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Heavy Metal Levels And Metal Pollution Indices Of Soils Around Active Solid Wastes Dumpsites In Rumueme And Elijiji Communities In Rivers State, Nigeria

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Abstract
Levels of Heavy Metals and pollution indices of soil samples around active municipal solid waste dump sites in Rumueme and Elijiji Communities in Rivers State, were determined. Heavy Metals were determined using Atomic Absorption Spectrophotometer by GBC XplorAA. The results showed maximum mean levels of Chromium (83.952±18.721 mg/kg), Lead (88.700±87.681 mg/kg), Copper (29.700±28.001 mg/kg) and Nickel (41.600±22.910 mg/kg) at the 0 – 15 cm depth. Enrichment Factor results suggest that chromium had significant to very severe enrichment across the stations. The results of soil metal pollution index showed that all soil samples in the study area were unpolluted. The study recommends that regular monitoring of activities around dump sites should be done routinely and strict environmental laws governing waste disposal be enacted and enforced.
Keywords: *Heavy metals, Solid Waste, Dumpsites, Pollution Indices, Rumueme, Nigeria*

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I. Introduction

Industrialization, urbanization and changes in consumption patterns have compounded the problem of dumpsite-waste management on soil and groundwater quality in Nigeria. Poor waste discarding system and waste management threatens the well-being and health of the local population, particularly those living adjacent or neighboring to dumpsites. Waste generation has been an issue for communities since the beginning of urbanization which is also called civilization. Waste is generated due to goods and service production and the utilization of natural resources (Uzoigwe and Agwa, 2012). There are many obstacles to the proper management of waste. In Nigeria, regular increases in population, industrialization and changes in consumption patterns have complicated waste management (Ogbuene *et al.,* 2013).

The impact of poor waste management on human health and well-being cannot be overemphasized. Individuals living adjacent to dumpsites are at high risk due to the potential of waste to pollute drinking water, food, vegetation, land and air (Njoroge, 2007). Waste comes from various sources: domestic residences, offices, institutions, commercial buildings, restaurants, agriculture, construction, and hospitals. The majority of the wastes generated from these sources ends up in dumpsites. Across many cities in Nigeria, collected wastes are usually burnt outdoors and ashes are poorly disposed of on-site. This act destroys the organic components and causes the oxidation of metals. The ashes left behind are enriched with metal, which results in pollution of the soil and drinking water quality surrounding this environment (Adeyi and Majolagbe, 2014; Temilola *et al*., 2014; Henry, *et al.,* 2017).

According to Mpofu *et al.* (2013), the movement of contaminants from sites where wastes are disposed of two adjoining ecosystems is complex and involves biological and physico-chemical processes. Open dumpsites could be a source of microbial and toxic chemical pollution of the soils and the quality of groundwater used as drinking water produce from boreholes in this environment. This can also pollute hand dug wells, posing serious health risks and leading to the destruction of biodiversity in the environment (Ogunmodede *et al*., 2014). Water can percolate through the refuse pile in the dumpsites. This leads to the formation of leachates that are enriched in nutrients (nitrogen, potassium and phosphorous), heavy metals, and other toxic substances, including cyanide and dissolved organics (Ogbeibu *et al*., 2013).

The composition of the wastes influences the concentration of the leachates' constituents which may be adsorbed on to the soil during this diffusion (Shaikh *et al*., 2012). This process creates health hazards, soil and water pollution, and offensive odours, which increase with an increase in ambient temperature levels (Abdus-Salam *et al.,* 2011). The produced leachate permeates into ground systems leading to change of physical and chemical properties of groundwater (Vasanthi *et al*, 2008). Longe and Enekwechi, (2007) stated that heavy metals

such as cadmium, arsenic, chromium have been reported at excessive level in groundwater due to landfill operation.

Active disposing of waste on dumpsites in Rivers State of Nigeria is rapidly growing in terms of population and infrastructure. Active waste dumpsites have effect on the soil quality in Nigeria, because it 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. The present study therefore was conducted to assess the significant impact of dumpsites in the two selected areas in Rivers state, Nigeria (Nsirim Road and Elejiji Dumpsites) on soil.

