, which generate garbage, plastics, textiles, stationary, and sludge from waste production contributes to increase concentration of heavy metals in the soil. This contamination also affects surface water, posing risks to plants the research was carried out at an open dumpsite located Nekede in Owerri west local Government Area, Imo State. It specifically examines the physical and chemical properties of certain waste soils, including pH, electrical conductivity, salinity, nitrate Nitrate nitrogen and heavy metals.

1.2 METHODOLOGY

Apart from the last two samples (6th and 7th samples) which served as the control samples, the rest were collected at random . These last two samples were collected from a site, about 1km away from the study area. This is to ensure that samples are free from any form of contamination from the waste dump. The samples were transferred into nylon bags and transported to the laboratory for further treatment and analysis.

The soil samples were air-dried, disaggregated and mechanically sieved using 100-mesh screen. Samples are considered acceptable if 100% passes through 100-mesh screen and also to ensure homogeneity prior to digestion. Digestion of soil samples were carried out according to standard procedures as described by and, where 0.2 grams of each sample was weighed and dried using crucibles. The samples were digested in acid mixtures of 5 ml nitric acid,3ml perchloric acid and 2ml hydrofluoric acid. They were placed on hot plates for ten minutes and later transferred to a fume chamber where they were allowed to cool. The cooled solutions were made up to 250 ml in volumetric flasks with de-ionized water. The obtained solutions were later used for the measurement of heavy metals including Lead (Pb), Copper (Cu), Chromium (Cr), Nickel (Ni), Cadmium (Cd), Zinc (Zn) and Cobalt (Co) using the Energy dispersive X Ray Florescence (EDXRF).

Table 1: Coordinates of the Sampling pointsvc

S/N	Sample Location (of The Dumpsite)	Longt.	Lat.	Elev (m)
1	Middle	007° 1’24.669’’E	05° 26’18.218’’N	74
2	Left flank	007° 1’23.583’’E	05° 26’16.608’’N	87
3	Right flank	007° 1’26.852’’E	05° 26’18.529’’N	71
4	Behind nokia lodge Nekede	007° 1’25.02’’E	05° 26’24.439’’N	71
5	Opposite the dumpsite	007° 1’23.211’’E	05° 26’21.946’’N	67
6	Umudibia Primary School	007° 1’56.02’’E	05° 26’39.458’’N	110
7	Behind Breatix waters	007° 1’8.97’’E	05° 25’42.527’’N	82

1.3 RESULTS AND DISCUSSION

The results of physiochemical characteristic of the soil samples collected on Nekede dumpsite, such as pH, salinity, conductivity, nitrate and nitrogen concentration in ppm, are summarized in Table 3. The soil PH in the study area ranged from 5.708-8.286, indicating slightly acidic to moderately alkaline. The PH of the soil is an important parameter that directly influences metal and mineral mobility (Gambrell, 1994).

Table 2: Soil physicochemical properties

Parameters/Sample points (cm)	**pH**	**Electrical Conductivity (μS/cm)**	**Salinity (ppm)**	**Nitrate (ppm)**	**Nitrate - nitrogen (ppm)**
Sample 1 Surface	8.098	176.1	900.00	101.60	22.80
15	8.276	0.212	600.00	83.60	16.60
30	8.286	0.240	500.00	72.60	12.40
Sample 2 Surface	7.720	3.63	300.00	59.60	13.00
15	7.931	0.214	400.00	43.20	9.70
30	8.115	181.30	300.00	22.30	5.30
Sample 3 surface	7.783	152.40	900.00	65.20	14.80
15	5.817	190.10	1100.00	37.80	10.30
30	5.822	181.10	600.00	42.70	13.40
Sample 4 surface	7.540	136.70	900. 00	60.00	13.60
15	8.074	151.40	600.00	47.30	10.80
30	7.771	1332.00	600.00	35.60	6.70
Sample 5 surface	8.088	159.00	600.00	39.60	8.80
15	7.635	0.227	500.00	34.70	7.20
30	7.851	161.10	400.00	28.80	5.60
Control 1 surface	7.340	114.60	1800.00	22.50	4.70
15	7.369	111.50	1500.00	21.60	3.90
30	7.432	117.80	1300.00	17.40	1.60
Control 1 surface	6.361	189.90	1100.00	20.40	2.80
15	5.708	125.20	900.00	16.30	1.70
30	6.421	116.80	700.00	12.50	1.40
FMenv Standard(2006)	6.50	100.00	1000	20.00	NS

