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Pollution Status of Solid Waste Disposal Site in Owerri municipal, Nigeria

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Abstract

This study was designed to assess the extent of contamination of soil by heavy metal (Pb, Hg, Cu, Zn, Cd, Cr, As), sulphate, nitrate, phosphate, and total petroleum hydrocarbon within the vicinity of some solid waste disposal sites. Composite soil samples were collected from three different depth profile (0 -10 cm, 10 -20 cm, and 20 -30 cm) in four solid waste disposal sites and a control station at the outskirt of Owerri municipality. Determination of total petroleum hydrocarbon in soil was carried out using Gas Chromatography-Flame ionisation instrument, heavy metal concentrations were determined using Atomic absorption spectrophotometer while nitrate, sulphate and phosphate were determined using spectrophotometric methods. The results obtained indicated a wide variation in the concentrations of different anions and heavy metals at various sampling sites. Sulphates, phosphates, total petroleum hydrocarbon and heavy metals from the solid waste disposal sites were higher than those obtained from the control soil station. Highest concentrations were recorded for samples within the depth of 0-10 cm. Generally, contamination seems to increase with increase in soil depth. Calculated pollution load index (PLI) ranged from 0.31 to 2.80, which indicated high pollution status. The index also varied with soil depth. However, geo-accumulation (I_{geo}) index suggested significant contribution of cadmium to soil contamination

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Introduction In Nigeria, dumpsites are potential sources of all forms of waste generated within the vicinity of the dumpsites (Eddy *et al*., 2006). Therefore, based on the activities of the environment around the dumpsite, several forms of contamination may be common around the dumpsite (Eddy and Ukpong, 2005; Eddy *et al.*, 2004). Wastes are generated in large quantities as a result of various activities of human beings thereby causing the environment unclean and harmful. The land, surface and ground water as well as air quality gradually became depreciated by waste disposal. Waste disposal can impact on the environment depending on the composition of the waste and the local practices of waste disposal (Modak *et al*., 2011). Solid wastes are generated from domestic, agricultural, industrial and commercial activities, and consists of food wastes, packaging in form of paper, metals, plastics, glass, clothing, and garden waste, and pathological waste, hazardous and radioactive wastes (Goswami and Sarma, 2007). The commonest method of waste disposal in Nigeria is the open dumps, trash, inert and recyclable wastes are disposed of in open holes or field on the ground with little or no compliance to the poor environmental regulation of the area. In order to have effective weight volume reduction and control of bacterial activities, the solid waste is burnt. As the solid waste gradually decomposes as a result of physicochemical and biological process, mineral elements from the waste dissolved in the presence of water or moisture and percolates through the aquifer. Heavy rainfall, shallow water table and very high humidity tend to increase the volume of leached that seeps into the soil and thereby contaminating the soil.

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Leached has the tendency to alter properties and behavior of the soil (Ebrahim *et al*., 2011; Sunil *et al*., 2008; Francisca and Glatstein, 2010; Ukpong and Agunwamba, 2011). As plants absorb mineral element contents of these leached, accumulation of trace and toxic metals occurred (Maria *et al*., 2015). Trace elements when ingested and assimilated in cells, tissues, and organs of the body as a result of consumption by man, may constitute harmful effect (Nor and Suhaimi, 2013). The effect of poor solid waste management has been linked to symptoms such as stress, headache, dizziness, nausea, and eyes irritation. Others are congenital anomalies, respiratory infections, cancer, brain, liver and nervous disorder. This study is designed to assess the pollution level of soil near some solid waste disposal site in Owerri municipal through the determination of trace elements, anions, and total hydrocarbon content.

Materials and methods

Sample Collection and Preparation

Composite soil samples were collected from three different depth profiles, 0 -10 cm, 10 -20 cm, 20-30 cm from each waste disposal site at Egbu, Amakohia, Nekede, Orji and control site at the outskirt of Emekuku in Owerri metropolis with the aid of depth calibrated soil auger. Samples were then collected in sterile polythene bags at soil depths of 0-10 cm, 10-20 cm and 20-30 cm respectively during the dry season (December, 2018)

Study area

Owerri is the capital of Imo State and is located in the south eastern Nigeria with coordinates: 5°29′06″N 7°02′06″E / 5.485°N. Owerri is made up of three local government area namely Owerri Municipal, Owerri North and Owerri West. Owerri city has an approximate land mass of 100 square kilometer with an estimated population of about 401,873 according to the 2006 census. The sampling sites were solid waste disposal site at Egbu, Amakohia, Nekede, Orji and control site at the outskirt of Emekuku.