Landfills have long been used as repositories for industries, municipal and commercial wastes. Nigeria, a developing country with non-adequate waste disposal or recycling processes is at a risk of metal and organometallic contamination of its soil and surface water bodies, which poses health hazard and soil deterioration for agricultural purposes. Food and farm waste products, metallic materials from damaged vehicle parts, electronics, computers, cans, etc, are also disposed in the same way as the other non-metallic materials, thereby constituting a source of metal contamination. Open dumps are generally unsanitary and constitute malodorous places in which disease-carrying vermin such as rats and flies proliferate (Bellebaum, 2005). Methane and other gases are released into the surrounding air as microorganisms decompose the solid wastes and fires pollute the air with acrid smoke and other numerous volatiles. Liquids that ooze and seep through the solid waste heap ultimately reach the soil, surface water and ground water. Hazardous materials such as heavy metals, pesticides and hydrocarbons that are dissolved in this liquid often contaminate soil and water (Adelekan and Alawode, 2011). Anikwe and Nwobodo (2001) suggested that continuous disposal of municipal waste on soil may lead to increase in heavy metals in the soil and surface water that would be inimical to deep feeding plants. Heavy metals such as arsenic, cadmium, lead, chromium, nickel, cobalt and mercury are of concern primarily because of their ability to harm soil organisms, plants, animals and human beings (Adelekan and Abegunde, 2011). More emphatic are the untreated dumplings that rapidly increase soil toxicity making such large area dumpsites potentially hazardous for agricultural purposes. Yet these workers (Anikwe and Nwobodo, 2001; Adelekan and Alawode, 2011; Adelekan and Abegunde, 2011) also indicate that municipal waste dumpsites bear soils that are sufficiently rich in organic matter that would be acceptable for surface feeder plants. Consequently, Brady (1996) and Helmore and Ratta (1995) reported that open dump fields perform a dual purpose of safe disposal of wastes and simultaneously create improved physical and chemical properties of soils that constitute productive agricultural fields. Other studies have also revealed that dumpsites around two major cities in Nigeria could be effectively utilized for residential and agricultural purposes without risk of heavy metal toxicity (Urunmatsoma and Ikhouria, 2005; Asalawalam and Eke, 2006). Old dump fields therefore can be seen to provide farmers with fertile plots for cultivation of vegetables and other surface feeder crops. Public concern about environmental pollution has focused attention on the disposal of urban and industrial waste hence this study intends to determine the contents of lead, chromium and cadmium and the fertility status of the soil of the dump field in Yenagoa area in view of interpreting the suitability of its soil for crop production.

II. Materials And Methods

The Study Area

Obio/Akpor Local Government Area of Rivers State is located between latitudes 4˚45′ N and 4˚60′ N and longitudes 6˚50′ E and 8˚00′ E. Rivers state is found in the coastal plain of the Eastern Niger Delta (UNEP, 2011). Temperature ranges from 21.2 ˚C to 33.4 ˚C. Annual rainfall is 4,700 mm/year (UNEP, 2011). The map of the study areas is shown in Fig. 1. Major economic activities of environmental significance in the study area include primary, secondary and tertiary institutions, hotels, hospitals, mechanic workshops, petrol stations and small-scale industries. The communities in the study area are densely populated, thus, large quantities of domestic and household wastes are generated and most of the time, dumped indiscriminately at several dumpsites at various locations in these communities.

Sample Collection

Soil samples were collected in wet and dry seasons, two soil samples each from Chief Nsirim Road, Rumueme, dump sites were collected based on the four cardinal points, North, South, East and West at five meters (5m) interval from the dumpsite at the depth of 0 – 15cm and 15cm – 30cm in 8 sampling points with the aid of soil augar and total of 16 samples. Soil samples at the Minidai-Rumuolumene Road, Rumuepirikom Port Harcourt dumpsite were collected randomly due to restrictions from buildings around the dumpsite, five (5) sampling points identifies and soils were collected at depth 0 cm – 15 cm and 15 cm – 30 cm, total of 10 soil samples were collected. The soils were separately bagged according to their depths in a labeled polythene bags sealed by twisting and tying the neck by means of adhesive tape. To provide extra protection, the bags were enclosed in

second polythene bags and were safely transported to the laboratory where they were air-dried before other subsequent laboratory processes.

