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Assessment of Heavy Metals Levels in Waste Receptacle Soils in Rukpokwu, Obio/Akpor, Port Harcourt, Rivers State, Nigeria

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ABSTRACT

Heavy Metals Levels in soils used as a waste receptacle in Rukpokwu, Obio/Akpor, Port Harcourt, Rivers State, Nigeria were assessed. The heavy metals were determined using Atomic Absorption Spectroscopy methods. The mean levels of the heavy metals investigated in the soil of temporary dumpsites of Rukpokwu were; iron (Fe) 256.649±17.533mg/Kg, lead (Pb) 11.984±3.435mg/Kg, copper (Cu) 9.295±2.075mg/Kg, zinc (Zn) 22.268±3.669mg/Kg, cadmium (Cd) 2.897±0.584mg/Kg, manganese (Mn) 6.586±0.654mg/Kg, chromium (Cr) 12.244±1.834mg/Kg, nickel (Ni) 9.185±2.046mg/Kg, arsenic (As) 2.003±0.284mg/Kg and cobalt (Co) 2.042±0.288mg/Kg. The levels of the studied heavy metals were in the order Fe > Zn > Cr > Pb > Cu > Ni > Mn > Cd > Co > As. The pollution assessment indices used in the evaluation of the heavy metals showed that anthropogenic activities have slightly influenced the concentration of heavy metals in the temporary dumpsites. The indices were contamination factor, which showed low contamination, geo-accumulation indicated not contaminated to moderate contamination, potential ecological risk revealed low risk and potential ecological risk index showed moderate risk. These indices revealed that the studied heavy metals have contaminated the soil slightly but have not reached an alarming level.

Keywords: Contamination Indices, dumpsites, heavy metals, pollution, Rukpokwu
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INTRODUCTION

The sudden increase in urban population owing to drift from rural areas has ended in the growth of anthropogenic activities, which has also resulted in commensurate increase in industrialization, commercial and economic development (Yiran et al., 2013). The increased anthropogenic activities that arose due to urbanization have brought about the generation of enormous waste and have also given rise to temporary dumpsites (waste receptacles) at selected areas for refuse disposal (Marcus et al., 2017; Iyama and Edori, 2020). There is no proper laid down guidelines and rules on the method of waste disposal as the diverse classes and kinds of wastes dumped are not carefully dumped at the mandatory chosen points as specified by the appropriate authorities. These wastes dumped comprises of certain hazardous chemicals and heavy metals which may pose risk to human health. These discarded wastes that emanated from homes, commercial centres, industries and other public places such as motor parks and restaurants and possesses undesirable effects on the geochemical levels of the various chemical species in the soil used for the refuse dumping (Nwoke and Edori, 2020b).

Soil naturally is a valuable resource and it is most useful in the support of food production both for humans and other creatures due to its significance in agriculture. Soil is vital in its compositions and through it, the elementary need of food is realized in the life of humans and other living creatures. The soil offers the basic sustenance for agricultural systems and food production (De Albal et al., 2003; Kekane et al., 2015). To improve productivity there is a need for the preservation of the ecosystem which relies more greatly on the soil than any other resource as the physicochemical nature, properties and biological constituents of the soil are very vital features and characteristics in agricultural productivity (Garcia et al., 2017, Martinez-Mera et al., 2017; Martinez-Mera et al., 2019). The soil is composed of numerous minerals, broken rocks and organic constituents that have brought about the alteration in reactions in the environment (Chesworth, 2008; Edori and Iyama, 2017). The different contaminants and pollutants are easily and naturally absorbed by the soil, no matter the amount, this has made the soil to become a natural sink to all pollutants. This has caused variations in the chemical and physical features of the soil. The potential of the soil to eliminate impurities, absorb oxygen, eliminate disease causing agents and liberating carbon dioxide to the atmosphere has made it a natural purifier (Edori and Iyama, 2017).

The ecology all over the biosphere has been greatly changed due to the influence of human which has occasioned the contamination and pollution of the environment and has led to increased loss of biodiversity (Raven, 2002; Li and Yang, 2008). Heavy metals are amongst the pollutants discharged into the environments through anthropogenic sources. Soil contamination by heavy metals is of greatest worry to humans owing to their poisonous effects, perseverance and non-degradable characteristics in the environment (Olayinka et al., 2017). At higher levels, heavy metals upset the composition and roles of microorganisms. The buildup of heavy metals ultimately in the soil affect the groundwater and also pass into the food chain producing serious health issues in humans. The hazardous nature of heavy metals has been recorded by certain authors (Momodu and Anyakora, 2010; Anyakora et al., 2011). The potential of heavy metals to accumulate and become very stable even at very low levels results in health hazard and harms in the human and animal systems, since there is at the moment no proper certified method applicable in removing them from the human system (Arora et al., 2008; Yusuf and Oluwole, 2009; Abdulhamid et al., 2015).