Sample analysis

Analysis of Total Petroleum Hydrocarbon (TPH)

10 g of previously homogenized and sterilized soil samples were transferred into an extracting bottle containing 5 g of anhydrous sodium sulphate and the mixture was stirred vigorously. 300 µg/mL of 1-chlorooctadecane (standard) was then added to the sample. 30 mL of dichloromethane was added in the extracting bottle containing the sample and the bottle tightly corked before transferring it to a mechanical shaker. The sample was allowed to settle for 1 h after agitation for 5 hour at room temperature in the mechanical shaker. The sample was filtered and the filtrate was allowed to concentrate to 1 mL by evaporation overnight in a fume chamber (LAWI, 2011; Alinnor and Nwachukwu, 2013).

Determination of total petroleum hydrocarbon in the soil was carried out by the aid of an Agilent 6890N Gas Chromatography- Flame Ionization Detector instrument. 3 µL of concentrated sample that was previously eluted from column was injected into Gas chromatograph. The micro-syringe of GC was first rinsed with dichloromethane (blank) and further rinsed with the sample before the analysis. The sample was separated into constituent compounds by injection of sample into the chromatographic column. The compounds after separation were passed through a flame ionization detector for detection and the amount of Total Petroleum Hydrocarbon (TPH) was resolved at a particular chromatogram in mg/Kg LAWI, 2011; Alinnor and Nwachukwu, 2013; Cortes *et al*., 2012).

Determination of Nitrate

The concentration of nitrates was determined using spectrophotometer (model 2000) at a wavelength of 543 nm (US EPA, 1998). The instrument automatically selected the stored programme for nitrate (64 Nitrate-N) and values obtained were converted to ppm Nitrate (NO_3^-) by multiplying by 4.4 (conversion factor). The concentrations of nitrate in the samples were calculated from equation below

$$NO_3^-(\mu g g^{-1}) = \frac{CV}{m}$$

where, C is the concentration of NO_3^- in the sample (ppm), V is the total volume of sample solution (100 mL) and M is the weight of the sample (1 g).

Determination of Sulphate and Phosphate

Sulphate content of the samples were determined by standard methods (US EPA, 1998; Osu and Ogoko, 2012). whereas the concentration of phosphate was determined via the method described by Dewis and Freitas (US EPA, 1998; Dewis, 1970).

Heavy Metal Determination

The digestion method proposed by the Ministry of Agriculture, Fisheries and Food (MAFF, 1981) was used with slight modifications. 1.0 g of dried and homogenized soil was accurately weighed into a 100 ml beaker and 10 ml of nitric acid was added. The beaker and its content was then heated until dryness. A mixture of 10 ml HNO_3 and 3 ml $HClO_4$ was added and solution was heated until fuming. The residue was treated with hot 6M HCl and the filtrate made up to 50 ml. This solution was used for Atomic

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Absorption Spectrophotometer (UNICAM SOLAR 32) analysis.

Geo-accumulation index

Geo-accumulation Index (I_{geo}) is very useful in evaluating the degree of metal contamination in both aquatic and terrestrial environment (Elias *et al*., 2011; Ogoko, 2014).

$$I_{Geo} = \frac{\ln(Mdtal\ concentration\ (C_m)}{1.5 \times Background\ value\ of\ the\ metal\ (B_m)}$$

here 1.5 is a correction factor due to variation in the background concentration as a result of lithologic differences. The descriptive classes of I_{geo} are as follows;

Less than (<) 0: practically uncontaminated
0—1: uncontaminated to slightly contaminated
2—3: moderately to highly contaminated
4—5: highly to very strongly contaminated
Greater (>) 5: very strongly contaminated

Pollution load index (PLI)

Pollution load index defines the estimated metal contamination status and the necessary action that is required to be taken in alleviating undesirable condition. PLI can be calculated using the formula below

$$PL1 = (CF_1 \times CF_2 \times CF_3 \ldots\ldots\ldots \times CF_N)^{1/N}$$

Where CF is the contamination factor, N is the number of metals evaluated. PLI is a potent tool in heavy metal pollution evaluation. According to Chakravarty and Patgiri (2009) PLI value > 1 is polluted while PLI value < 1 indicates no pollution. The degree of contamination with respect to measured back ground values of a geologically similar and uncontaminated area (or the average crustal composition of the metal) is described as Contamination Factor (CF). CF is therefore expressed as $CF=C_m/B_m$. CF is the contamination factor, C_m refers to the metal concentration and B_m is the background value of the metal.