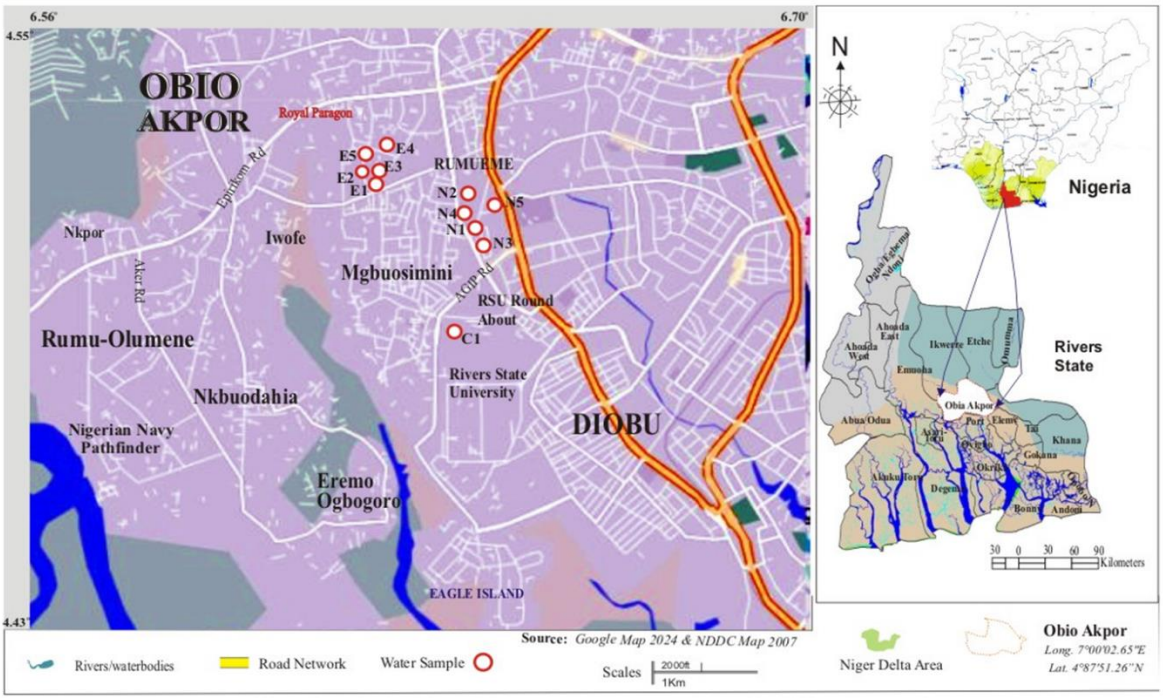

Fig. 1: Map showing Sampling Locations for Soil Samples
[N= Nsirim; E = Elejiji; C = Control]

Heavy Metals in Soil

In flame atomic of absorption spectrometry, a sample is aspirated as a fine mist into a flame and atomized. A light beam is directed through the flame into a monochromator, followed by photodetector which measures the amount of the light absorbed by the atomized elements in the flame. As each metal has its own characteristic absorption wavelength, a source lamp composed of that element is used which makes it free from spectral or radiation interferences. The amount of the energy at the characteristic wavelength absorbed in the flame is proportional to the concentration of the elements in the sample over a specific limit of concentration range.

Standard solutions of respective known metal concentrations in water with a matrix similar to the samples were prepared. Appropriate volume of the samples was then digested each with 1ml conc. HCl for 20-30 min. The blank was also prepared and digested accordingly. The absorbance was then read out on the display screen after aspiration.

$$\text{Conc. of sample (ppm)} = \frac{\text{Sample absorbance}}{\text{Standard absorbance}} \times \text{conc of std.} \times \text{dilution factor}$$

Pollution Indices

Environmental pollution indices are useful in establishing or estimating the ecological risks posed by contaminants naturally or anthropogenically introduced into different ecosystem matrices. Numerous studies have applied contaminant pollution indices, such as the contamination factor (CF), geo-accumulation index (Igeo), enrichment factor (EF), pollution load index (PLI) and the combined pollution index (PLI), for ERA and monitoring of the impacts of anthropogenic activities to the levels of heavy metal in the environment.

Contamination Factor evaluates the ratio of contamination to that of background environmental heavy metal levels. Cf Reflects preliminary contaminant enrichment in the environment.

$$C_f = \frac{C_m}{C_b}$$

where cm is the concentration of metal m; cb is the pre-industrial concentration of metal m. Classification: CF < 1, low contamination; 1 ≤ CF ≤ 3, moderate contamination; 3 < CF≤ 6, considerable contamination; CF ≥ 6, very high contamination.

The geochemical load index (Igeo), is useful in evaluating heavy metal contamination based on the ratio of the concentration in the soil/water to the geogenic background levels. Evaluates the degree of metal contamination or pollution in the environment.

$$I_{geo} = \left(\frac{C_n}{1.5B_n}\right)$$

where Cn is the measured concentration of the heavy metal; Bn is the environmental background value of the metal; 1.5 is the background matrix correction coefficient to moderate the impact of possible variations due to lithogenic and anthropogenic influences. Classification: Igeo ≤ 0, uncontaminated; 0 < Igeo ≤ 1, uncontaminated to moderately contaminated; 1 < Igeo ≤ 2, moderately contaminated, 2 < Igeo ≤ 3, moderately to strongly contaminated; 3 < Igeo ≤ 4, strongly contaminated; 4 < Igeo ≤ 5, strongly to extremely contaminate; Igeo > 5, extremely contaminated (Caeiro *et al.,* 2005).