Some heavy metals are present naturally in the environment (Fe, Cu, Mn, Vn, Sn), and are vital plant nutrients at certain levels, while others (Hg, Pb, Cd, Ag, Cr) might be introduced due to anthropogenic activities and are hazardous or poisonous at low levels (Opaluwa et al., 2012). Heavy metals are metals or metalloids whose density is higher than 4.5g/cm^3, have great stability and cannot be destroyed nor degraded and possess the ability to accumulate in the soil. Sources of heavy metals in the soil include; aerial deposition, fertilizers and pesticides application, discarded metallic goods, animal and agricultural wastes, industrial effluents, power plants, domestic wastes and vehicular exhaust (Chopra et al., 2009). The contamination of the soil by heavy metals is of serious concern because of its consequence on the general ecosystem and the carcinogenic effects on humans.

This work was therefore undertaken to examine the concentrations of some heavy metals in the soils used as temporary waste receptacle within the Rukpokwu area of Port Harcourt, Rivers State, Nigeria and the contamination status of the soils due to this activity.

MATERIALS AND METHODS

Collection of Soil Samples

Soil samples were collected at random from three temporary dumpsites in Rukpokwu Obio/Akpor, Port Harcourt and a control site at the open field of the Community Primary School, Rukpokwu with the aid of soil auger. The samples were collected at three different points at a sampling site or location and then properly mixed together to form a composite sample. After each sampling, the auger was thoroughly washed in water and dried in order that the samples from one location do not influence those of other locations. The soil samples were immediately put into polythene bags after collection and then transported to the laboratory for pretreatment and digestion before the concentrations of the heavy metals were determined.

Sample Pretreatment and Soil Digestion

The samples were dried overnight in an oven at a temperature of 105^{o}C so that moisture will be removed from the soil particles. The dried samples were sieved mechanically in a 0.5 mm mesh and then pulverized to a size of about 0.063 mm using the method of Madrid et al. (2002), and El-Sherbiny et al. (2019). The pulverized soil was then weighed (1.00g±0.01 accuracy) and was digested using a mixture of nitric acid and perchloric acid (HNO_3/$HCLO_4$) in a ratio of 4:1 in a beaker. The samples were heated at a temperature of 40^{o}C for an hour and was increased to 140-170^{o}C for 4 hours until a clear solution was noticed. The clear solution was filtered and then diluted to 50ml by adding deionized water.

Determination of Heavy Metals

The Atomic Absorption Spetrophotometer Model SG71906, Germany was used to determine the concentrations of heavy metals in the soils samples from the temporary dumpsites using the prescribed method (APHA-AWWA-WPCF, 1985). The digests were aspirated directly into a nitrous oxide/acetylene flame being generated by a cathode lamp at a specific wavelength for each metal to be analyzed. For each heavy metal investigated, calibration curves were obtained and standards for blank samples were prepared for each metal before the aspiration of sample was performed. The level or concentration of each metal was then displayed by the system monitor at specific absorbance. The concentrations of the metals were measured in mg/Kg of soil sample at a detection limit of <0.001mg/Kg. The heavy metals analyzed were iron (Fe), lead (Pb), copper (Cu), zinc (Zn), cadmium (Cd), manganese (Mn), chromium (Cr), nickel (Ni), arsenic (As) and cobalt (Co).

Pollution Assessment Models

These are pollution guides which shows the degree of pollution and how intense it is due to human activities on the soil. The assessment indices or guides used in this study are Contamination index or factor (CF), geo-accumulation index (Igeo), potential ecological risk coefficient (E^i_r) and potential toxicity response (RI) (Edori and Kpee, 2017; Edori and Edori, 2021).

Contamination Factor (CF)

This index was first resolved by Hakanson (1980) and also used by Lacatusu, (2000). The contamination index equation is mathematically given as in equation 1,

$CF = Cn/Bn$, [1]

Where Cn is the concentration of the investigated metal and Bn is the background value (level) of the measured metal.

Contamination index resolved by Hakanson (1980) and applied by El-Sherbiny et al., (2019) were CF < 1 = low level of contamination, 1< CF < 3 = moderate level of contamination, 3 < CF < 6 = considerable level of contamination and CF > 6 = high level of contamination.

Geo-accumulation Index (Igeo)

The index relates contamination of the levels of heavy metals at present and original concentrations before there was any industrial activities in the soils under study. The calculation method used by Muller (1969) was adopted as in eqn 2.