The physicochemical analysis of soils fromlk the study area reveals considerable variation in pH, electrical conductivity (EC), salinity, nitrate, and nitrate–nitrogen levels when compared with control samples and the Federal Ministry of Environment (FMEnv, 2006) permissible limits. These variations highlight the influence of leachate infiltration from the Nekede dumpsite on surrounding soils.Soil pH values ranged from 5.822 to 8.286 across all depths. Most samples exhibited alkaline conditions (pH > 7), particularly in the surface horizons (e.g., Sample 1 at 30 cm, pH 8.286), likely due to alkaline ash, lime-based materials, and decomposing organic matter within the waste stream. Slightly acidic values, such as in Sample 3 at 30 cm (pH 5.822), may be attributed to organic acid production during waste decomposition and mineral weathering. Control samples recorded near-neutral to slightly acidic pH values (6.361–7.432), indicating minimal anthropogenic influence.Electrical Conductivity values varied widely, from 111.50 µS/cm to 3.63 mS/cm, with most dumpsite samples exceeding the FMEnv limit of 100 μS/cm. The highest EC was recorded at the surface of Sample 2 (3.63 mS/cm), indicating substantial soluble salt enrichment. Elevated EC in these soils suggests high ionic concentrations from leachate migration, which can adversely affect soil structure, water retention, and crop productivity.Salinity ranged between 300 and 1500 ppm, with several readings above the FMEnv threshold of 1000 ppm. The highest salinity was found in Sample 4 at 15 cm depth (1500 ppm), suggesting evaporative concentration and salt accumulation in the intermediate layer. Such high salinity can impair osmotic balance in plants, reduce water uptake, and degrade soil healthNitrate concentrations ranged from 16.30 to 101.60 ppm, with most dumpsite soils exceeding the FMEnv limit of 20 ppm. The highest nitrate concentration was found in Sample 1 (surface) at 101.60 ppm, reflecting contamination from decomposing organic matter, fertilizer residues, and possibly septic effluent. Given nitrate's high mobility, these values represent a significant risk for groundwater contamination and surface water eutrophication. Nitrate–Nitrogen levels varied from 1.40 to 22.80 ppm, with the highest value corresponding to the same location as peak nitrate. Although FMEnv does not provide a nitrate–nitrogen limit, the WHO drinking water guideline is 10 mg/L, and several surface and sub-surface samples exceeded this value. Such elevated nutrient levels further indicate the vulnerability of the area's aquifer to contamination.In terms of vertical distribution, surface soils generally showed higher nitrate and salinity levels than deeper horizons, reflecting direct leachate exposure. However, instances such as Sample 4 at 30 cm, where deeper layers recorded elevated EC and nitrate, suggest downward contaminant migration through the soil profile. This points to an active leachate percolation process capable of affecting sub-surface strata and groundwater. Control samples displayed markedly lower EC, salinity, and nitrate values compared to dumpsite-adjacent samples, confirming the dumpsite as a principal source of contamination.

Relative to WHO drinking water standards and agricultural soil benchmarks, the observed contamination poses both environmental and public health concerns. Nitrate levels up to 101.60 ppm and nitrate–nitrogen up to 22.80 ppm exceed WHO safety limits (50 mg/L nitrate; 10 mg/L nitrate–nitrogen), creating risks such as methemo globinemia ("blue baby syndrome") in infants and nutrient-driven eutrophication in aquatic systems. Elevated EC and salinity values surpass agricultural tolerance thresholds, potentially leading to soil structure degradation, reduced infiltration, and diminished crop yields. The detection of these contaminants at multiple depths underscores the persistence and mobility of leachate, necessitating urgent waste containment, leachate management, and remediation interventions to protect soil quality, preserve groundwater safety, and maintain ecological health.