Results and Discussion

The results of nitrate ion, sulphate ion, total petroleum aromatic hydrocarbons and total hydrocarbon contents were presented in Table 1. The results shown a depth –wise steady decrease in the concentration of the above parameters analyzed. The depth profile 0-10 cm recorded the highest concentration whereas profile 20-30 cm recorded the lowest levels of NO_3^-, SO_4^{2-} , PO_4^{3-}, TPAHs and TPH respectively. The concentration of nitrate ions ranged from 1094 mg/kg to 2910 mg/kg (Egbu), 930 mg/kg to 1340 mg/kg (Amakohia), 122.3 mg/kg to 2180 mg/kg (Nekede) and 102.8 mg/kg to 1150.0 mg/kg (Orji). These values of nitrates ions were well above the range of 71.0 mg/kg to 231.0 mg/kg recorded in the reference soil sample. The nitrate contents tend to increase as the dumping activities intensify. Organic matter content in the refuse site could have been broken down exothermically by the presence of microorganism, following a two steps process. Organic matter content may have decomposed into ammonia through a process known as ammonification and afterward by nitrification to nitrate. Nitrate percolates in to the soil and permeates into an underlying aquifer in the presence of water. (Osu *et al*., 2012).

The concentration of sulphate ions ranged from 101.24 mg/kg to 183.5 mg/kg (Egbu), 85.7 mg/kg to 130.5 mg/kg (Amakohia), 89.4 mg/kg to 150.0 mg/kg (Nekede) and 45.4 mg/kg to 110.0 mg/kg (Orji). These values of sulphate ions were well above the range of 20.65 mg/kg to 74.20 mg/kg recorded in the reference soil sample. The concentration of phosphate ions fluctuated from 11.13 mg/kg to 27.4 mg/kg (Egbu), 9.21 mg/kg to 17.9 mg/kg (Amakohia), 4.50 mg/kg to 8.20 mg/kg (Nekede) and 5.50 mg/kg to 9.20 mg/kg (Orji). These values of sulphate ions were well above the range of 1.78 mg/kg to 3.80 mg/kg recorded in the reference soil sample.

Table 1: Total petroleum hydrocarbon (TPH) and anions in dumpsites (mg/Kg)

Dumpsite	Depth (cm)	NO_3^-	SO_4^{2-}	PO_4^{3-}	TPH
Egbu	0 – 10	2910.0± 0.06	183.50 ± 0.10	27.40 ± 1.20	1970.20 ±0.02
	10 – 20	1980.00±1.22	136.12±1.09	18.10±0.12	910.10±0.08
	20 – 30	1094.00±0.89	101.24±0.23	11.13±0.02	162.30±0.04
Amakohia	0 – 10	1340.00±0.42	130.5±1.50	17.90±0.97	1401.00±0.05
	10 – 20	1420.00±0.76	92.00±1.23	13.00±0.26	740.70±1.32

	20 – 30	930.10±0.34	85.70±1.56	9.21±1.22	107.10±2.00
Nekede	0 – 10	2180.0±6.23	150.0±3.42	8.20±1.43	1366.00±2.04
	10 – 20	1582.0±2.23	106.9±1.45	7.80±0.87	811.30±0.34
	20 – 30	122.30±0.34	89.40±1.34	4.50±0.98	108.05±1.23
Orji	0 – 10	1150.00±1.67	110.0±1.43	9.20±1.43	1096.00±1.22
	10 – 20	1062.0±0.98	81.90±1.56	7.00±0.04	634.30±1.23
	20 – 30	102.8±2.30	45.40±1.23	5.50±1.23	129.05±2.43
Control	0 – 10	231.0±0.04	74.20±0.20	3.80±0.12	0.10±0.35
	10 – 20	180.10±0.89	65.60±0.74	2.84±0.84	0.00±0.67
	20 – 30	71.00±0.69	20.65±0.67	1.78±0.04	0.00±0.04

