

RESEARCH ARTICLE

DETERMINATION OF HEAVY METALS AND ENVIRONMENTAL HEALTH STATUS OF AGRO SOILS IN IKOT ABASI, NIGER DELTA, NIGERIA

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ARTICLE DETAILS

Article History:

Received 09 June 2023

Revised 18 July 2023

Accepted 22 August 2023

Available online 24 August 2023

ABSTRACT

Heavy metal pollution of soils is a worldwide concern due to the security of the agricultural products derivable from the heavy metal contaminated soils. The toxic metals enter the soil-agro ecosystem through natural processes derived from anthropogenic activities and geological weathered materials. This study is aimed at investigating the contamination status of soils from Ikot Abasi, Akwa Ibom State, being an area of intense agricultural and industrial activities. Twelve locations were demarcated for soil sampling, whereby top (0- 15 cm) and sub-surface (15 – 30cm) soil samples were obtained. The soil samples were air-dried and subjected to heavy metal determination (iron, Fe; cadmium, Cd; lead, Pb; zinc, Zn; copper, Cu; vanadium, V; nickel , Ni; chromium, Cr ; mercury, Hg) by inductively coupled plasma– optical emission spectrometer (AGILENT 720 ICP-OES). The mean concentrations of heavy metals during the dry and wet seasons followed the order: Fe > Zn > Cu > Cr > Ni > Pb > V > Cd > Hg. The geo-accumulation index (Igeo) determined for all the metals studied were less than one , which falls in the Class zero , implying that the soils of the study area is practically unpolluted ; the potential ecological risk (RI) were less than one , which was in the class of no potential ecological risk : modified degree of contamination (mCd) calculated for both seasons falls in the category of less than 1.5 , which is nil to very low degree of contamination of the soils of the study area; pollution load index (PLI), falls in the category of PLI of zero, which is excellence with no metal pollutant contamination. The public concern in respect of the security of the agricultural products derivable from the heavy metal contaminated soil, seem not to be applicable in the soils of Ikot Abasi, however, regular monitoring, is recommended to check possible future contamination.

KEYWORDS

Ecosystem, Heavy metals, Geo-accumulation, Pollution load index, Contamination factor

1. INTRODUCTION

Industrialisation and development have led to incessant and injurious pollution of the environmental components with heavy metals and other pollutants therefore, heavy metal pollution of soils is drawing worldwide attention and concern. The security of the agricultural products from the heavy metal contaminated soils is what is making the public concern critical as far as there is food chain (Giaccio et al., 2012). Heavy metals refer basically to metals and metalloids that possess biological toxicity, such as cadmium, mercury, arsenic, lead, and chromium (Martínez-Graña et al., 2014). These toxic metals which are ubiquitous in the environment enter the soil-agro ecosystem through geological weathered materials and anthropogenic activities (García Sánchez, 2008). Heavy metal pollution poses a great threat to the health and well-being of organisms and human beings due to potential accumulation risk through the food chain (Etesin et al., 2015; Fernando et al., 2017). Heavy metals in soils are the most essential components of the environment and the food chain which constitute important factor in human health (Ahmed et al., 2015; Ali et al., 2016).

It is a verified fact that geological substrates and the weathering processes are the major determinant of the concentrations of heavy metals in the natural or unpolluted soil background (Alloway, 1990). Moreso, rocks and other geological materials have a greater influence on the content of heavy

metals in soils, which in most cases may exceed critical values (Salonen et al., 2007). However, it is almost with difficulty to determine natural background levels, in terms of the geochemical composition of virgin soils, due to the fact that atmospheric depositions can contaminate soils with certain trace pollutants (Sayadi and Sayyed, 2011). This makes the estimation of the geochemical baseline more useful, as to indicate that there exists conditions where a certain human impact on the environment had been there (Lalor, 2008; Sprynskyy et al., 2007). The soil component receives significant amounts of contaminants from different sources annually, acts as a sink for a wide variety of discharges and emissions, comprising several heavy metals, some of which are toxic to the environment and animals, including man (Etesin et al., 2015).

Soil heavy metals create toxic effects on soil microorganisms which results in the alteration of the diversity, population size and overall activity of the soil microbial communities (Ashraf and Ali, 2007). There has been reported case of enhanced lead metal concentration in soils which led to decrease in soil productivity and uptake of the metal by the plants from soils which poses a great health risk to humans through the food chain (Jordao et al., 2006) . Generally, uptake of soil heavy metals by plants is a potential health threat to human that should be given serious consideration (Nuralykyzy et al., 2021). The consumption of heavy metal contaminated food can seriously deplete some essential nutrients in the

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[10.26480/jcleanwas.02.2023.55.60](https://doi.org/10.26480/jcleanwas.02.2023.55.60)

body that are further responsible for decreasing immunological defences, intrauterine.