EF is used to determine the level of human effects on heavy metals in soil. The metals enrichment factor in soil were determined using the equation below (Zia *et al*., 2017). EF evaluates the severity/ pollution state of anthropogenic enrichment of individual heavy metal.

$$EF = \frac{\left({}^{M_s}/_{C_{ref}}\right)}{\left({}^{M_{cr}}/_{C_{cr}}\right)}$$

where ${}^{M_s}/_{C_{ref}}$ is the ratio of metal concentration in the sample to reference metal C; ${}^{M_{cr}}/_{C_{cr}}$ is the ratio of the background value of metal M to the reference metal C. In this research, copper (Cu) was selected as the reference because of its natural abundance in the earth crust of the study area. In EF determination, the reference values are included for normalization (to compensate for distortions from geogenic/anthropogenic activities). Classification: EF < 2, none to minor enrichment; 2 ≤ EF < 5, moderate enrichment; 5 ≤ EF < 10, significant enrichment; 10 ≤ EF < 25, severe enrichment; 25 ≤ EF < 50, very severe enrichment; EF > 50, extremely severe enrichment. The use of reference elemental values makes the EF index a more reliable indicator of heavy metal pollution.

III. Results

Heavy Metal Levels in Soil

The heavy metals levels recorded in soil samples in the study area are shown in Tables 1 and 2. At a depth of 0 – 15 cm, the mean chromium levels ranged from 11.002±15.554 – 83.952±18.721 mg/kg at the sampling stations and 3.602±5.089 mg/kg at the Control; the mean copper levels ranged from 0.001±0.000 – 29.700±28.001 mg/kg at the sampling stations and 3.051±4.313 mg/kg at the Control; the mean iron levels ranged from 1223.800±728.674 – 20716.000±13955.459 mg/kg at the sampling stations and 693.800±152.594 mg/kg at the Control; the mean nickel levels ranged from 24.350±25.385 – 41.600±22.910 mg/kg at the sampling stations and 25.100±0.707 mg/kg at the Control; the mean lead levels ranged from 0.010±0.000 – 88.700±87.681 mg/kg at the sampling stations and 6.355±8.973 mg/kg at the Control.

At a depth of 15 – 30 cm, the mean chromium levels ranged from 9.042±13.291 – 48.952±69.224 mg/kg at the sampling stations and 10.052±14.211 mg/kg at the Control; the mean copper levels ranged from 0.001±0.000 – 14.800±14.001 mg/kg at the sampling stations and 0.001±0.000 mg/kg at the Control; the mean iron levels ranged from 788.200±9.617 – 23035.000±9432.097 mg/kg at the sampling stations and 1267.100±93.480 mg/kg at the Control; the mean nickel levels ranged from 28.900±15.132 – 47.550±18.455 mg/kg at the sampling stations and 39.800±38.325 mg/kg at the Control; the mean lead levels ranged from 0.010±0.000 – 115.550±147.573 mg/kg at the sampling stations and 34.905±49.349 mg/kg at the Control.

Soil Heavy Metal Pollution Indices

Result of various pollution indices for heavy metals in the soil samples are shown in Tables 3 – 7.

At the 0 – 15 cm depth, Contamination Factor levels for chromium ranged from 0.11 – 0.84 at the stations and 0.04 at the control; levels for copper ranged from 0.00 – 0.83 at the stations and 0.08 at the control; levels for iron ranged from 0.03 – 0.55 at the stations and 0.02 at the control; levels for nickel ranged from 0.70 – 1.19 at the stations and 0.72 at the control; levels for lead ranged from 0.00 – 1.04 at the stations and 0.07 at the control.

At the 15 – 30 cm depth, Contamination Factor levels for chromium ranged from 0.09 – 0.49 at the stations and 0.10 at the control; levels for copper ranged from 0.00 – 0.41 at the stations and 0.00 at the control; levels for iron ranged from 0.02 – 0.42 at the stations and 0.03 at the control; levels for nickel ranged from 0.83 – 1.36 at the stations and 1.14 at the control; levels for lead ranged from 0.00 – 1.36 at the stations and 0.41 at the control.

At the 0 – 15 cm depth, Enrichment Factor levels for chromium ranged from 0.52 – 6.61 at the stations and 1.97 at the control; levels for copper ranged from 0.00 – 2.82 at the stations and 4.64 at the control; levels for nickel ranged from 1.43 – 36.69 at the stations and 39.28 at the control; levels for lead ranged from 0.00 – 29.02 at the stations and 4.09 at the control.

