HEALTH RISK ASSESSMENT OF HEAVY METALS IN SOIL AROUND METAL SCRAP RECYCLING AREAS DURING WET AND DRY SEASONS IN OGIJO, OGUN STATE (SW Nigeria)

ABSTRACT

Aim: The aim of the study is to investigate the levels and risks associated with heavy metals in the soil samples collected during the dry and wet seasons around metal scrap recycling areas in Ogijo, Ogun State.

Study design: The soil samples were collected randomly within the industries and communities in the vicinity of the scrap metal recycling industries (SMRI) and analyzed with XRF.

Place and Duration of Study: The study was carried out in Ogijo in Sagamu Local Government Area, Ogun State, located within Southwestern Nigeria. The soil samples were collected in dry and wet seasons (5th to 7th March and 24th to 25th September, 2020 respectively.

Methodology: Soil samples within the industries and communities in the vicinity of the SMRwere collected randomly, dried and then sieved through a 2mm mesh stainless sieve.The sieved sample was analyzed for heavy metal concentration by using S2 Ranger, BrukerUKX-Ray Fluorescence Spectroscopy techniques (XRF).

Results: The results of the analyzed soil showed that the range of concentrations of heavy metals in the soil samples collected during dry season were: Fe (40100 - 87300 mg/kg); Mn (400 - 3500 mg/kg); Zn (600 -1300 mg/kg); Pb (400 - 1000 mg/kg) and during wet season: Fe (26100 -82700); Mn (500- 4200) mg/kg. Zn (600 – 1300) mg/kg; and Pb was only detected in S3 sample (600mg/kg). The results of the heavy metals were found to exceed the WHO permissible limits of heavy metals. Contamination index, degree of contamination and pollution load indices indicated slight contamination to excessive pollution, very high risk of degree of contamination and extremely polluted soils respectively. Geo-accumulation index was uncontaminated to moderate contamination ($0<Igeo\leq1$) with different metals at different locations that were not detected and with all the detected Zn concentration (except at S1) to extreme contamination ($Igeo\geq5$).Heavy metal enrichment during both dry and wet seasons ranged from background rank ($EF \leq 1$) to moderate enrichment. Eri values ranged from low (Eri) <40) to moderate ecological risk (Eri > 80) with all the risk indices of the locations low (RI <150). The cumulative non-carcinogenic, the health index (HI) for ingestion and dermal for soil during the dry season were all above 1 indicating non - carcinogenic health concern for the residents of the study areas as they recorded higher values.The CRI was far above the acceptable limit indicating that residents in S3 during wet season and S2 and S9 during the dry season have probability of contracting cancer through ingestion within the life time of 70 years.

Conclusion: The results of pollution indices show that the quality of soil in the study entirely deteriorated with respect to the DPR background. This indicates that the soil could not be used for any agricultural and domestic purposes.

*Keyword: Heavy metals, pollution indices, scrap metal, recycling,*Ogijo

1. INTRODUCTION

There is an emerging environmental and human health problem in the world due to the indiscriminate disposal and storage of metal scraps. The environmental problem with heavy metals is that they are unaffected during the degradation of organic waste and have toxic effects on living organisms when exceeding a certain concentration. Exposure to heavy metals has been reported to cause blood and bone disorders, kidney damage and decreased mental capacity and neurological damage [1]. Industries, through their various processes, generate toxic pollutants. Some of these pollutants are in particulates form, while others are not. In developed countries, environmental protection agencies ensure that industries install and maintain pollution abatement technologies in order to reduce concentrations of the pollutants to meet permissible guidelines. However, insomecountries, environmental protection agencies are hardly effective, in that very little efforts are geared towards pollution control devices, if they exist at

all. The consequence of the ineffectiveness is that industries emit these pollutants into the workplace and the environments. Unfortunatelyinsomecountries, industries are sometimes located in residential and commercial areas partly due to lack of proper enforcement of urban planning bye-laws. Both the populace in the vicinity of such industries and the workers in the industries are exposed to the pollutants as since they spend most of their time within the polluted environment [2]

Scrap metals are among the most important priced materials in Municipal Solid Waste [3]. Iron and steel scrap recycling has been of double advantage to Nigeria in terms of its contribution to secondary steel smelting. The scrap serves as a raw material source and a waste management method for handling materials that would have otherwise constituted various forms of environmental hazards into useful forms [4 - 5].Human exposure has risen dramatically as a result of an exponential increase of their use in several industrial, agricultural, domestic and technological applications. Environmental pollution is very prominent in point source areas such as mining, foundries and smelters, and other metal-based industrial operations [6].

Heavy metals such as As, Cd, and Cr even at trace amounts, are toxic. This has been reported to be constituents of particulate matter associated with iron and steel production [7]. Ogijo community has been shown to contained considerable amounts of industries that are reported to discharge toxic metals arising from activities of these industries into the environment and these could have serious effects on the health of humans. However, there is limited documented information on the level of soil contamination with heavy metals around the Ogijo iron and steel foundry. The aim of this study is to assess the levels of heavy metals in soilsfrom metal recycling facilities that converts scrap materials into steel products in Ogijo, Ogun State.