$Igeo = Log_2 [(Cn)/(1.5Bn)]$ [2]

Where, Cn is the measured concentration of metal, Bn is the background value of the measured metal, 1.5 constant which minimizes the changes on the background levels due to lithologic effects.

The interval used in interpreting and classifying geo-accumulation index as applied by Odewande and Abimbola (2008) and adopted in this work is Igeo < 0, not contaminated, 0 < Igeo < 1, not contaminated to moderate contamination, 1 < Igeo, 2, moderate contamination, 2 < Igeo < 3, moderate to strong contamination, 3 < Igeo < 4, strong contamination, 4 < Igeo < 5, strong to extreme contamination and Igeo > 5, extreme contamination.

Potential Ecological Risk Coefficient (E^i_r)

This index was calculated using the formula of Hakanson (1980), and it is expressed mathematically as,

$E^i_r = T^i_r \times C^i_r = T^i_r \times C^i_s / C^i_n$ [3]

Where, T^i_r is toxic response factor of the investigated metal, C^i_r is the metal's contamination factor, C^i_s is the concentration of heavy metals in the studied soil and C^i_n is the background concentration for heavy metals. The response factors for the metals investigated are Pb = 5, Cu = 5, Cd = 30, Cr = 2, Ni = 5, Mn = 1, Zn = 1, Co = 5 and As = 10.

The interval used in interpreting the categories of potential ecological risk coefficient are; $E^i_r < 40$; low risk, $40 \le E^i_r < 80$; moderate risk, $80 \le E^i_r < 160$; considerate risk, $160 \le E^i_r < 320$; high risk and $E^i_r \le 320$; very high risk.

Potential Ecological Risk Index (RI)

The index was calculated by applying the equation

$RI = \Sigma E^i_r$ [4]

It is used to calculate the sum of various risk factors and in the assessment of the toxic level of the various heavy metals studied in the soil. The interval of classification applied for interpreting potential ecological risk index are RI < 150; low ecological risk, 150 ≤ RI < 300; moderate ecological risk, 300 ≤ RI < 600; considerate ecological risk and RI > 600; very high ecological risk.

RESULTS AND DISCUSSION

The results obtained for the heavy metals investigated in the three temporary dumpsites in Rukpokwu are provided in Table 1. The contamination factors (CF) of the various heavy metals are given in Table 2, the geo-accumulation index (Igeo) is in Table 3, and the Potential Ecological Risk Coefficient (E^i_r) and the Potential Ecological Risk Index (RI) are provided in Table 4.

Heavy Metals Levels in Temporary Dumpsites in Rukpokwu, Obio/Akpor Port Harcourt

The concentrations of the different heavy metals evaluated within the dumpsites in Rukpokwu, Obio/Akpor, Port Harcourt are provided in Table 1.

Iron (Fe)

The level of iron (Fe) recorded in the stations of the temporary dumpsites at the time of research were in the range 189.714-274.181mg/Kg. The average level of iron (Fe) recorded for the different stations was 256.649±17.533 mg/Kg while the concentration at the control station was 97.483±10.212mg/Kg. The level of Fe obtained in this work was within the same range reported by Ogbonna et al. (2009) in soils of waste dumpsites in Port Harcourt municipality and environs which had the range of 56.42-280.16mg/Kg at a depth of 30cm and a range of 20.11-250.36mg/Kg at a depth of 1m but lower than that recorded by Akpoveta et al. (2010) in metal scrap dumps in Delta State.

Iron is naturally present in meat, whole meal products, potatoes and vegetables. The human body absorbs Fe

Table 1: Heavy Metals Levels (mg/Kg) in the Temporary Dumpsites in Rukpokwu, Obio/Akpor, Port Harcourt.

	Stations/Locations				
Heavy Metals (mg/Kg)	**SARS Road**	**Elikpokpodi**	**Checking Point**	**Mean±SD**	**CPS (Control)**
Iron (Fe)	274.181	239.116	189. 714	256.649±17.533	97.483±10.212
Lead (Pb)	16.327	11.714	7.918	11.984±3.435	4.321±1.031
Copper (Cu)	9.816	6.534	11.536	9.295±2.075	3.604±0.920
Zinc (Zn)	21.317	27.161	18.326	22.268±3.669	9.364±1.121
Cadmium (Cd)	2.367	3.711	2.613	2.897±0.584	0.619±0.007
Manganese (Mn)	5.724	7.306	6.728	6.586±0.654	3.917±0.120
Chromium (Cr)	11.692	14.714	10.325	12.244±1.834	5.387±0.412
Nickel (Ni)	9.526	11.502	6.526	9.185±2.046	4.748±0.852
Arsenic (As)	1.692	2.378	1.938	2.003±0.284	0.960±0.101
Cobalt (Co)	2.400	1.694	2.031	2.042±0.288	0.653±0.008

Table 2: Contamination Factor (CF) Analysis of Heavy Metals in the Temporary Dumpsites in Rukpokwu, Obio/Akpor, Port Harcourt.