At the 15 – 30 cm depth, Enrichment Factor levels for chromium ranged from 0.25 – 9.23 at the stations and 3.01 at the control; levels for copper ranged from 0.00 – 1.24 at the stations and 0.00 at the control; levels for nickel ranged from 1.96 – 53.45 at the stations and 34.10 at the control; levels for lead ranged from 0.00 – 12.99 at the stations and 12.32 at the control.

Table 3: Contamination Factor

STATION	Cr	Cu	Fe	Ni	Pb
	0 – 15 cm depth				
RSU Ctrl	0.04	0.08	0.02	0.72	0.07
Nsirim 1	0.20	0.14	0.11	0.70	0.00
Nsirim 2	0.38	0.30	0.26	0.76	0.00
Nsirim 3	0.30	0.83	0.55	0.78	0.00
Nsirim 4	0.13	0.17	0.25	0.86	0.00
Nsirim 5	0.39	0.23	0.40	0.79	0.00
Elejiji 1	0.11	0.02	0.16	1.04	0.13
Elejiji 2	0.21	0.00	0.03	1.18	0.93
Elejiji 3	0.20	0.09	0.03	1.05	0.52
Elejiji 4	0.54	0.14	0.37	1.06	1.04
Elejiji 5	0.84	0.38	0.45	1.19	0.12
	15 – 30 cm depth				
RSU Ctrl	0.10	0.00	0.03	1.14	0.41
Nsirim 1	0.30	0.41	0.33	0.92	0.00
Nsirim 2	0.14	0.08	0.22	1.08	0.11
Nsirim 3	0.09	0.23	0.37	1.00	0.02
Nsirim 4	0.11	0.25	0.42	0.83	0.00
Nsirim 5	0.32	0.17	0.34	1.04	0.67
Elejiji 1	0.13	0.15	0.31	1.36	0.05
Elejiji 2	0.19	0.00	0.02	1.11	0.27
Elejiji 3	0.49	0.39	0.61	1.31	0.86
Elejiji 4	0.21	0.09	0.22	1.26	1.36
Elejiji 5	0.24	0.18	0.29	1.36	1.00

Contamination Factor Range	Pollution/Risk Degree
$CF < 1$	Low contamination
$1 \leq CF \leq 3$	Moderate contamination
$3 < CF \leq 6$	Considerable contamination
$CF \geq 6$	Very high contamination

Table 4: Enrichment Factor

STATION	Cr	Cu	Fe	Ni	Pb
	0 – 15 cm depth				
RSU Ctrl	1.97	4.64	RM	39.28	4.09
Nsirim 1	1.90	1.35	RM	6.51	0.00
Nsirim 2	1.44	1.16	RM	2.89	0.00
Nsirim 3	0.55	1.51	RM	1.43	0.00
Nsirim 4	0.52	0.69	RM	3.52	0.00
Nsirim 5	0.96	0.57	RM	1.95	0.00
Elejiji 1	0.69	0.15	RM	6.56	0.85

Elejiji 2	6.61	0.00	RM	36.69	29.02
Elejiji 3	5.98	2.82	RM	32.23	15.83
Elejiji 4	1.44	0.38	RM	2.86	2.81
Elejiji 5	1.87	0.83	RM	2.65	0.28
	15 – 30 cm depth				
RSU Ctrl	3.01	0.00	RM	34.10	12.32
Nsirim 1	0.89	1.24	RM	2.78	0.00
Nsirim 2	0.62	0.35	RM	4.97	0.53
Nsirim 3	0.25	0.61	RM	2.70	0.04
Nsirim 4	0.25	0.60	RM	1.96	0.00
Nsirim 5	0.92	0.50	RM	3.05	1.95
Elejiji 1	0.42	0.48	RM	4.34	0.14
Elejiji 2	9.23	0.00	RM	53.45	12.99
Elejiji 3	0.81	0.64	RM	2.16	1.42
Elejiji 4	0.95	0.38	RM	5.60	6.06
Elejiji 5	0.84	0.61	RM	4.67	3.45

RM = Reference Metal

Enrichment Factor Range	**Pollution/Risk Degree**
$EF < 2$	None to minor enrichment
$2 \leq EF < 5$	Moderate enrichment
$5 \leq EF < 10$	Significant enrichment
$10 \leq EF < 25$	Severe enrichment
$25 \leq EF < 50$	Very severe enrichment
$EF > 50$	Extremely severe enrichment

At the 0 – 15 cm depth, Geo-Accumulation Index levels for chromium ranged from 0.08 – 0.62 at the stations and 0.03 at the control; levels for copper ranged from 0.00 – 0.44 at the stations and 0.05 at the control; levels for iron ranged from 0.02 – 0.29 at the stations and 0.01 at the control; levels for nickel ranged from 0.24 – 0.41 at the stations and 0.25 at the control; levels for lead ranged from 0.00 – 2.96 at the stations and 0.21 at the control.