** Mean of three ± Standard Deviation

The maximum total petroleum hydrocarbon concentrations that ranged from 162.3 mg/kg to 1910 mg/kg were obtained at Egbu. A lower range of TPH (129.1 mg/kg to 1096 mg/kg) were detected at Orji sampling site. At the reference station, very low concentrations of TPH (0.00 to 0.01 mg/kg) were obtained. These values were far lower than TPH recorded at Egbu, Amakohia, Nekede and Orji respectively. Maximum recommended tolerance limit for TPH is 1000 mg/Kg (DPR, 2002; NSC, 2009). It was observed that soil samples from depth profile 0-10 cm had TPH values above the maximum tolerance limit, indicating contamination by petroleum hydrocarbons.

The results of heavy metal concentrations were as presented in Tables 6-10. Lead concentrations varies from 0.65 mg/kg to 3.21 mg/kg (Egbu), 0.30 to 3.01 mg/kg (Amakohia), 0.20 mg/kg to 3.81 mg/kg (Nekede), 0.85 mg/kg to 2.84 mg/kg (Orji), and 0.01 to 0.02 mg/kg (reference or control). Samples from Nekede recorded the slightly higher concentration of Pb compared to Orji sampling station which had lower Pb concentration. These values of Pb were nevertheless well above those recorded for the reference samples. Generally, the values of Pb obtained in this study were well below the average crustal abundance of 16 mg/Kg in an uncontaminated soil. Lead is known to be a highly toxic element and exposure at concentration levels above 0.01mg/L could be harmful to health (WHO, 1998; Asemave *et al*., 2012; Anhwanye *et al*, 2012).

Table 2: Heavy Metals concentration in the studied dumpsites (mg/kg)

Dumpsite	**Depth (cm)**	**Pb**	**Hg**	**Cu**	**Zn**	**Cd**	**Cr**	**As**
Egbu	0 – 10	3.24±0.01	0.20±0.03	12.20±0.01	136.0±0.21	2.05±0.45	0.02±0.00	0.05±0.01
	10 – 20	2.01±0.20	0.09±0.01	8.25±0.10	134.10±0.56	1.53±1.20	0.01±0.00	0.02±0.00
	20 – 30	0.65±0.01	0.02±0.00	3.11±0.01	101.30±1.02	0.78±0.03	0.01±0.00	0.01±0.00
Amakohia	0 – 10	3.01±0.20	0.10±0.00	13.80±0.04	123.50±1.29	1.56±0.09	0.03±0.00	0.06±0.00
	10 – 20	1.68±0.10	0.05±0.00	7.01±0.02	100.20±1.28	0.98±0.00	0.01±0.00	0.04±0.01
	20 – 30	0.30±0.00	0.01±0.00	2.80±0.06	80.80±1.20	0.20±0.00	0.00±0.00	0.01±0.00

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Nekede	0 – 10	3.81±0.62	0.15±0.01	8.10±0.02	128.00±1.20	2.56±1.31	0.02±0.01	0.04±0.00
	10 – 20	2.18±0.94	0.03±0.01	5.31±0.05	98.20±0.79	1.08±0.03	0.02±0.00	0.03±0.01
	20 – 30	0.20±0.01	0.02±0.01	1.20±0.35	75.80±1.46	0.80±0.01	0.01±0.00	0.01±0.00
Orji	0 – 10	2.84±0.08	0.18±0.01	10.90±1.25	116.01±2.55	1.05±0.01	0.04±0.01	0.02±0.00
	10 – 20	1.41±0.53	0.12±0.01	5.15±0.67	92.10±1.23	0.63±0.10	0.02±0.00	0.01±0.00
	20 – 30	0.85±0.00	0.08±0.01	2.55±1.54	61.30±2.76	0.10±0.00	0.01±0.00	0.01±0.00
Control	0 – 10	0.02±0.00	0.01±0.00	0.95±0.00	116.00±7.00	0.05±0.01	0.01±0.00	0.00±0.00
	10 – 20	0.01±0.01	0.01±0.00	0.90±0.04	85.50±2.00	0.03±0.01	0.01±0.00	0.00±0.00
	20 – 30	0.01±0.00	0.00±0.00	0.50±0.00	51.00±3.40	0.00±0.00	0.00±0.00	0.00±0.00