	Sample Locations			
Heavy metals	**SARS Road**	**Elikpokpodi**	**Checking Point**	**Mean**
Fe	0.0072	0.0063	0.0050	0.0062
Pb	0.192	0.138	0.093	0.141
Cu	0.273	0.182	0.320	0.258
Zn	0.152	0.193	0.131	0.159
Cd	2.959	4.639	3.266	3.621
Mn	0.013	0.017	0.015	0.015
Cr	0.117	0.147	0.103	0.122
Ni	0.272	0.329	0.186	0.262
As	0.130	0.183	0.149	0.154
Co	0.137	0.085	0.102	0.108

which come from animal foodstuffs more freely than Fe from plant foodstuffs. Iron (Fe) is a vital constituent of the hemoglobin; the component that readily gives the red colouration in blood and is responsible in the transportation process of oxygen to and through the several tissues and organs of the body (Wei et al., 2005). When Fe is allowed to come in contact with body tissues and permitted to persist, it causes various disease conditions like: choroiditis, conjunctivitis, and retinitis. Protracted inhalation of extreme concentrations of the smokes and dust of iron oxide could give rise to the development of a disease condition of benign pneumoconiosis, which is also called siderosis, which is apparent as an x-ray change. Nevertheless, cases of physical lung malfunction and impairment have not been linked to siderosis. High level intake of the oxides of iron enhances the chance of lung cancer development particularly in workers open to pulmonary carcinogens (Rind et al., 2013). Anaemia is a known common disease disorder in humans that is linked to Fe deficiency. The normal daily intake of Fe essential or suggested for males and females are 7 and 11 mg respectively (Banjari et al., 2015).

Lead (Pb)

The results recorded for the concentrations of lead (Pb) in the temporary dumpsites during the period of investigation ranged from 7.918-16.327mg/Kg with an average concentration value of 11.984±3.435 while the concentration at the control station was 4.321±1.031mg/Kg. The concentration of Pb recorded in this work was higher than that obtained by Nwoke and Edori, (2020a) in farmlands close to a dumpsite in Rumuagholu which recorded a value range of 0.011±0.00-2.72±0.21mg/Kg and those of Sor et al. (2020) which ranged from 2-11-3.194 mg/Kg with a mean value of 2.685±0.382mg/Kg in the oil-bearing communities of Gokana, Rivers State, Nigeria. The range of concentration for Pb obtained in this work is an indication that if the temporary dumpsites are not properly checked and regulated, there is the tendency of accumulation as observed by Misra and Mani (2009) in their study. High level of Pb in the soil produces undesirable effects as it ultimately passes to humans via the food chain. Lead **(**Pb) can cause many physiological discrepancies or imbalances and diseases such as damage to the kidney, hearing impairment, brain damage, reduction in the ability to learn, effect on the central nervous system and reduction in growth (Rehman et al., 2013; Sor et al., 2020).

Copper (Cu)

The results obtained in this work for the level of copper (Cu) in the temporary dumpsites at the time this research

Table 3: Geo-Accumulation Index (Igeo) Analysis of Heavy Metals in the Temporary Dumpsites in Rukpokwu, Obio/Akpor, Port Harcourt.

	Sample Locations			
Heavy metals	**SARS Road**	**Elikpokpodi**	**Checking Point**	**Mean**
Fe	0.001	0.001	0.001	0.001
Pb	0.039	0.028	0.019	0.029
Cu	0.055	0.037	0.064	0.052
Zn	0.031	0.039	0.026	0.033
Cd	0.594	0.931	0.655	0.727
Mn	0.003	0.003	0.003	0.003
Cr	0.023	0.030	0.021	0.025
Ni	0.055	0.066	0.037	0.053
As	0.026	0.037	0.030	0.031
Co	0.027	0.017	0.020	0.021