Table 3: Result of some heavy metal concentration in open waste landfill

Site	**Depth (cm)**	**Ni ($mg\ kg^{-1}$)**	**Pb ($mg\ kg^{-1}$)**	**Cu ($mg\ kg^{-1}$)**	**Zn ($mg\ kg^{-1}$)**	**Fe ($mg\ kg^{-1}$)**
1	surface	540	42	316	869	39285
	15	647	211	414	1152	45741
	30	512	115	261	997	54749
2	surface	372	0	357	956	39230
	15	587	19	296	703	31938
	30	438	17	328	1034	33098
3	surface	566	5	332	821	28566
	15	698	0	342	850	43906
	30	432	17	328	1034	33098
4	surface	603	83	415	876	38817
	15	626	128	308	705	35049
	30	617	8	297	755	36210
5	surface	495	132	385	921	63420

	15	439	1	345	786	42809
	30	674	59	287	769	674
control 1	surface	474	0	273	704	29049
	15	491	103	298	680	34155
	30	583	48	340	644	39259
control 2	surface	453	0	387	662	40480
	15	74	111	353	741	52550
	30	587	0	392	731	59330

The table presents the concentrations of selected heavy metals (Ni, Pb, Cu, Zn, and Fe) in soils collected at various depths from an open waste landfill, alongside control samples. Results indicate significant contamination in landfill sites compared to controls, suggesting anthropogenic sources, primarily from waste materials and leachate percolation.Nickel concentrations in landfill soils range up to 698 mg/kg, far exceeding the WHO/NSDWQ permissible limit for agricultural soils (50–100 mg/kg). Control sites recorded much lower values (as low as 156 mg/kg). Elevated Ni likely originates from metal alloys, batteries, and electronic waste. The irregular variation with depth indicates active leachate migration rather than surface-only deposition. Lead levels in landfill soils reach 211 mg/kg, surpassing the WHO permissible limit (~85 mg/kg) in several samples. Control site values were much lower (0–33 mg/kg). Pb sources include discarded batteries, paints, plastics, and e-waste. The high Pb concentrations pose serious risks due to its neurotoxic and bioaccumulative properties. Copper concentrations range from 12 to 42 mg/kg in landfill soils, slightly higher than controls (3–8 mg/kg). Although Cu levels are below critical contamination thresholds (~100 mg/kg), the elevated values suggest contributions from discarded electrical wiring, alloys, and industr ial materials.Zinc concentrations are markedly high in landfill soils, reaching up to 1197 mg/kg, significantly exceeding the WHO/FAO soil limit (~300 mg/kg). Controls recorded 226–490 mg/kg. Likely sources include galvanized metals, rubber waste, and metal scraps. Excess Zn can impair plant nutrient uptake and affect soil health., Iron concentrations are extremely high across all landfill depths, with values up to 547,490 mg/kg, considerably greater than controls (~49,879 mg/kg). While Fe is naturally abundant in soils, the elevated levels here suggest additional contributions from rusting metal debris and ash residues.

1.4.1 Three-Dimensional View of some of the Physicochemical Water Quality Parameters

Measured:

The contour and 3-D surface plots of some of the measured physicochemical water quality indices are presented in Figures 4(a) to 18(b). The observed level of each water quality parameter is shown with colours and values of the colours are also clearly indicated with the unit of the water quality index.

Cadmium

The concentration of cadmium within the study area shows high concentration within the North-western part of the study area while lower concentration of the element can be seen within the Northern part of the area. The concentration ranges from as high as 2,300mk/kg to as low as 1,550mk/kg.

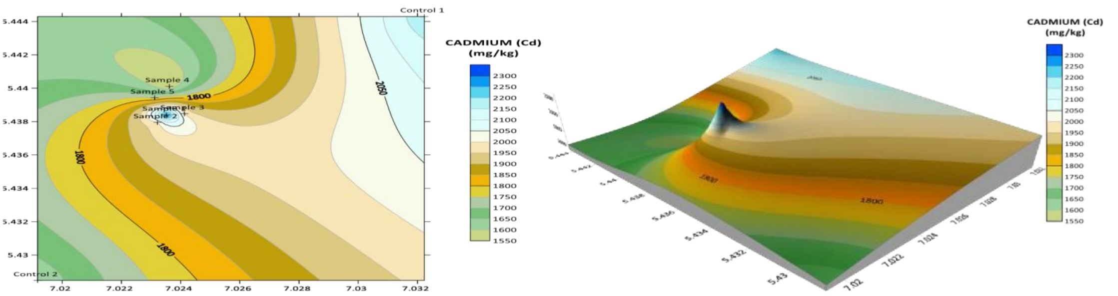


Fig 9: 3D and Spatial plots of cadmium

Iron

The concentration of iron within the study area shows high concentrations within the South-western part of the study area while low concentrations is shown in the North-eastern part of the study area. The concentration of Iron ranges as high as 59,000mg/kg to as low as 33,000mg/kg.