At the 15 – 30 cm depth, Geo-Accumulation Index levels for chromium ranged from 0.07 – 0.23 at the stations and 0.07 at the control; levels for copper ranged from 0.00 – 0.22 at the stations and 0.00 at the control; levels for iron ranged from 0.01 – 0.33 at the stations and 0.02 at the control; levels for nickel ranged from 0.28 – 0.47 at the stations and 0.39 at the control; levels for lead ranged from 0.00 – 3.85 at the stations and 1.16 at the control.

At the 0 – 15 cm depth, Ecological Risk Factor levels for chromium ranged from 0.22 – 1.68 at the stations and 0.07 at the control; levels for copper ranged from 0.00 – 4.13 at the stations and 0.42 at the control; levels for nickel ranged from 3.48 – 5.94 at the stations and 3.59 at the control; levels for lead ranged from 0.00 – 5.22 at the stations and 0.37 at the control.

At the 15 – 30 cm depth, Ecological Risk Factor levels for chromium ranged from 0.19 – 0.63 at the stations and 0.20 at the control; levels for copper ranged from 0.00 – 2.06 at the stations and 0.00 at the control; levels for nickel ranged from 4.13 – 6.82 at the stations and 5.69 at the control; levels for lead ranged from 0.00 – 6.80 at the stations and 2.05 at the control.

At the 0 – 15 cm depth, Soil Metal Index levels ranged from 23.0 – 63.2 at the stations and 18.6 at the control while at the 15 – 30 cm depth, Soil Metal Index levels ranged from 31.8 – 73.1 at the stations and 33.6 at the control.

Table 5: Geo-Accumulation Index (I-geo)

STATION	**Cr**	**Cu**	**Fe**	**Ni**	**Pb**
	0 – 15 cm depth				
RSU Ctrl	0.03	0.05	0.01	0.25	0.21
Nsirim 1	0.15	0.08	0.06	0.24	0.00
Nsirim 2	0.28	0.16	0.14	0.26	0.00
Nsirim 3	0.22	0.44	0.29	0.27	0.00
Nsirim 4	0.10	0.09	0.13	0.30	0.00

Nsirim 5	0.29	0.12	0.22	0.27	0.00
Elejiji 1	0.08	0.01	0.09	0.36	0.38
Elejiji 2	0.16	0.00	0.02	0.41	2.65
Elejiji 3	0.14	0.05	0.02	0.36	1.47
Elejiji 4	0.40	0.08	0.20	0.37	2.96
Elejiji 5	0.62	0.20	0.24	0.41	0.35
	15 – 30 cm depth				
RSU Ctrl	0.07	0.00	0.02	0.39	1.16
Nsirim 1	0.22	0.22	0.18	0.32	0.00
Nsirim 2	0.10	0.04	0.12	0.37	0.32
Nsirim 3	0.07	0.12	0.20	0.34	0.05
Nsirim 4	0.08	0.13	0.23	0.28	0.00
Nsirim 5	0.23	0.09	0.18	0.36	1.89
Elejiji 1	0.10	0.08	0.17	0.47	0.13
Elejiji 2	0.14	0.00	0.01	0.38	0.76
Elejiji 3	0.36	0.21	0.33	0.45	2.44
Elejiji 4	0.16	0.05	0.12	0.43	3.85
Elejiji 5	0.18	0.09	0.16	0.47	2.84

I-geo Range	**Pollution/Risk Degree**
$0 < \text{I-geo} \leq 1$	Uncontaminated to moderately contaminated
$1 < \text{I-geo} \leq 2$	Moderately contaminated
$2 < \text{I-geo} \leq 3$	Moderately to strongly contaminated
$3 < \text{I-geo} \leq 4$	Strongly contaminated
$4 < \text{I-geo} \leq 5$	Strongly to extremely contaminate
I-geo > 5	Extremely contaminated