1.1 Soil pollution indices

Pollution assessment models are indicators used to assess the presence and intensity of anthropogenic contaminant deposition on soils. In this study, the following pollution assessment models were employed: Contamination Index (CI), Pollution Load Index (PLI), Contamination Degree (CD), Geo-accumulation Index (Igeo), ecological factors, risk index and Nemerow Index

1.1.1 Contamination index (CI): The contamination factors were calculated as

CF= $Cn/_{Bn}$ (1)

Where Cn = measured metal concentration and Bn = background concentration from control site. Contamination factor was expressed as; CF<1 (low risk), 1≤ CF<3 (moderate risk), 3≤CF<6 (considerable risk) and CF≥6 (very high risk)[8.9]

1.1.2 Degree of contamination = $\Sigma CF_a+CF_b+CF_{C+}CF_d+CF_f+$CFn. the degree of contamination was assessed as; CD<8 (low risk), 8≤CD<16 (moderate risk), 16≤CF<32 (considerable risk) and CD>32 (very high risk). [9, 10]

1.1.3 Pollution Load Index = $\sqrt{CFa\ x\ CFb\ x\ CFc\ x\ CFd\ x\ CFe\ x\ CFf\ xCFn}$. The pollution load index was depicted as; PLI < 1 (no pollution); 1< PLI< 2 (moderate pollution); 2< PLI< 3 (heavy pollution); 3<PLI (extremely heavy pollution). [8. 10]

1.1.4 Ecological risk= (Tr) x (CF), where CF is the contamination factor and Tr is the toxic response factor viz: Cr=2, Pb=Cu=5, Cd=30 and Zn=1. The ecological risks were classified as Er<40 (low), 40≤Er<80 (moderate), 80≤Er<160 (considerable), 160≤Er<320 (high) and Er≥320 (very high) [8 – 10]

1.1.4 Risk index = $\Sigma Eria+Erib+Eric+Erid+Erie+Erin$. The resultant values were rated as; R'<150 (low), 150≤R'<300 (moderate), 300≤R'<600 (considerable) and R'≥ 600 (very high).[9, `10]

1.1.5 Enrichment factor $=\frac{\text{HM s / Fe s}}{\text{HMb/ Feb}}$. Where enrichment factor of ≤1 (background rank), 1- 2 (minimal enrichment), 2 – 5 (moderate enrichment), 5 – 20 (significant enrichment), 20 – 40 (very high enrichment) and >40 (extremely high enrichment).[10].

1.1.6 Geo-accumulation index = Log_2 (C*i*/1.5Bn)Geo-accumulation index was reflected as; Igeo≤0 (uncontaminated), 0<Igeo≤1 (uncontaminated to moderate contamination), 1<Igeo≤2 (moderate contamination), 2<Igeo≤3 (moderate to heavy contamination), 3<Igeo≤4 (heavy contamination), 4<Igeo≤5 (heavy to extreme contamination) and Igeo≥5 (extreme contamination [8 - 11].

1.2Health Risk Characterization

The risk exposure pathways involve taking the average daily intake (ADI) of the toxic metals (mg/kg day) following oral ingestion and dermal contact route using the methods described in equations 1 and 2

$ADIing = 10^{-6} \times Csoil \times (IngR \times EF \times ED)/(BW \times AT)$ ….. (1)

$ADIdermal = 10^{-6} \times Csoil \times (SA \times AF \times ABS \times EF \times ED)/(BW \times AT)$ …… (2)

The ADIingand ADIdermal stand for average daily intake (ADI) for ingestion, inhalation and dermal exposure pathways respectively and Csoil is the heavy metal concentration in the soils around metal recycling area. Other parameters and their corresponding functions are described in Table 1[12].

Table 1: Exposure factors used for the health risk assessment through different exposure pathways for soil

Factor	**Unit**	Adults
Body weight (BW)	Kg	70
Exposure frequency (EF)	days/year	350
Exposure duration (ED)	years	30
Ingestion rate (IngR)	mg/day	100
Skin surface area (SA)	m^2	5800
Soil adherence factor (AF)	mg/cm^2	0.7
Dermal Absorption factor (ABS)		0.1
Conversion factor (CF)	kg/mg	10-6
average time (AT) For carcinogen For non - carcinogen	Days	 365 x 70 365 x ED

Hazard Quotient (HQ), the health index (HI) and the probability of developing any type of cancer over a lifetime Will be evaluated by equations 4 – 6 respectively

$HQ = ADIi/RfDi$ …… (4)

$HI = \Sigma HQi$ …… (5)

$CRI = ADIi \times CSFi$ …….... (6)

(/RfDi of Fe, Mn,Pb and Zn are 0.7,0.046,0.035 and 0.3 respectively while theCSFi of Pb is 8.5)[12]