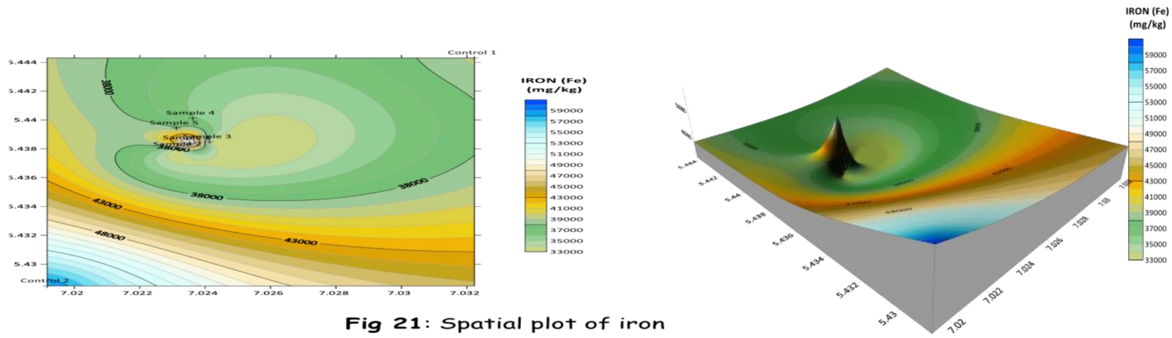


Fig 11: 3D and Spatial plot of iron

Nickel

The concentration of nickel in the study area is relatively high in the Northwestern part of the study area whereas lower concentration of nickel is within the eastern part of the area. The concentration of nickel ranges as high as 670mg/kg to as low as 430mg/kg.

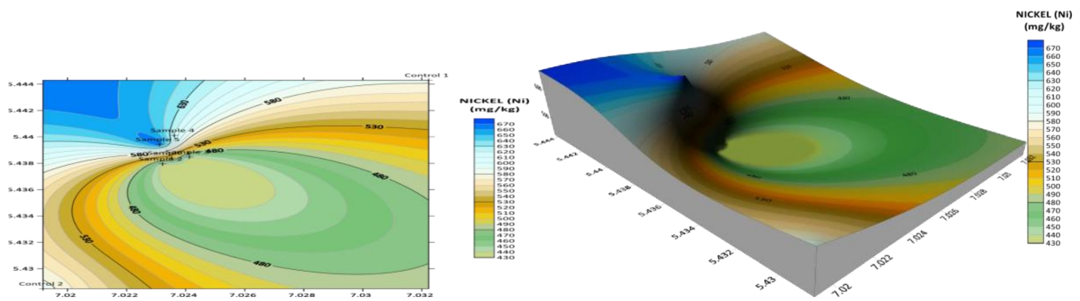


Fig 12: 3D and Spatial plot of nickel

Surface

Cadmium

The concentration of cadmium is relatively high near surface is it ranges as high as 2400mg/kg to as low as 200mg/kg with high concentration within the western part and lower concentration within the North-eastern part.

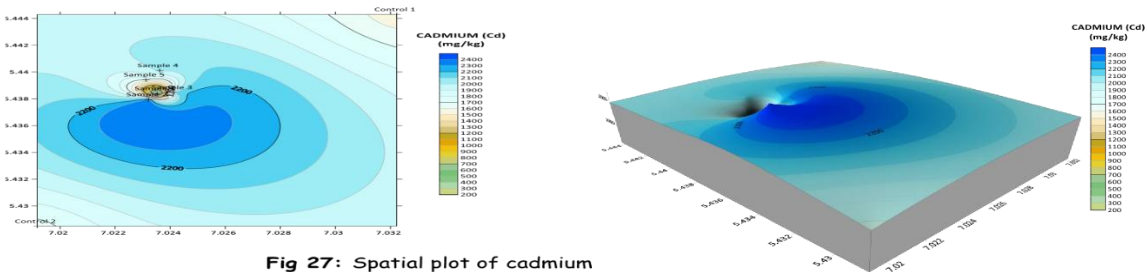
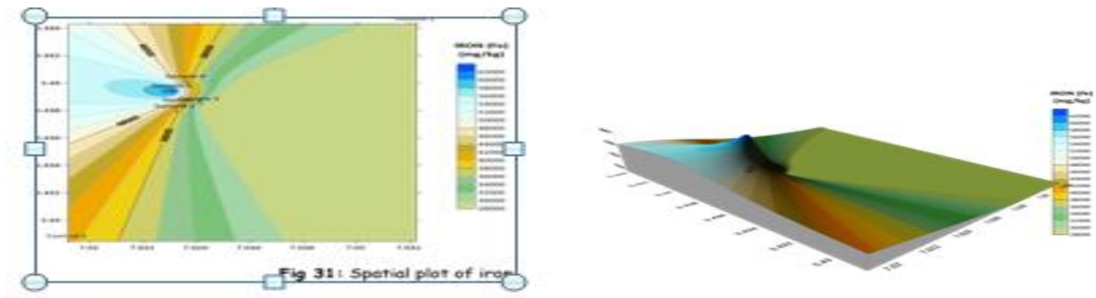