was carried out ranged between 6.534 and 11.536mg/Kg. The mean concentration value for the stations was 9.295±2.075mg/Kg while the concentration at the control station was 3.604±0.920mg/Kg. The value of Cu obtained in this research was higher than that recorded by Nwoke and Edori (2020a) which recorded the range of 1.35±0.33 to 2.19±1.01mg/Kg and those recorded by Hammed et al. (2017) with a concentration value of 0.34 to 0.91mg/Kg at Ibadan, Oyo State in Western Nigeria. Copper (Cu) is important to plants and animals, for the significant role it plays in the overall functioning and development of metabolic activities in plant life and the DNA condition opposition mechanism in humans. The absence of Cu impedes development and growth in animals and results in cardiovascular diseases and myelination of the spinal cord, reproduction, skin blemishes and effect on the connective tissues (Buck, 1978; Anderson, 1997; Sor et al., 2020). Biological systems such as enzymes like alkaline phosphodiesterase, lipase adenosine triphosphate, aldotase, pepsin and aminoacyl RNA are affected as a result of excess Cu (Owen, 1981).

Zinc (Zn)

The recorded results for zinc (Zn) within the stations of the temporary dumpsites during the period of investigation fell within the range of 18.326-27.161mg/Kg. The average concentration of zinc (Zn) in the soil was 22.268±3.669mg/Kg at the time the research was conducted with the recorded concentration at the control station as 9.364±1.121mg/Kg. The values of contamination obtained in this work for Zn is probably lower than that reported by Akpoveta et al. (2010) which was 74.26 and 97.21 for metal scrap dumps in parts of Delta State.

Zinc (Zn) is chemical stable in the +2 oxidation state (Cotton et al., 2011). Zinc (Zn) is readily made available to the environment through: mining, refining and smelting process of zinc and other metals, electroplating processes in the industries and from bio-solids. Zinc **(**Zn) is a very essential metal in pre and post-natal growth (Hambidge and Krebs, 2007). The ecological and health consequences of Zn is in the fact of its corrosiveness to the skin and causes irritation and impairment to the mucous membrane. Zinc **(**Zn) deficiency leads to slow or stunted growth, interruption in sexual development, diarrhea, easy contact with the infection, while unwarranted use or extreme intake of Zn is concomitant with ataxia, shortage in copper intake and weakness or weariness (Hambidge and Krebs, 2007; Maret, 2013).

Cadmium (Cd)

The concentration value obtained for cadmium (Cd) in the different stations of the temporary dumpsites was in the range of 2.367-3.711mg/Kg. The mean concentration of Cadmium (Cd) at the time the study was carried out was 2.897±0.584 with a concentration value of 0.619±0.007mg/Kg at the control station. The concentration of Cd in this work was higher than that obtained by Nwoke and Edori (2020a) which ranged from 0.04±0.01-0.47±0.22mg/Kg in farmlands close to a dumpsite and that of Hammed et al., (2017) which was < 1.0mg/Kg in Ibadan, Oyo State. Known sources of Cd in the environment include burning of municipal waste, smelting and refining of metals, burning fossil fuels (coal or petroleum), iron and steel production industries and nickel-cadmium batteries (Sahmoun and Case, 2005). Other sources of Cd are majorly from phosphate fertilizers, household and sewage slurry, degenerated/damaged automobile tyres, lubricants and quarrying and manufacturing of metals (ATSDR, 2011). Human contact to Cd could result into disease of the lungs, kidney dysfunction or damage, gastric and intestinal ailment, cancer, heart disease, liver and brain poisoning and anaemia, bronchitis, intestinal and gastric ailment, cancer, disorder of heart, liver and brain. Chronic and acute poisoning by Cd may degenerate into renal dysfunction, anaemia, olfactory epithelium destruction with subsequent restlessness and bronchitis (Drebler and Schulz, 2002; Sorahan and Esmen, 2004).

Manganese (Mn)

The concentration value obtained for manganese (Mn) in the different stations of the temporary dumpsites

Table 4: Potential Ecological Risk Coefficient (E^i_r) and Potential Ecological Risk Index (RI) Analysis of Heavy Metals in the Temporary Dumpsites in Rukpokwu, Obio/Akpor, Port Harcourt**.**

	Sample Locations			
Heavy metals	**SARS Road**	**Elikpokpodi**	**Checking Point**	**Mean**
Fe	NA	NA	NA	NA
Pb	0.960	0.690	0.465	0.705
Cu	1.365	0.910	1.600	1.292
Zn	0.152	0.193	0.131	0.159
Cd	88.770	139.170	97.980	108.640
Mn	0.013	0.017	0.015	0.015
Cr	0.234	0.294	0.206	0.245
Ni	1.360	1.645	0.930	1.312
As	1.300	1.830	1.490	1.540
Co	0.685	0.425	0.510	0.540
RI	94.839	144.999	103.327	114.388

investigated was in the range 5.724-7.306mg/Kg. The mean concentration of manganese (Mn) at the time this investigation was carried out was 6.586±0.654mg/Kg with a concentration value of 3.917±0.120mg/Kg at the control site**.** The level of Mn recorded in this work was far lower than that reported by Abdulhamid et al. (2015) which was obtained from farms in Minna with a level of 292.76mg/Kg.