Cadmium (Cd) is a well-known heavy metal toxicant and the target organs for Cd toxicity have been identified as liver, placenta, kidneys, lungs, brain and bones (Sobha et al., 2007). Depending on the extent of exposure, the causal effects include nausea, vomiting, abdominal cramps, dyspnea and muscular weakness. Severe exposure may result in pulmonary edema and death. Pulmonary effects (emphysema, bronchiolitis and alveolitis) and renal effects may occur following sub-chronic inhalation exposure to cadmium and its compounds (Hinojosa et al., 2004). Heavy metals could originate from both parent materials through natural processes into the soil agro-ecosystem and anthropogenic activities. The impact of heavy metal pollution could be very damaging to the health and well-being of organisms, and humans due to potential accumulation risk through the food chain. Remediation using chemical, physical, and biological processes have been adopted to solve the problem (Singh and Kalamdhad, 2011). This present study is conducted to evaluate the levels of some selected heavy metals in the soil of the study area and compare heavy metal

contamination in the soils with comparable references like averages of world heavy metal levels (soil, surface rock, shale, background, and earth's crust), certain indices like enrichment factor, geo-accumulation index, pollution load index and modified degree of contamination, in order to delineate polluted areas from unpolluted ones.

2. MATERIALS AND METHODS

2.1 The study Area

The study area, Ikot Abasi lies within the Niger Delta zone in South-eastern Nigeria (Figure 1). It is located between latitude 4.3111 ° and 4.4512 ° North and between longitude 7.5213 ° and 8.0219 ° East (Ikot Abasi: The Aluminium Town, 1997; Etesin et al.2013) . Ikot Abasi is an industrial hub of Akwa Ibom State, Nigeria, that hosts some major multinational companies and facilities, like Exxon Mobil Offshore Platforms , Aluminium Smelter Company of Nigeria (ALSCON), SEPTA gas station, Ibom Power Company Limited, Ikot Abasi and other Oil Platforms located offshore Ikot Abasi coast.

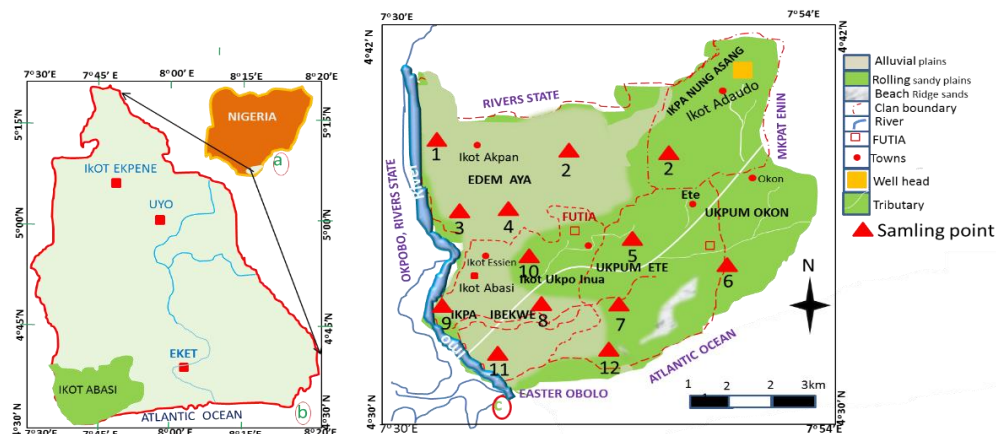


Figure 1: Map of Ikot Abasi showing the sampling locations

The study area is underlain by the sedimentary formation which is of the Late Tertiary and Holocene ages (Udo et al., 2013). There is the occurrence of deposits of recent alluvium and beach ridge sands stretching the coast and the estuaries of the Imo , Qua Iboe Rivers and flood plains of Uta Ewa creek (Magnus et al., 2012). The study area is made up of matured, coarse and moderately well sorted coastal plain sands, which overlies the Bende-Ameki formation and goes south westward (Akankpo and Igbokwe, 2011). The landscape of the study area consists of a lowly plain and riverine areas with no portion that is above sea level of 175 meters. The physiography of the study area has the characteristics of a beach ridge complex and succession of sub-parallel sand ridges (Kumer, 2013).

The physical relief of the study area is flat, having some marshy river-washed soils close to the banks of the Qua Iboe River (Etesin et al., 2013). Ikot Abasi Local Government Area falls within the tropical zone and its vegetation is the green foliage of trees/shrubs and the oil palm tree belt. The Local Government Area has two seasons: the wet season (March – September) and the dry season (October – February). There are abundant deposits of crude oil and clay in the study area. Forest resources are also abundant and may include mangroves, nipa palm, timber, palm produce while the area is also noted for seafood production. Farm crops range from yam, cassava, cocoyam, plantain to maize and vegetables (Akankpo and Igbokwe, 2011).

2.2 Soil sample collection

Twenty-four (24) soil samples were collected from the study area to cover November, December, 2021 and January 2022 during the dry season and April, May, and June 2022 during the rainy season. Soil samples were collected using an auger, at 0–15 cm and 15–30 cm soil layers and the soil samples were stored in black polyethylene bags. The soil samples were air-dried and sieved to 63 micron sizes according to the method of (APHA, 2005).