2.0 MATERIALS AND METHODS

2.1 Area of Study

Ogijo is in Sagamu local Government Area, Ogun State, located within Southwestern Nigeria. The Local Government has an area of 614 km^2 and it's geographical coordinates are 6° 42' 0" North, 3° 31' 0" East. The industries in the study area are mostly scrap metal recycling companies. The Sagamu is a conglomeration of thirteen towns located in Ogun State along the Ibu River and Eruwuru Stream between Lagos and Ibadan, founded in the mid-19th century by members of the Remo branch of the Yoruba people in south-western Nigeria. The 13 towns that made it up are: Makun, OffinSonyindo, Epe, Ibido, Igbepa,Ado, Oko, Ipoji,Batoro, Ijoku, Latawa and Ijagba.It is the capital of Remo Kingdom and the paramount ruler of the kingdom - Akarigbo of Remo's palace is in the town of Offin in there. The Sagamu region is underlain by major deposits of limestone, which is used in the city's major industry, the production of cement. Agricultural products of the region include cocoa and kola nuts. Sagamu is the largest kola nut collecting center in the country.

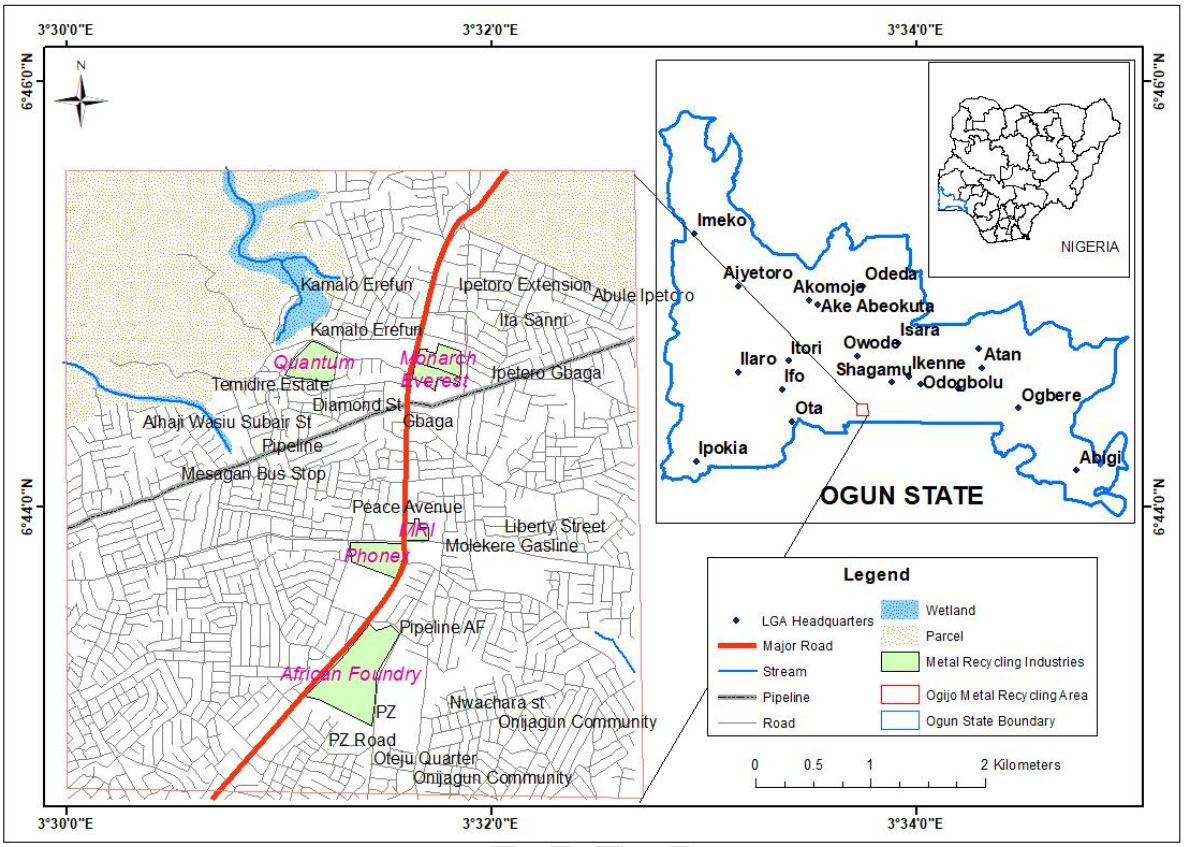

Figure 1 Map of the Study Area Showing Soil Sampling Points

The soil samples were collected from the following locations: Kamalo (S1),Erefun (S2), Ipeterogbaga (S3), Ipetero (S4),Ita Sanni (S5), Ita Sanni (S6), Ipetero Pipeline (S7), Blessed Estate (S8), Jagun Community (S9), Aiyedade (S10), PZ Estate Afi Suru (S11), Mayoteju (S12), Ajoshe (S13), Alasia Powerline (S14), Milverton Avenue (S15) and Unilag campus (CS, which serve as the control).