The major source of Mn in the atmosphere is from crustal rock. Other normal sources of origin are forest fires, ocean spray, plants and volcanic eruptions. In anaerobic environments, manganese oxide is reduced and dissolved, while direct reduction of particulate manganese oxides is achieved in aerobic environments thus making it available (Stokes et al., 1988). It can also be available through weathering of Mn (II)-containing minerals and low pH environments. Manganese (Mn) in the soil, could originate from crustal sources, atmospheric deposition, wash-off from plant exteriors, leakage from plant materials, detached or excretion of material from deciduous plants and decay of dead plants and animals matter. The main anthropogenic sources of manganese in the environment are from household and industrial wastewater discharges, sewage slurry, minerals' exploration and exploitation, emissions of alloys, steel works, iron production, combustion of fossil fuels and fuel additives (ATSDR, 2000).

Effects of Mn generally arise in the respiratory tract and brain and its toxicity usually show in such symptoms like nerve damage, forgetfulness and hallucinations**.** Toxicity of Mn could results in diseases such as; bronchitis, lung embolism and Parkinson. Acute exposure to Mn could cause impotence. It is also related to such syndromes like feeble muscles, dullness in activity, schizophrenia, restlessness and headaches (ATSDR, 2012). Manganese is important for the normal growth of the bone structure, reproduction, amino acids metabolism, lipids, carbohydrates and proper running of the central nervous system (Adamu et al., 2016).

Deficiency of Mn can result into certain health issues such as fatness, intolerance of glucose, blood clotting, skin complications, lowered cholesterol levels, skeleton conditions, birth deficiencies, changes of hair colour and neurological signs. Long-time contact to Mn can consequently cause harm to the central nervous system, cause permanent disability and several disease signs and pneumonia (ATSDR, 2012). Excess of manganese in human body can result into pneumonia, reproductive system disorder that might lead to infertility, adverse effects on the lungs and the brain (Adamu et al., 2016).

Manganese is vital to man in regard to proper mental health and transfer of oxygen from lungs to other body cells. Manganese in biological systems, acts as an activator, co-factor or co-enzyme in a number of reactions that are related to carbohydrate, fat and protein metabolism. Manganese-bound enzymes are essential in the purification of superoxide free radicals that scavenge for oxygen and also acts as an antioxidant.

Chromium (Cr)

The recorded results for Chromium (Cr) within the stations of the temporary dumpsites during the period investigated fell within the range 10.325-14.714mg/Kg. The average concentration of chromium (Cr) in the stream was 12.244±1.834mg/Kg at the time the research was conducted with recorded concentration at the control station as 5.387±0.412mg/Kg. The range of concentration for Cr obtained in this work was higher than that obtained by Marcus *et al*., (2017) which ranged from 5.67±0.02 to 11.22±2.04mg/Kg. Chromium is identified as the 17th most abundant element in the Earth's crust (Avudainayagam et al., 2003). Major occurrences of chromium in the environment come from plumbing materials, pipes containing Cr, wastewater, solid waste, tanneries, electroplating, dyes and mordants, ceramics, refractory bricks and paint pigments (Avudainayagam et al., 2003). Chromium is most stable in the oxidation states of 0, +3, and +6 in the environment. Two of these oxidation states are not toxic in the environment, but Cr (III) has environmental concerns and health consequences. It is poisonous to body tissue and causes diseases such as irritation, dermatitis, ulceration of skin, damage of nasal septum and it is also carcinogenic (Zhitkovich, 2011).

Nickel (Ni)

The level of nickel (Ni) recorded for the various stations of the temporary dumpsites during the period investigated fell within the range 6.526-11.502mg/Kg. The mean concentration obtained within the time the research was conducted was 9.185±2.046mg/Kg with a concentration value of 4.748±0.852mg/Kg at the control station. The value of Ni obtained in this work was lower than that obtained by Marcus *et al*., (2017) which was in the range 7.61±0.78-18.29±3.00mg/Kg but was higher than that obtained by Nwoke and Edori (2020) in farmlands within the vicinity of a dumpsite which ranged from 1.42±0.08-2.90±0.96mg/Kg and that recorded by Edori and Kpee (2017) in the abattoir. Nickel (Ni) pollution naturally originates from volcanic eruptions, forest fires, bubble busting and gas exchange in ocean, weathering of soils and geological materials. Human sources of Ni pollution come from refining and melting of metals, burning of coal, landfill, industrial wastes and sewage slurry. Nickel (Ni) enters into the atmosphere through Ni-based industries. Ni is discharged or released from industrial wastewater, fossil-burning generators and solid wastes (Cempel & Nikel, 2006). Human exposure to Ni may result in health consequences, such as respiratory disorders, dermatitis, cancer of the lungs, sinus, allergic reactions, skin rash, eczema and asthmatic outbreak. Other consequences include stomach pain, the effect on the kidney which manifests in the increase of protein in the urine and blood effect due to an increase in the red blood cell (ATSDR, 2005).