Fig 13: 3D and Spatial plot of cadmium

Iron

There is a high concentration of Iron in the western part of the study area while lower concentration can be seen in the South-western part of the area. It ranges as high as 6,300mg/kg to as low as 2,800mg/kg.



Nickel

The concentration of Nickel is relatively high in the Northern part of the study area whereas lower concentration of the element is seen in the western part of the area. The concentration ranges as high as 610mg/kg to as low as 370mg/kg.

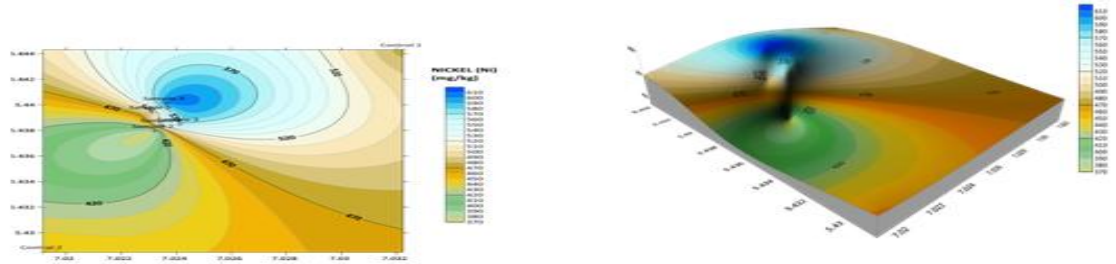
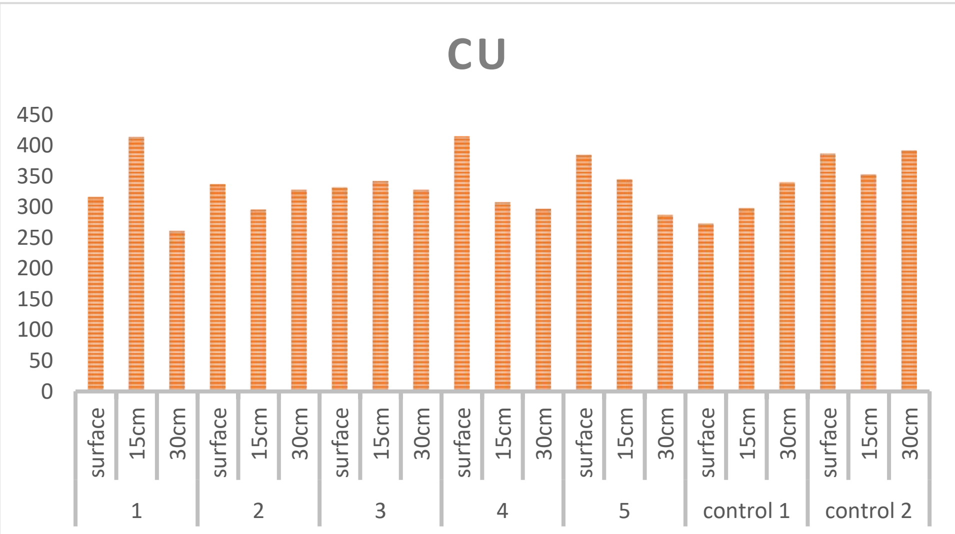