2.2 SAMPLING AND SAMPLE PREPARATION

2.2.1 Soil Sampling

Soil samples for the studied areas were collected using stainless-steel auger. The soil samples were collected randomly within the industries and communities in the vicinity of the scrap metal recycling industries (SMRI). At each sampling site, 4 soil samples were obtained from each site in a 10 m square grid at a depth of 15cm and mixed to obtain composite samples for each of the sites. The samples were placed in polythene bags sealed, labeled and transported to laboratory prior to heavy metal analyses. The soil samples were collected in dry and wet seasons (5th to 7th March and 24th to 25th September, 2020 respectively). In the laboratory, the soil samples were dried and then sieved through a 2mm mesh stainless sieve.

2.2.2 Determination of heavy metals by XRF: The2mm mesh sieved samples were analyzed for heavy metal concentration by using S2 Ranger, Bruker UK X-Ray Fluorescence Spectroscopy techniques (XRF) [13].

2.3 Quality Control

Standard operation procedures (SOPs) were followed in laboratory techniques. Sampling was done according to established protocols from the scrap metal recycling sites and control site, and precautions were taken to prevent contamination during the sampling process. They were air dried and stored in sterilized containers prior to analysis. The equipment wascalibrated and handled in accordance to National Chemical Laboratories (NCLs) regulations.

2.4 Statistical Analysis

The statistical analysis was performed using the analysis of variance (ANOVA), correlation and t-test to determine the differences between treatments mean at significant level ($p = 0.05$). Standard errors of mean were estimated. All statistics were run using statistical package for social sciences (SPSS) (25.0) version.

3.0 RESULTS AND DISCUSSION

3.1 Heavy Metal Concentrations in Soil Samples

The concentrations (mg/kg) of Cd, Cr,Fe, Mn, Zn and Pb of soil samples during dry and wet seasons are depicted in Table 2. Generally, the concentrations of the metals in the soil samples were in the decreasing order: of Fe>Mn>Pb>Zn >Cd = Cr.

3.1.1 Cadmium (Cd) and chromium (Cr)

In all the soil samples collected both in dry and wet seasons, the concentration of Cd and Cr were found to be below detection limit. This indicates that the soil could not be likely contaminated with Cd and Cr. The long-term use of contaminated soil with high levels of metals may cause an accumulation of the metals in soils and crops [14].

3.1.2 Iron (Fe)

The concentration of Fe in the soil samples collected during dry season ranged from 40100 to 87300 mg/kg while the concentration of Fe during wet season ranged from 26100 to 82700 mg/kg. The highest concentration of 87300 mg/kg of Fe was observed in sample at S1 (dry season) while the lowest concentration of 40100 mg/kg of Fe was observed in sample CS (dry season) which serves as control during dry season. In the wet season, the highest concentration of 82700 mg/kg of Fe was observed at of S1 and the lowest concentration of 26100 mg/kg of Fe was observed at CS. The Fe contents of the soils are higher than the FAO/WHO (2001) [15] safe limit of 425 mg/kg. The results obtained in this study were higher than the findings of Oladebeye [16] who observed Fe concentration in the range of 22089 to 64282 mg/kg in soil sample from Owo and Edo axes. The high concentrations of Fe in the soil samples may suggest a very rich anthropogenic source of Fe, which allows the percolation of Fe to the soil depths rather the surfaces. High levels of exposure to Fe dust may cause respiratory diseases such as chronic bronchitis and ventilation difficulties.

3.1.3 Manganese (Mn)

The range of Mn concentrations in the soil samples during dry season was between 400 and 3500 mg/kg during the dry season while the concentration of Mn during wet season ranged from 500 to 4200 mg/kg. The highest concentration of 3500 mg/kg of Mn during dry season was observed at S13 while the lowest concentration of 500 mg/kg of Mn was observed at S2.. During wet season, the highest concentration of 4200 mg/kg of Mn was observed at S3 while the lowest concentration of 500 mg/kg of Mn was observed in sample S2. Oladebeye[16] reported a lower concentration of Mn between 104.39 and 1642.32 mg/kg in his study. Manganese is a very essential trace heavy metal for plant and animals' growth. Its deficiency produces severe skeletal and reproductive abnormalities in mammals. High concentration of manganese (Mn) causes hazardous effects on lungs and brains of humans.