Arsenic (As)

The concentration of Arsenic (As) observed in the various stations of the temporary dumpsites at the time of this work ranged from 1.692 to 2.378mg/Kg. The average level of arsenic (As) obtained in the temporary dumpsites at the time of this work was 2.003±0.284mg/Kg with a concentration value of 0.960±0.101mg/Kg at the control station. The result for arsenic (As) obtained in this work was higher than that obtained by Edori and Kpee (2017) which ranged from 0.066±0.00 to 1.130±0.02 mg/Kg in selected abattoirs in Port Harcourt. The presence of arsenic in the aquatic environment constitutes a health hazard to humans and animals and exposure to arsenic even at low concentrations can also be poisonous (UNICEF, 2008). Arsenic is one environmental contaminant that is poisonous. It has the ability to exist in the +5 and +3 oxidation states and is absorbed easily into the tract of the gastro-intestine (Smith and Steinmaus, 2007). The effects due to arsenic toxicity may result in skin lesions and stigmatization which may ruin the life of an individual in his developmental stages and eventually affect the entire family (UNICEF, 2013).

Cobalt (Co)

The level of cobalt (Co) recorded in the different stations of the temporary dumpsites investigated was in the range 1.694-2.400mg/Kg. The mean concentration of cobalt (Co) at the time this investigation was carried out was 2.042±0.288mg/Kg with a concentration value of 0.653±0.008mg/Kg at the control site. The result for Cobalt (Co) obtained in this work was higher than that obtained by Edori and Kpee (2017) which ranged from0.017±0.00-0.370±0.01mg/Kg in selected abattoirs in Port Harcourt.

Pollution Indices of Heavy Metals Pollution in the Temporary Dumpsites in Rukpokwu, Obio/Akpor Port Harcourt

Contamination Factor

The contamination factors of heavy metals in the temporary dumpsites in Rukpokwu, Obio/Akpor Port Harcourt are given in Table 2.

The results for the contamination factor or index in the temporary dumpsites studied are shown in Table 2. The results revealed that Fe ranged from 0.0050 to 0.0072 with a mean value of 0.0062, Pb; 0.093 to 0.192 with a mean value of 0.141, Cu; 0.182 to 0.320 with a mean value of 0.258, Zn; 0.131 to 0.193 with a mean value of 0.159, Cd; 2.959 to 4.6392, with a mean value of 3.621, Mn; 0.013 to 0.017 with a mean value of 0.015, Cr; 0.103 to 0.117 with a mean value of 0.122, Ni; 0.184 to 0.329 with a mean value 0.262, As; 0.130 to 0.183 with a mean value of 0.154 and Co; 0.085 to 0.137 with a mean value of 0.108. The contamination index used by Hakanson (1980) and adopted by El-Sherbiny et al., (2019) were $CF < 1$ = low level of contamination, $1 < CF < 3$ = moderate level of contamination, $3 < CF < 6$ = considerable level of contamination and $CF > 6$ = high level of contamination. Considering the contamination factor classification, the soil of the temporary dumpsites in the different stations of Rukpokwu, Obio/Akpor, Port Harcourt were all at the classification range of $CF < 1$ except cadmium (Cd) which was at the classification interval of $3 < CF < 6$. The results obtained therefore revealed that all the heavy metals were still at the stage of low contamination degree except cadmium (Cd) that is at the stage of a considerable level of contamination. The contamination of the temporary dumpsites by the heavy metals were in the order Cd > Ni > Cu > Zn > As > Pb > Cr > Co > Mn > Fe. The contamination factor results showed that the soil value of the temporary dumpsites within Rukpokwu, Obio/Akpor, Port Harcourt has not been affected to a high level. The soils of the studied dumpsites have not been affected and contaminated by heavy metals to the level of contamination observed by Nwankwoala and Ememu (2018) in the soils of Okpoko near filling stations in

Eastern Nigeria and that of El-Sherbiny et al. (2019) within a cement industry in Saudi Arabia.