Fig 33: Spatial plot of nickel

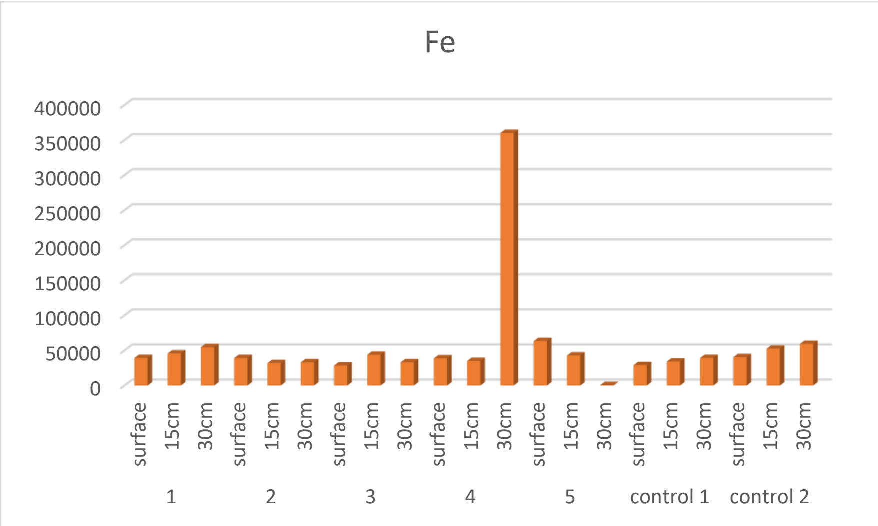
Table 4: The result of some heavy metal concentration in open waste landfill

Site No	Depth (cm)	Ni (mg kg^{-1})	Pb (mg kg^{-1})	Cu (mg kg^{-1})	Zn (mg kg^{-1})	Fe (mg kg^{-1})
1	surface	540	42	316	869	39285
	15	647	211	414	1152	45741
	30	512	115	261	997	54749
2	surface	372	0	357	956	39230
	15	587	19	296	703	31938
	30	438	17	328	1034	33098
3	surface	566	5	332	821	28566
	15	698	0	342	850	43906
	30	432	17	328	1034	33098
4	surface	603	83	415	876	38817
	15	626	128	308	705	35049
	30	617	8	297	755	36210
5	surface	495	132	385	921	63420
	15	439	1	345	786	42809
	30	674	59	287	769	674
control 1	surface	474	0	273	704	29049
	15	491	103	298	680	34155
	30	583	48	340	644	39259
control 2	surface	453	0	387	662	40480
	1	74	111	353	741	52550
	30	587	0	392	731	59330

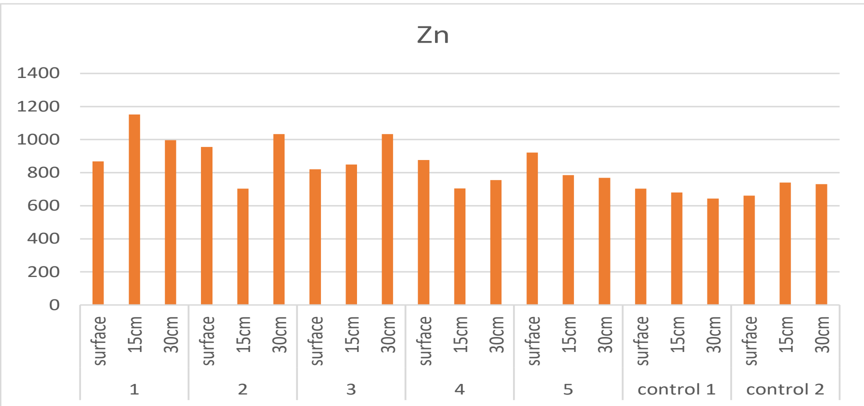
Analysis of soil sample located in the vicinity of a municipal dumpsite.



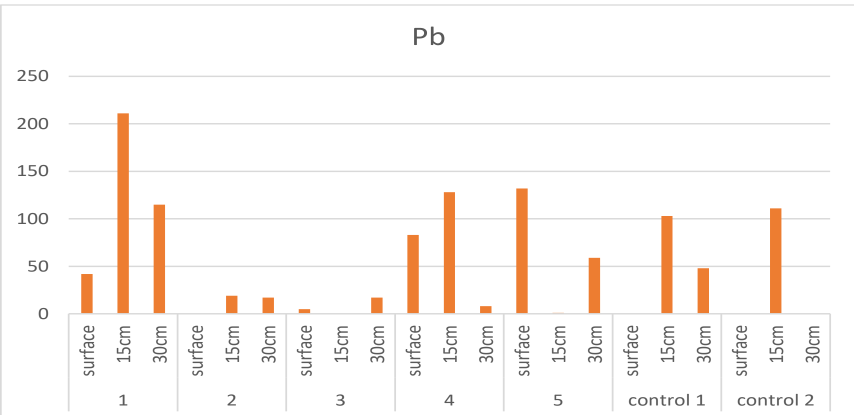
The results indicate Cu with the highest levels recorded at surface soils (0 m) in close proximity to the dumpsite.