Table 2: Concentrations of heavy metals in soil (mg/kg) around metal recycling areas of Ogijo, Ogun State during wet and dry seasons

Location	Wet season						Dry season						
	Cd	Cr	Fe (mg/kg)	Mn (mg/kg)	Pb (mg/kg	Zn (mg/kg)	Cd	Cr	Fe (mg/kg)	Mn (mg/kg)	Ni (mg/kg)	Pb (mg/kg)	Zn (mg/kg)
S1	ND	ND	82700±20.38d	3900±11.25d	ND	600±5.87a	ND	ND	87300.0±38.45d	700.0±11.48a	ND	ND	600±3.51b
S2	ND	ND	60400±31.21c	500±5.27a	ND	ND	ND	ND	49800.0±27.56a	500.0±6.87a	ND	1000±0.34b	ND
S3	ND	ND	81400±25.71d	4200±9.08d	600±30 a	600±6.47a	ND	ND	69200.0±28.14b	3400.0±11.80d	ND	ND	ND
S4	ND	ND	64300±10.97c	3500±11.27d	ND	ND	ND	ND	55800.0±37.41b	1800.0±8.71b	ND	ND	ND
S5	ND	ND	55700±38.12b	1600±8.47a	ND	ND	ND	ND	75100.0±28.43c	1600.0±8.47b	ND	ND	400±2.87a
S6	ND	ND	74100±25.19c	2700±12.10c	ND	ND	ND	ND	65400.0±29.15b	3200.0±10.14d	ND	ND	400±3.61a
S7	ND	ND	73700±25.69c	2800±9.84c	ND	ND	ND	ND	82300.0±27.19d	2300.0±8.74c	ND	ND	ND
S8	ND	ND	43800±31.06b	1900±8.24a	ND	ND	ND	ND	75400.0±28.24c	1700.0±6.14b	ND	ND	400±2.18a
S9	ND	ND	55900±27.84b	1800±8.31a	ND	1300±9.82b	ND	ND	79600.0±37.15c	2800.0±9.46d	ND	400±0.21a	700±6.18b
S10	ND	ND	64300±27.35c	2100±10.08b	ND	ND	ND	ND	57700.0±38.14b	3100.0±8.51d	ND	ND	ND
S11	ND	ND	67100±38.15c	2000±8.13b	ND	ND	ND	ND	73300.0±27.19c	2200.0±4.97c	ND	ND	400±3.17a
S12	ND	ND	64700±28.17c	2000±12.08b	ND	ND	ND	ND	64700.0±24.17b	2000.0±5.78c	ND	ND	ND
S13	ND	ND	58600±22.13b	1700±5.64a	ND	ND	ND	ND	72300.0±23.14c	3500.0±14.27d	ND	ND	400±3.78a
S14	ND	ND	57400±32.17b	2000±6.17b	ND	ND	ND	ND	62200.0±25.11b	1800.0±6.41b	ND	ND	ND
S15	ND	ND	73400±31.08c	2100±7.82b	ND	ND	ND	ND	85900.0±41.57d	3000.0±9.47d	ND	ND	600±6.72b
CS	ND	ND	26100±21.81a	ND	ND	ND	ND	ND	40100.0±27.54a	400.0±2.78a	ND	ND	ND
WHO	0.35	100	425			50							

Note: Mean values with different superscript alphabets are significant at p = 0.05

3.1.4 Zinc (Zn)

In wet season, Zn has a mean concentration ranging from 600 to 1300 mg/kg, with the lowest values of 600 mg/kg at S1 and S3 and the highest value of 1300 mg/kg was found at WS9. In the dry season, Zn has mean concentration ranging from 400 to 700 mg/kg, with the lowest values of 400 mg/kg at S5, S6,S8, S11and S13 while at S9 had the highest Zn concentration of 700 mg/kg as observed in Table 2.The Zn concentrations obtained were found to be above the WHO (2008) permissible limit (50 mg/kg). Zn concentrations in the range of 0.00 to 184.74 mg/kg were measured in polluted soils reported by Oladebeye [10]. Also, Kodomet al., [17] reported lower values for Zn from soils samples collected around industrial area in Kumasi, Ghana. These high values suggested anthropogenic contribution pollution of the soil; metal recycling facilities that convert scrap materials into steel products in the study area could contribute to high input of Zn in the soils.

3.1.5 Lead (Pb)

The concentration of Pb in the analyzed soil samples ranged from 400 and 1000 mg/kg at S2 and S9 respectively in dry season and was detected only in sample S3 (600mg/kg) in wet season. In this study, soil samples from S2 had the highest Pb concentration while at S9 had the lowest Pb concentration. The Pb concentrations in the detected soil samples were found to be above WHO permissible limit (300 mg/kg) of Pb in soil. The High Concentration of lead in the soils from samples during dry seasons at the locationsS2 and S9 and during wet season at locationS3 could be due to the activities carried out in the metal recycling industrial areas, automobile exhaust fumes and atmospheric depositions. Human beings, animals and soil are the ultimate recipients of the lead particulate. Pb levels obtained in this study were lower than reported by Sridhar et al. [18] in soil samples collected in Ibadan and Lagos with concentrations from 81.91 to 4060 and 140.0 to 5454 mg/kg in residential and mechanic areas respectively. Lead is ranked as one of the most toxic heavy metals affecting man, animal and plant which have been used by mankind for several years because of its wide variety of applications [19]. Pb has been presented to affect every organ in the body. Akbarpour *et al*. [20] reported that Pb is a toxicant, cardiovascular system, central and peripheral nervous systems, kidneys, immune system, and reproductive system [21]. Irreversible brain damage reported, when the Pb level of blood exceeds 100 µg/dl in adults and 80-100 µg/dl in children