Table 6: Ecological Risk

STATION	**Cr**	**Cu**	**Fe**	**Ni**	**Pb**
	0 – 15 cm depth				
RSU Ctrl	0.07	0.42	NC	3.59	0.37
Nsirim 1	0.41	0.72	NC	3.48	0.00
Nsirim 2	0.76	1.52	NC	3.81	0.00
Nsirim 3	0.60	4.13	NC	3.91	0.00
Nsirim 4	0.26	0.84	NC	4.31	0.00
Nsirim 5	0.77	1.15	NC	3.94	0.00
Elejiji 1	0.22	0.12	NC	5.21	0.67
Elejiji 2	0.43	0.00	NC	5.91	4.67
Elejiji 3	0.39	0.46	NC	5.27	2.59
Elejiji 4	1.07	0.71	NC	5.32	5.22
Elejiji 5	1.68	1.88	NC	5.94	0.62
	15 – 30 cm depth				
RSU Ctrl	0.20	0.00	NC	5.69	2.05
Nsirim 1	0.59	2.06	NC	4.60	0.00
Nsirim 2	0.27	0.38	NC	5.38	0.57
Nsirim 3	0.19	1.13	NC	4.99	0.08
Nsirim 4	0.21	1.26	NC	4.13	0.00
Nsirim 5	0.63	0.85	NC	5.21	3.34
Elejiji 1	0.27	0.76	NC	6.82	0.23
Elejiji 2	0.38	0.00	NC	5.54	1.35
Elejiji 3	0.98	1.94	NC	6.55	4.30
Elejiji 4	0.43	0.43	NC	6.29	6.80
Elejiji 5	0.49	0.88	NC	6.79	5.02

NC = Not Calculated; due to unavailability of data

Ecological Risk Factor Range	Pollution/Risk Degree
Er < 40	Low potential ecological risk
40 ≤ Er < 80	Moderate potential ecological risk
80 ≤ Er < 160	Considerable potential ecological risk
160 ≤ Er < 320	High potential ecological risk
Er > 320	Very high potential ecological risk

Table 7: Soil Metal Index (SMI)

STATION	SOIL METAL INDEX	
	0 – 15 cm depth	15 – 30 cm depth
RSU Ctrl	18.6	33.6
Nsirim 1	23.0	39.2
Nsirim 2	34.2	32.3
Nsirim 3	49.1	34.1
Nsirim 4	28.1	32.1
Nsirim 5	36.2	50.7
Elejiji 1	29.4	40.2
Elejiji 2	47.2	31.8
Elejiji 3	37.8	73.1
Elejiji 4	63.2	62.8
Elejiji 5	59.5	61.5

SMI Range	Pollution Degree
SMI < 100	Unpolluted Soils
SMI > 100	Polluted Soils

IV. Discussion

Heavy Metal Levels in Soil

The results obtained from analysis of the various heavy metals in sediment were also compared with the standard limits established by the DPR (2002) target and intervention values for soils/sediments. Target values indicate the soil quality required for the full restoration of the soil's functionality for human, animal and plant life; the target values therefore indicate the soil quality levels ultimately aimed for (DPR, 2002). The intervention values indicate the quality for which the functionality of soil for human, animal and plant life are, or threatened with being seriously impaired; concentrations in excess of the intervention values correspond to serious contamination (DPR, 2002).

The target and intervention values for chromium in soil are 100 mg/kg and 380 mg/kg respectively (DPR, 2002). All stations recorded chromium levels below the target and intervention values for chromium at both the 0 – 15 cm and 15 – 30 cm depths. Elejiji 5 recorded the highest level of 83.952 mg/kg. These results suggest that the chromium levels in soil in the study area were within desirable concentrations and pose no potential threats of contamination.

The target and intervention values for copper in soil are 36 mg/kg and 190 mg/kg respectively (DPR, 2002). All stations recorded copper levels below the target and intervention values. Nsirim 3 recorded the highest level of 29.700 mg/kg. These results suggest that the copper levels in soil in the study area were within desirable concentrations and also suggest low potential threats of contamination.

The target and intervention values for lead (Pb) in sediment are 85 mg/kg and 530 mg/kg respectively (DPR, 2002). Only Elejiji 4 recorded lead level of 88.700 mg/kg and 115.500 mg/kg, at the 0 -15 cm and 15 – 30 cm depths respectively, above the target value. However, lead levels in all stations were below the intervention value. These results suggest that the lead levels in soil in the study area were within desirable concentrations, except in Elejiji 4, and pose no potential threats of contamination.

The target and intervention values for nickel in soil are 35 mg/kg and 210 mg/kg respectively (DPR, 2002). At the 0 – 15 cm depth, the Control station and Nsirim 1 – 5 stations recorded nickel levels below the target value while all the Elejiji 1 – 5 sample stations recorded nickel levels above the target value. At the 15 – 30 cm depth, all the sample stations, including the control station, recorded nickel levels above the target value; except Nsirim 1, Nsirim 3 and Nsirim 4 stations which recorded nickel levels below the target value. The nickel

levels, however, were below the intervention value. These results suggest potential threats of contamination in most of the stations, especially those at Elejiji.