** Mean of three ± Standard Deviation

The concentration of mercury ranged from 0.02 mg/kg to 0.20 mg/kg, 0.01 mg/kg to 0.10 mg/kg, 0.02 mg/kg to 0.15 mg/kg, 0.08 mg/kg to 0.18 mg/kg and 0.00 mg/kg to 0.01 mg/kg in soil samples from Egbu, Amakohia, Nekede, Orji and the reference station respectively. Concentrations of Hg in the reference station were far much lower than those of the other stations assessed. Maximum range of copper concentrations (3.11 mg/kg to 12.20 mg/kg) was recorded at Egbu sampling station while minimum ranges of concentrations (1.20 mg/kg to 8.10 mg/kg) were obtained at Nekede station. Copper is an essential micronutrient needed for healthy growth of both plants and animals. In plants, copper is useful in water regulation, disease resistance and healthy seed production.

Zinc and cadmium concentrations were higher at soil samples from Egbu (101.30 mg/kg and 0.78 to 2.05 mg/kg) and lower in soil samples obtained from Orji (61.3 mg/kg to 116.01 mg/kg and 0.10 to 1.05 mg/kg) respectively. Zinc is an important trace and least toxic metal with numerous agricultural, biological as well as industrial applications and is mainly use for the corrosion protection of steel (Rajappa, 2008). High concentration of Zinc in soil is associated with Phyto-toxicity there by affecting the activity of not only weeds, but also earthworms and microorganisms (Preda and Cox, 2002; Aboud and Nandini, 2009).

The concentration of Cadmium in the soils of dumpsites investigated was above WHO (2004) maximum permissible limits of 0.003mg/L. The concentration of chromium ranged from 0.01 mg/kg to 0.02 mg/kg, 0.00 mg/kg to 0.03 mg/kg, 0.01 mg/kg to 0.02 mg/kg, 0.01 mg/kg to 0.04 mg/kg and 0.00 mg/kg to 0.01 mg/kg in soil samples from Egbu, Amakohia, Nekede, Orji and the reference station respectively. Arsenic contents in soil samples varied from 0.01 mg/kg to 0.05 mg/kg, 0.01 to 0.06 mg/kg, 0.01 to 0.04 mg/kg, and 0.01 to 0.02 mg/kg at Egbu, Amakohia, Nekede, Orji and the reference station respectively. These values of arsenic were slightly higher than the permissible limit of 0.01mg/L (WHO, 2008). The values of Arsenic obtained in this study were below the average crustal abundance of 5mg/Kg in an uncontaminated soil. Health hazards associated with long term exposure to arsenic includes skin, lungs and bladder cancer. Others are neurotoxicity, diabetes and cardiovascular disease (Oti and Nwabue, 2013; Flanagan *et al*., 2012).From the above results, the concentrations of the heavy metals investigated in all the refuse stations were higher than in the reference sample. The results also revealed a steady decrease in the concentration of the above parameters analyzed with depth profile. The depth profile 0-10 cm recorded the highest concentration whereas profile 20-30 cm recorded the lowest levels of heavy metals as stated previously.From geochemical perspective, calculation of geoaccumulation index (Table 11) revealed the presence of contamination of cadmium ranging from moderately to highly contamination across most of the study stations.

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Table 3: Geoaccumulation index of soil sample with the vicinity of Refuse Dump

Station	Depth (cm)	Pb	Hg	Cu	Zn	Cd	Cr	As
Egbu	0-10	-2.00	0.51	-2.15	-5.26	4.11	1.33	-6.62
	10-20	-2.48	-0.29	-2.54	-5.27	3.82	0.67	-7.54
	20-30	-3.61	-1.79	-3.51	-5.55	3.14	0.67	-8.23
Amakohia	0-10	-2.08	-2.49	-2.03	-5.36	3.83	2.00	-6.44
	10-20	-2.66	-0.88	-2.71	-5.56	3.37	0.67	-6.84
	20-30	-4.38	-2.49	-3.62	-5.78	1.78	0.00	-8.23
Nekede	0-10	-1.84	0.22	-2.56	-5.32	4.33	1.33	-6.84
	10-20	-2.40	-1.39	-2.98	-5.58	3.47	1.33	-7.13
	20-30	-4.79	-1.79	-2.72	-5.84	3.17	0.67	-8.23
Orji	0-10	-2.13	0.41	-2.27	-5.42	3.44	2.66	-7.54
	10-20	-2.83	0.01	-3.02	-5.65	2.93	1.33	-8.23
	20-30	-3.34	-0.41	-3.84	-6.06	1.09	0.67	-8.23
Control	0-10	-7.09	-2.49	-4.71	-5.42	0.39	0.67	-12.83
	10-20	-7.78	-2.49	-4.76	-5.72	-0.12	0.67	-12.83
	20-30	-7.78	-4.79	-5.35	-6.23	-5.82	0.00	-12.83