Table 3: The contamination factors, degrees of contamination and pollution load indices of heavy metals in soil during wet and dry seasons

Location	Contamination factors (wet)					CD	PLI	Contamination factors (dry)					CD	PLI
	Cr	Fe	Mn	Pb	Zn			Cr	Fe	Mn	Pb	Zn		
S1	0.00	16.54	45.88	0.00	4.29	66.71	14.78	0.00	17.46	8.24	0.00	4.29	29.98	8.49
S2	0.00	12.08	5.88	0.00	0.00	17.96	8.43	0.00	9.96	5.88	11.76	0.00	27.61	8.83
S3	0.00	16.28	49.41	7.06	4.29	77.04	12.49	0.00	13.84	40.00	0.00	0.00	53.84	23.53
S4	0.00	12.86	41.18	0.00	0.00	54.04	23.01	0.00	11.16	21.18	0.00	0.00	32.34	15.37
S5	0.00	11.14	18.82	0.00	0.00	29.96	14.48	0.00	15.02	18.82	0.00	2.86	36.70	9.29
S6	0.00	14.82	31.76	0.00	0.00	46.58	21.70	0.00	13.08	37.65	0.00	2.86	53.58	11.18
S7	0.00	14.74	32.94	0.00	0.00	47.68	22.04	0.00	16.46	27.06	0.00	0.00	43.52	21.10
S8	0.00	8.76	22.35	0.00	0.00	31.11	13.99	0.00	15.08	20.00	0.00	2.86	37.94	9.49
S9	0.00	11.18	21.18	0.00	9.29	41.64	12.97	0.00	15.92	32.94	4.71	5.00	58.57	10.54
S10	0.00	12.86	24.71	0.00	0.00	37.57	17.82	0.00	11.54	36.47	0.00	0.00	48.01	20.52
S11	0.00	13.42	23.53	0.00	0.00	36.95	17.77	0.00	14.66	25.88	0.00	2.86	43.40	10.25
S12	0.00	12.94	23.53	0.00	0.00	36.47	17.45	0.00	12.94	23.53	0.00	0.00	36.47	17.45
S13	0.00	11.72	20.00	0.00	0.00	31.72	15.31	0.00	14.46	41.18	0.00	2.86	58.49	11.91
S14	0.00	11.48	23.53	0.00	0.00	35.01	16.44	0.00	12.44	21.18	0.00	0.00	33.62	16.23
S15	0.00	14.68	24.71	0.00	0.00	39.39	19.04	0.00	17.18	35.29	0.00	4.29	56.76	13.71
CS	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 3 presents the contamination factor, degree of contamination and pollution load index of soil heavy metals for dry season. The contamination factor ranged from low (CF < 1) to very high (CF ≥ 6). Apart from metals that were not detected and the detected Zn, all other detected metals concentrations depicted very high (CF ≥ 6) with DPR (2002) [22] background scenario. Ngole-Jeme&Fantke [23] reported lowerheavy metal and metalloid contamination factors *Cf* at the different sites that ranged from 1.3 to 345 (Site 1), 0.4 to 3.2 (Site 2) and 0.4 to 2 (Site 3), with abandoned gold mine tailings contaminated soil of Krugersdorp, South Africa

The degree of contamination of the detected metals were all at very high risk (CD>32) except in S1, S2 and the controlwhile pollution load index that provides information about heavy metal toxicity indicated that the soils were extremely heavy pollution (3<PLI) during wet and dry season in all locations (except the control)with the DPR background considerations. This is however contrary to the work of Aigberua et al. [10] on heavy metals in sediment of Taylor creek due to anthropogenic activities in the Niger Delta region of Nigeria and Ikpe et al. [24] on use of integrated pollution indices in assessing heavy metals pollution in soils of three auto mechanic villages in Abuja both recorded pollution at different levels. The results of contamination factor, degree of contamination and pollution load index show that the quality of soil in the study area is entirely deteriorated with respect to the DPR (2002) [22]background.

Table 4: Ecological factors, Risk indices and Enrichment factors of soils in metal recycling areas