Geo-Accumulation Index (Igeo)

The results for the geo-accumulation of the investigated heavy metals in the temporary dumpsites in Rukpokwu; Obio/Akpor, Port Harcourt are provided in Tables 3.

Table 3 provided the results for the geo-accumulation index of heavy metals in the soil of selected temporary dumpsites in Rukpokwu, Obio/Akpor, Port Harcourt. The results obtained for geo-accumulation index of the investigated heavy metals were in the range: Fe; 0.001 in all the stations, Pb; 0.019-0.039 with an average value of 0.029, Cu; 0.037-0.064 with an average value of 0.052, Zn; 0.026-0.039 with an average value of 0.033, Cd; 0.594-0.931 with an average value of 0.727, Mn; 0.003 in all the stations, Cr; 0.021-0.030 with an average value of 0.025, Ni; 0.037-0.066 with an average value of 0.053, As; 0.026-0.037 with an average value of 0.031 and Co; 0.017-0.027 with an average value of 0.021 in the three dumpsites used for the investigation. The mean values obtained for the geo-accumulation index of the investigated heavy metals in the temporary dumpsite within Rukpokwu community in Obio/Akpor Port Harcourt were in the order Cd > Ni > Cu > Zn > As > Pb > Cr > Co > Mn > Fe. The results recorded for all the heavy metals in the soils samples of the temporary dumpsites were all higher than zero and fall into the interval of interpretation range 0 < Igeo < 1, which showed that the temporary dumpsites were still at the stage of not contaminated to moderate contamination. The geo-accumulation of the heavy metals studied in the temporary dumpsites was low possibly due to the frequency with which the refuse dumps are being evacuated from the various and that might not give room for the accumulation of heavy metals that possibly would have leached from the refuse dumped into the soil.

Potential Ecological Risk Coefficient (E^i_r) and Potential Ecological Risk Index (RI)

The results for Potential Ecological Risk Coefficient ($E^i r$) and Potential Ecological Risk Index (RI) of the studied heavy metals in the temporary dumpsites in Rukpokwu; Obio/Akpor, Port Harcourt are provided in Table 4.

The results obtained for potential ecological risk coefficient revealed that Pb ranged between 0.465-0.960 with an average of 0.705, Cu range was between 0.910-1.600 with an average of 1.292, Zn ranged from 0.131-0.193 with an average of 0.159, Cd ranged 88.770-139.170 with an average of 108.640, Mn ranged between 0.013-0.017 with an average of 0.015, Cr ranged between 0.206-0.294 with an average of 0.245, Ni was in the range of 0.930-1.645 with an average value of 1.312, As ranged between 1.300-1.490 with an average value of 1.540, and Co ranged from 0.425-0.685 with an average value of 0.540 in the sample locations points of the temporary dumpsites in Rukpokwu, Obio/Akpor, Port Harcourt. The results obtained from the temporary dumpsites indicated that the mean value of potential ecological risk coefficients of the heavy metals, were in the order Cd > As > Ni > Cu > Pb > Co > Cr > Zn > Mn. The application of the categories of interpretation for ecological risk coefficient of the heavy metals investigated revealed that they all fell into the category $E^i_r < 40$, which signifies that all the heavy metals investigated were still at low risk at the time of investigation except Cd that was at $80 \leq E^i_r < 160$; which indicated considerate risk.

The results obtained for potential ecological risk index (RI) for the sample locations at the temporary dumpsites were 94.839, 144.999 and 103.327 for SARS Road, Elikpokpodi and Checking Point respectively with an average value of 114.388 for the stations. The results obtained for the potential ecological risk index (RI) in temporary dumpsites were in the category of 150 ≤ RI < 300, which showed that the soils of the temporary dumpsites were still at a moderate risk level at the time of this study.

CONCLUSION

The continuous monitoring of the soil environment used as dumpsite is vital in the evaluation for the renewal, rebuilding, safety and fortification of the dumpsite environment. This will help to promote hygiene and also keep the integrity of the dumpsite environment and that of plants, animals and humans that inhabit such environs**.** Results of heavy metals in the soils of the dumpsites were all higher than that obtained from the control station which was an indication that human influence has greatly contributed to the levels of the studied heavy metals.

Pollution index models' analysis revealed that the soils of the area were contaminated by all the heavy metals in varying degrees although it was still at low degree. The contamination factor revealed that all the heavy metals were still at the stage of low contamination degree except cadmium (Cd) that is at the stage of a considerable level of contamination. The geo-accumulation index showed that the temporary dumpsites were still at the stage of not contaminated to moderate contamination while the potential ecological risk and potential ecological risk index showed low risk at the dumpsites.

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