The target value for iron (Fe) in soil is 38000 mg/kg (DPR, 2002). Iron levels in all stations were below the target value. These results suggest that the iron levels in soil in the study area were within desirable concentrations.

Soil Heavy Metal Pollution Indices

The results of the pollution indices calculated for the heavy metals in sediment were compared with the established pollution ranges to determine the degree of pollution/contamination based on the various indices.

Contamination Factor

Results of the Contamination Factor suggest that chromium, copper and iron had low contamination levels at both depths. Moderate nickel contamination levels, at the 0 – 15 cm depth, was recorded at the Elejiji 1, Elejiji 2, Elejiji 3, Elejiji 4 and Elejiji 5 stations, while at the 15 – 30 cm depth, the Control station, Nsirim 2, Nsirim 3, Nsirim 5, Elejiji 1, Elejiji 2, Elejiji 3, Elejiji 4 and Elejiji 5 stations also recorded moderate nickel contamination levels. Moderate lead (Pb) contamination levels, at the 0 – 15 cm depth, was recorded at the Elejiji 4 station, while at the 15 – 30 cm depth, the Elejiji 4 and Elejiji 5 stations also recorded moderate lead contamination levels.

Enrichment Factor (EF)

Enrichment Factor results suggest that low heavy metal enrichment was recorded in most stations, especially for chromium, copper and lead. However, moderate chromium enrichment was recorded only at the Control station at the 15 – 30 cm depth. Moderate copper (Cu) enrichment was recorded only at the Control and Elejiji 3 stations, at the 0 – 15 cm depth. Moderate nickel (Ni) enrichment, at the 0 – 15 cm depth, was recorded at the Nsirim 2, Nsirim 4, Elejiji 4 and Elejiji 5 stations, while the Nsirim 1, Nsirim 2, Nsirim 3, Nsirim 5, Elejiji 1, Elejiji 3, and Elejiji 5 stations recorded moderate nickel enrichment at the 15 – 30 cm depth. Moderate enrichment of lead (Pb) at the 0 – 15 cm depth, was recorded at the Control and Elejiji 4 stations while only Elejiji 5 recorded moderate lead enrichment at the 15 – 30 cm depth.

Significant chromium enrichment was recorded at Elejiji 3 and Eljiji 2, at the 0 – 15 cm and 15 – 30 cm depths respectively. Significant nickel enrichment at the 0 – 15 cm depth was recorded at the Nsirim 1 and Elejiji 1 stations while the Elejiji 4 station recorded significant nickel enrichment at the 15 – 30 cm depth. Significant lead enrichment was recorded on at Elejiji 4 station at the 15 – 30 cm depth.

Severe enrichment was observed only for lead and was recorded in Elejiji 3 station at the 0 – 15 cm depth, and the Control and Elejiji 2 stations at the 15 – 30 cm depth.

Very Severe enrichment was observed for nickel and lead metals. Very severe nickel enrichment was recorded at the Control, Elejiji 2 and Elejiji 3 stations at the 0 – 15 cm depth while the Control and Elejiji 2 stations recorded very severe nickel enrichment at the 15 – 30 cm depth. Very severe lead enrichment was recorded only at Elejiji 2 station at the 0 – 15 cm depth.

Geo-accumulation Index (I-geo)

The Geo-accumulation Index results suggest that all stations were uncontaminated with the heavy metals analyzed except for lead. Elejiji 3 was moderately contaminated with lead at the 0 – 15 cm depth while the Control and Nsirim 5 stations were also moderately contaminated with lead at the 15 – 30 cm depth.

Strong lead contamination was recorded at the Elejiji 2 and Elejiji 4 stations while the Elejiji 3, Elejiji 4 and Elejiji 5 stations also recorded strong lead contamination at the 15 – 30 cm depth.

Ecological Risk Factor (Er)

Ecological Risk results suggest that all the stations posed low potential ecological risk.

Soil Metal Index (SMI)

Soil Metal Index levels in the study area suggested that all the stations had unpolluted soils at the 0 – 15 cm and 15 – 30 cm depths.

V. Conclusion

The assessment of the soil samples in the study area revealed that most stations had chromium, iron, lead, nickel and manganese levels below their respective target values. Enrichment factor results revealed significant to very severe enrichment observed for chromium and nickel ions while the results of the soil metal index showed that all soil samples in the study area were unpolluted.