	Ecological factors (wet)			Risk Index	Ecological factors (dry)				Risk Index	Enrichment factor (wet)				Enrichment factor (dry)				
Location	**Cr**	**Pb**	**Zn**	**(wet)**	**Cd**	**Cr**	**Pb**	**Zn**	**(dry)**	**Cr**	**Mn**	**Pb**	**Zn**	**Cd**	**Cr**	**Mn**	**Pb**	**Zn**
S1	0.00	0.00	4.29	4.29	0.00	0.00	0.00	4.29	4.29	0.00	2.77	0.00	0.26	0	0.00	0.47	0.00	0.25
S2	0.00	0.00	0.00	0.00	0.00	0.00	58.82	0.00	58.82	0.00	0.49	0.00	0.00	0	0.00	0.59	1.18	0.00
S3	0.00	35.29	4.29	39.58	0.00	0.00	0.00	0.00	0.00	0.00	3.04	0.43	0.26	0	0.00	2.89	0.00	0.00
S4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.20	0.00	0.00	0	0.00	1.90	0.00	0.00
S5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.86	2.86	0.00	1.69	0.00	0.00	0	0.00	1.25	0.00	0.19
S6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.86	2.86	0.00	2.14	0.00	0.00	0	0.00	2.88	0.00	0.22
S7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.23	0.00	0.00	0	0.00	1.64	0.00	0.00
S8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.86	2.86	0.00	2.55	0.00	0.00	0	0.00	1.33	0.00	0.19
S9	0.00	0.00	9.29	9.29	0.00	0.00	23.53	5.00	28.53	0.00	1.89	0.00	0.83	0	0.00	2.07	0.30	0.31
S10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.92	0.00	0.00	0	0.00	3.16	0.00	0.00
S11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.86	2.86	0.00	1.75	0.00	0.00	0	0.00	1.77	0.00	0.20
S12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.82	0.00	0.00	0	0.00	1.82	0.00	0.00
S13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.86	2.86	0.00	1.71	0.00	0.00	0	0.00	2.85	0.00	0.20
S14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.05	0.00	0.00	0	0.00	1.70	0.00	0.00
S15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.29	4.29	0.00	1.68	0.00	0.00	0	0.00	2.05	0.00	0.25
CS	0.00	0.00	0.00	0.00	0	0	0	0	0.00	0.00	0.00	0.00	-	0	0.00	.00	0.00	0.00

The ecological factors(Eri),risk indices (RI) and Enrichment factors for wet and dry seasons of soil samples from the study areas is displayed in Table 4. Eri for Pb values ranged from 0.00 (low, Eri <40) at different locations including the control to moderate ecological risk (Eri > 80) at S2 during dry season. Zn values were all low, (Eri) <40) including the control. Soils contaminated by heavy metals can cause serious ecological risks and negatively impact human health due to various forms of interaction (agriculture, livestock, etc.) where highly toxic heavy metals can enter the food.All the risk indices of the locations were low (RI <150). The results indicated the areas are safe domain for most benthic organisms.

Heavy metal enrichment during the wet season ranged from background rank (EF ≤ 1) with many metals in different locations to moderate enrichment (2 - 5). Minimal enrichment (1- 2) were observed with Mn at S5,S9 -S13, S15 during wet season and S4, S5 - S7, S11 - S12 and S14 during the dry season; Pb at S2 during the dry season and CS, Zn (S9) and moderate enrichment (2 – 5) with Mn at S1. S3, S6, S7, S8, S14 during the wet season and at S3, S6, S9, S10, S13 and S15 during the dry season. Heavy metal enrichment within soil of the study area may have resulted from the presence of scraps recycling plants.

Geo-accumulation index was uncontaminated to moderate contamination ($0<Igeo\leq1$) with different metals at different locations that were not detected and with all the detected Zn concentration (except at S1) during wet season (Table 5). Geo-accumulation index was moderate contamination ($1<Igeo\leq2$) only with Pb at S9 and Zn at S1 during the wet season. The Geo-accumulation index was moderate to heavy contamination ($2<Igeo\leq3$) with Fe at S2, S4, S10, Pb S2 during wet and with Zn at S1 and S3 during dry season. Heavy contamination geo accumulation index ($3<Igeo\leq4$) was with Fe at S1. S3, S5 –S9, S11 – S15 during wet season and heavy to extreme contamination geo accumulation factor index ($4<Igeo\leq5$) was observed with Pb at S2 and Zn at S10 both during the dry season with all other heavy metals detected were in extreme contamination ($Igeo\geq5$). The order of heavy metals responsible for the geo-accumulation in the soils is as follows: Fe > Zn >Pb. This high risk of contamination in the area could be because; metal scrap-recycling is fast becoming a major activity due to increasing per capita consumption of steel and shortage of iron ore in the country. Scrapyards are haphazardly sited in the areas where all kinds of scraps from abandoned automobiles, machineries, and electrical appliances are disassembled and recycled for further uses. Many of these scrap materials are made up of materials that are toxic and adversely affect the environment after improper management [25].Therefore, measure needs to be put in place to reduce anthropogenic activities in the area, because, these metals are very hazardous to health of humans, plants and animals when in high concentrations (Nwankwoala&Ememu [8]. This is slightly higher than in the work of Charles et al. ,[13] that found soil of abandoned mine area of Du in Plateau with Igeo class ($0 \leq Igeo< 1$ to ($4 \leq Igeo< 5$).