However, the reference station was uncontaminated and recorded very low values of geoaccummulation index (I_{geo}). The depth profile 0-10 cm recorded the highest cadmium contamination while profile 20-30 cm had the lowest levels of cadmium contamination.

Industrial and developing cities are more likely to have highest level of bioavailability of Cd (Uba *et al*., 2008). This could be ascribed to the growing throwing away of non-serviceable metal scraps, plastics, wastes from paint industries, and batteries into refuse site which upon decomposition seeped and accumulated in the soil over a period of time (Mico *et al*.,2006; Ogoko 2014). Cadmium is a strong carcinogens, teragens, and mutagens which could cause liver and kidney dysfunction.Pollution load index (PLI) of soil samples were presented in Table 4.

Table 4: Contamination factor (CF) and Pollution load index (PLI) of soil sample

Station	Depth (cm)	Pb CF	Hg CF	Cu CF	Zn CF	Cd CF	Cr CF	As CF	PLI
Egbu	0-10	0.20	2.50	0.174	1.03	13.67	2.00	0.01	2.80
	10-20	0.13	1.13	0.118	1.02	10.2	1.00	0.004	1.94
	20-30	0.04	0.25	0.044	0.77	5.20	0.00	0.002	0.90
Amakohia	0-10	0.19	1.15	0.197	0.94	10.40	3.00	0.012	2.27
	10-20	0.11	0.625	0.100	0.76	6.53	1.00	0.008	1.31
	20-30	0.09	0.125	0.04	0.61	1.33	0.00	0.002	0.31
Nekede	0-10	0,24	1.89	0.116	0.97	3.73	2.00	0.008	1.28
	10-20	0.14	0.38	0.076	0.74	7.20	2.00	0.006	1.51
	20-30	0.01	0.25	0.017	0.57	5.33	0.00	0.002	0.88
Orji	0-10	0.18	2.25	0.156	0.88	7.01	4.00	0.004	2.07
	10-20	0.09	1.55	0.074	0.70	4.20	2.00	0.002	1.23
	20-30	0.053	1.01	0.036	0.46	0.67	0.00	0.002	0.318
Control	0-10	0.001	0.13	0.014	0.88	0.33	1.00	0.00	0.34
	10-20	0.001	0.13	0.013	0.66	0.20	1.00	0.00	0.29
	20-30	0.001	0.00	0.007	0.39	0.00	0.00	0.00	0.06

Contamination factor obtained from soil samples of depth profile 0 – 10 cm were greater than 1.0 across all the stations investigated, indicating that it is the most contaminated among the three depth profiles evaluated.

Pollution load index (PLI) of soil profile 0 -10 cm across Egbu, Amakohia, Nekede and Orji were 2.80, 2.27, 1.28 and 2.07 respectively. Similarly, PLI values of soil profile 10 -20 cm were 1.94, 1.31, 1.51 and 1.23 at Egbu, Amakohia, Nekede and Orji respectively. It is worthy to note that PLI greater than 1.0 revealed that the sampling stations were polluted with heavy metals. PLI of depth profile 20 -30 cm

were lower than those of 10 -20 cm and 0 -10 cm respectively.

Conclusion

The study reveals that the concentrations of sulphate, nitrate, phosphate, lead, mercury, copper, zinc, chromium and zinc ions in the soil are relatively comparable to the permissible limit but may tend to increase drastically if the discharged of heavy metal ions into the environment is unabated. The concentration of cadmium was well above the permissible tolerance limit indicating pollution of the soil. It is therefore recommended that remedial measures be adopted to clean up the soil of cadmium using suitable remediation technologies.

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