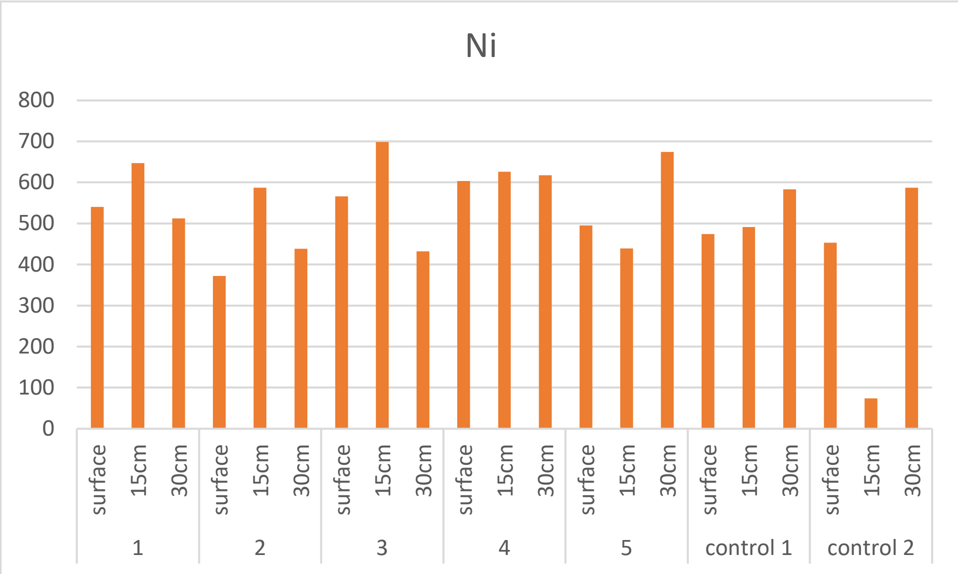
The results indicate Fe with the highest levels recorded at site 4 (30cm) in close proximity to the dumpsite



The results indicate Zn with the highest levels recorded at site 1(15cm) in close proximity to the dumpsite.



The results indicate Pb with the highest levels recorded at site 1 (15cm) in close proximity to the dumpsite



The results indicate Ni with the highest levels recorded at site3 (15cm) in close proximity to the dumpsite.

Table 5: Assessment Of Soil Contamination Level

METALS	CONTAMINATION FACTOR	GEO ACCUMULATION FACTOR	ENRICHMENT FACTOR	POLLUTION LOAD INDEX
Ni	81.6574	5.76655	0.003870	11984107.63
Pb	21.5471	3.84446	0.001400	
Cu	118.2607	6.30086	0.002305	
Zn	86.5179	5.84996	0.005516	
Fe	3.9709	1.40450	4.182447	

The table presents the assessment of soil contamination level using various indices such as Contamination Factor (CF), Geoaccumulation Factor (Igeo), Enrichment Factor (EF), and the Pollution Load Index (PLI). These parameters provide insights into the degree of soil pollution, the extent of metal accumulation, the source of contamination, and the overall pollution status.

Contamination Factor (CF): The contamination factor indicates the degree of soil contamination by each heavy metal. According to Hakanson (1980): CF < 1 → Low contamination1 ≤ CF < 3 → Moderate contamination, 3 ≤ CF < 6 → Considerable contamination, CF ≥ 6 →Very high contamination. Results: Ni (81.6574), Cu (118.2607), Zn (86.5179), Pb (21.5471) →Very high contamination Fe (3.9709) →

Considerable contamination, this indicates that the soils are heavily polluted with Ni, Cu, Zn, and Pb, while Fe shows considerable contamination.