Table 5: Geo accumulation of heavy metals in soil during dry season

Location	Geo accumulation factor (dry)					Geo accumulation factor (wet)			
	Cd	Cr	Fe	Pb	Zn	Cr	Fe	Pb	Zn
S1	-	-	11.03	-	2.86	-	3.54	-	1.51
S2	-	-	8.05	-	-	-	2.73	2.97	-
S3	-	-	10.85	4.71	2.86	-	3.21	-	-
S4	-	-	8.57	-	-	-	2.90	-	-
S5	-	-	7.43	-	5.79	-	3.32	-	0.93
S6	-	-	9.88	-	5.04	-	3.12	-	0.93
S7	-	-	9.83	-	-	-	3.46	-	-
S8	-	-	5.84	-	5.39	-	3.33	-	0.93
S9	-	-	7.45	6.19	-	-	3.41	i.65	-
S10	-	-	8.57	-	4.57	-	2.94	-	-
S11	-	-	8.95	-	5.34	-	3.29	-	0.93
S12	-	-	8.63	-	-	-	3.11	-	-
S13	-	-	7.81	-	6.10	-	3.27	-	0.93
S14	-	-	7.65	-	-	-	3.05	-	-
S15	-	-	9.79	-		-	3.52	5.43	-
CS	-	-	-	-	-	-	-	-	-

Table 6: Nemerow Index (IIN) for metals in the soils of Sagamu metal recycling areas during wet and dry Seasons

Season	**Cr**	**Fe**	**Pb**	**Zn**
Wet	0	13.71	6.66	7.35
Dry	0	4.78	3.76	1.83

The IIN in study area (Table 6) soils ranged from safety domain in metals that were not detected to seriously polluted domain in all the metals detected. The serious degree of contamination indicated by this index may be due to anthropogenic processes (scrap recycling in the areas), which led to an increase in geological concentrations in the soils. By using the IIN, heavy metal contamination levels were in the order of dry < wet.This agrees with the work ofFernando *et al*. [9] that reported that, the Nemerow Index pollution levels in the La Zanja area showed that most soil samples (70%) were contaminated, 20% were moderately contaminated, and 10% were strongly contaminated, mainly by Pb.

Table 7: Ingestion and dermal health indices of heavy metals in soil during wet and dry season

Sample code	Wet season		Dry season		
	HIing	HIder	HIing	HIder	Total
S1	0.12	0.49	0.08	0.33	1.02
S2	0.06	0.23	0.22	0.88	1.39
S3	0.22	0.91	0.10	0.41	1.64
S4	0.10	0.40	0.07	0.28	0.85
S5	0.07	0.27	0.08	0.34	0.76
S6	0.10	0.39	0.10	0.39	0.98
S7	0.10	0.40	0.10	0.40	1
S8	0.06	0.25	0.09	0.34	0.74
S9	0.07	0.29	0.17	0.69	1.22
S10	0.08	0.33	0.09	0.36	0.86
S11	0.08	0.33	0.09	0.36	0.86
S12	0.08	0.32	0.08	0.32	0.8
S13	0.07	0.29	0.11	0.43	0.9
S14	0.07	0.30	0.08	0.30	0.75
S15	0.09	0.36	0.11	0.45	1.01
CS	0	0.00	0	0.00	0
Total	1.37	5.64	1.56	6.44	

Key:HIing = Ingestion health index **:**HIder dermal health index

The total non-carcinogenic health indices (HI) for various heavy metals for the ingestion and dermalpathways for each different soil in the study area were summarized in Table 7. The non-carcinogenic risks posed by combining the respective HQ values for each exposure pathways (health index (HI))values were observed to be<1, which means there was no associatedpotential health risks for residents of the study areas. The HI values higher in dermal pathway than ingestion pathway. The HI values for both ingestion and dermal were higher during the wet season than during dry season. According to thelocation, the HIs increase in the order S3>S2>S1>S15>S7>S6>S14>S10=S11>S4. The control area was not associated withany potential health risk in the metals studied.

Table 8: Cancer risk (CRI) values for heavy metals through the ingestion exposure pathway of soils around the recycling industries in Lagos

Location	Pb wet	Pb dry
S1	-	-
S2		0.005
S3	0.002	
S4		
S5	-	-
S6	-	-
S7	-	-

S8	-	-
S9	-	0.003

The lifetime cancer risk (CRI) for the adults are presented in Table 8. The cancer risk was analyzed for Pb (because the slope factors for Mn, Zn and Fe were not available) for the ingestion exposure pathway. For regulatory purposes, a cancer risk in the range of 10^{-6} to 10^{-4} is considered acceptable [12]. From the results presented, the CRI was far above the acceptable limit of 10^{-6} – 10^{-4} indicating that residents in S3 during wet season and S2 and S9 during the dry season have a probability of contracting cancer through ingestion within the life time of 70 years due to Pb.

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4.0 CONCLUSION

The investigated levels of heavy metals in the soil samples collected both during the dry and wet seasons around metal scrap recycling in Ogijo, Ogun State were found to exceed the World Health Organization permissible limit for heavy metals in unpolluted soil. The results of pollution indices showed that the quality of soil in the study entirely deteriorated with respect to the DPR background. This indicates that the soil could not be used for any agricultural and domestic purposes. The HIs were all lower than 1 but the CRIs were far above the acceptable limits indicating that residents in S3 during wet season and S2 and S9 during the dry season have a probability of contracting cancer (due to Pb) through ingestion within the life time of 70 years

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