Geoaccumulation Factor (Igeo): The geoaccumulation factor measures the degree of metalaccumulation compared to background values. Classification: Igeo ≤ 0 → Unpolluted, 0–1 → Unpolluted to moderately polluted, 1–2 → Moderately polluted, 2–3 → Moderately to strongly polluted, 3–4 → Strongly polluted, 4–5 → Strongly to extremely polluted, > 5 → Extremely polluted

Results: Ni (5.7666), Cu (6.3010), Zn (5.8500) → Extremely polluted, Pb (3.3445) → Strongly polluted, Fe (1.0495) → Moderately polluted. This shows that Cu, Ni, and Zn exhibit severe accumulation in the soil.

Enrichment Factor (EF): The enrichment factor helps distinguish between natural and anthropogenic contributions. Classification: EF < 2 → Deficiency/minimal enrichment (natural origin), 2 ≤ EF < 5 → Moderate enrichment, 5 ≤ EF < 20 → Significant enrichment, 20 ≤ EF < 40 → Very high enrichment (, EF) ≥ 40 → Extremely high enrichment

Results: Ni, Pb, Cu, Zn → EF < 0.01–0.005, suggesting minimal enrichment

Fe (4.1824) → Moderate enrichment. This implies that Ni, Pb, Cu, and Zn occur in high concentrations but may be influenced by background adjustments, while Fe shows moderate anthropogenic influence.

Pollution Load Index (PLI): The pollution load index provides an overall assessment of contamination: PLI > 1 → Polluted, PLI< 1 → Unpolluted

Result: PLI = 11,984,107.63, which is extremely high, indicating that the soil is severely polluted overall.

1.4.2 CONCLUSION AND RECOMMENDATION

This research work focuses on physical and chemical properties of an open waste dumpsite and heavy metal contamination levels in Nekededumpsiteand its environ Imo State southeastern Nigerian. From the result obtained, iron (Fe) had the highest content all through the analysis. The results showed also that activities within the various control points might have been responsible for the increased level of iron (Fe) in the landfill. Results of physical and chemical properties indicated that refuse dumpsite soils to be slightly acidic.Relative to WHO drinking water standards and agricultural soil benchmarks, the observed contamination poses both environmental and public health concerns. Nitrate levels up to 101.60 ppm and nitrate–nitrogen up to 22.80 ppm exceed WHO safety limits (50 mg/L nitrate; 10 mg/L nitrate–nitrogen), creating risks such as methemoglobinemia ("blue baby syndrome") in infants and nutrient-driven eutrophication in aquatic systems. Elevated EC and salinity values surpass agricultural tolerance thresholds, potentially leading to soil structure degradation, reduced infiltration, and diminished crop yields. The detection of these contaminants at multiple depths underscores the persistence and mobility of leachate, necessitating urgent waste containment, leachate management, and remediation interventions to protect soil quality, preserve groundwater safety, and maintain ecological health. The elevated concentrations of Ni, Pb, and Zn are of particular concern due to their toxicity, persistence, and potential to contaminate groundwater. Pb and Ni pose serious health risks including neurological damage, kidney dysfunction, and potential carcinogenic effects. Zn, while essential in small amounts, can disrupt soil-plant nutrient balance at high concentrations. Continuous leaching from the landfill threatens nearby water sources, making them unsafe for human and animal consumption.The study reveals that the open waste landfill is a significant source of heavy metal pollution in the area. Concentrations of several metals exceed permissible limits, highlighting the urgent need for regular monitoring, pollution control measures, and remediation strategies to protect soil and groundwater quality.Thus, The soils under study are severely contaminated with Ni, Cu, Pb, and Zn, which show values far above pollution thresholds. The geoaccumulation factor indicates extreme levels of accumulation for these metals, while enrichment factor suggests minimal to moderate enrichment. The very high PLI confirms the severe ecological risk posed by these contaminants, pointing to strong anthropogenic influences such as waste dumping, industrial discharges, and other pollution sources.

It is therefore appropriate to recommend as follows; that solid waste deposited at the landfill contained materials with high heavy metal content; hence, adequate refuse disposal mechanism should be put in place to reduce the high acidic content. Sorting into biodegradable and non – biodegradable ones before deposition should be keenly encouraged. It is also recommended that proper remediation work should be done on such site found to contain high level of heavy metals before it can be used for the cultivation of edible food crop in order to avoid heavy metal poisoning through bio magnification. Lastly, it will be very important to adhere strictly and comply with regulatory limits in sludge to be released from the villages into the environment. Long-term monitoring, enforcement of waste management regulations, and implementation of remediation methods such as phytoremediation or soil washing are recommended to mitigate the risks.

Declaration of Conflicting Interests

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