2.3 Soil samples digestion

Digestion of the soil samples was carried out according to the methods adopted (Shiraishi et al., 1990; Etesin et al., 2015). One gram of < 63 micron soil samples were extracted in a 250 ml borosilicate beaker using 4: 1 ratio, HNO₃ : HClO₄ mixed acid solution and allowed to stand overnight, heated to near dryness on a hot plate. 20 ml of 5 M HNO₃ solution was added and allowed to cool. The digests were allowed to stand overnight and then filtered through Whatman Grade A filter paper. The

filtrates were transferred to 100 ml volumetric flasks and made up to the mark with 0.5 M HNO₃.

2.4 Analysis of digested soil samples

Metal concentrations were measured in the soil filtrates by inductively coupled plasma – optical emission spectrometer (AGILENT 720 ICP-OES). Suitable internal chemical standards (Merck, Germany) were used to calibrate the instrument. Accuracy and precision of the metal analyses were checked against standard reference materials from National Institute of Standards and Technology (NIST). Manufacturer's instrument parameters are listed in Appendix 1.

2.5 Index of geo-accumulation (Igeo)

The geo-accumulation index (Igeo) determination for each metal was based on the equation development by Muller which is widely used by researchers (Abdullah et al., 2021; Benson et al., 2016):

$$I_{geo} = \log_2 \frac{C_n}{1.5B_n} \quad (1)$$

Where $\log_2 = 0.3010$, C_n is the measured concentration of the metal/element in the sediment or soil sample, and B_n represents the standard reference background level for the metal (generally considered as the pristine, preindustrial or uncontaminated level or concentration of the metal). The factor 1.5 is the constant introduced to normalize possible natural (lithogenic) variations in the sediment or soil (Abdullah et al., 2020; Abraham and Parker, 2008; Benson et al., 2016).

The geo-accumulation index classifies sediments into seven (7) grades as originally proposed by Muller for the assessment of sediment or soil quality, which are (Abraham and Parker, 2018):

Class 0 – Igeo value < 0 – implying that the sample is practically unpolluted;

Class 1 – Igeo value > 0 – 1 rated as unpolluted to moderately polluted;

Class 2 – Igeo > 1 – 2, moderately contaminated;

Class 3 – Igeo > 2 – 3, moderately to slightly polluted;

Class 4 – Igeo > 3 – 4, moderately to strongly polluted;

Class 5 – Igeo > 4 – 5, strongly to extremely polluted; and

Class 6 – Igeo > 5, very strongly to extremely polluted

2.6 Pollution load index (PLI)

Pollution load index is calculated by the formula modified by others (Islam et al., 2015 b; Ali et al., 2016):

$$PLI = (CF_1 \times CF_2 \times CF_3 \times \dots \times CF_n)^{1/n} \quad (2)$$

Where,

CF_i = Concentration of metal in soil /concentration of background metal (Islam et al., 2015a)

When $PLI = 0$, soil or sediment is excellent , no pollution

When $PLI = 1$, baseline pollutant level

When $PLI > 1$, progressive deterioration of soil quality.

2.7 Potential ecological risks index (RI)

The potential ecological risks index of metals in soil is calculated thus;

$$\text{Risk index (RI)} = \text{Sum} (E_{ri}) \quad (3)$$

$$E_{ri} = \text{Sum} T_{ri} (C_s/C_n) \quad (4)$$

Where,

E_{ri} , is nominal risk for a single metal

C_s is concentration of metal in soil

C_n is background concentration of metals

T_{ri} is toxic response for a given metal , and the values for these metals are : Cd , 30 ; Cr , 2; Ni , 5 ; Pb , 5 ; Zn , 1 .

Nominal risk (E_{ri}) for metal is classified as (Kumar et al., 2019b):

$E_{ri} < 40$, low risk

$E_{ri} > 40 \leq 80$, moderate risk

$E_{ri} > 80 \leq 160$, considerable risk

$E_{ri} > 160 \leq 320$, high risk

$E_{ri} > 320$, very high risk

Hence, RI is classified as (Benson et al., 2016);

$RI < 150$, low risk

$RI > 150 \leq 300$, moderate risk

$RI > 300 \leq 600$, high risk

$RI > 600$, very high risk

2.8 Modified degree of contamination (mC_d) in soils

The modified degree of contamination (mC_d) in soils and sediments is calculated by the expression (Benson et al., 2016):

$$mC_d = \text{Sum} (CF_i / n) \quad (5)$$

where, n , is the number of metals considered.

The classification of mC_d is as given below:

$mC_d < 1.5$, no contamination to very low degree of contamination

$mC_d > 1.5 < 2$, low degree of contamination

$mC_d > 2 < 4$, moderate degree of contamination

$mC_d > 4 < 8$, high degree of contamination

$mC_d > 8 < 16$, very high degree of contamination

$mC_d > 16 < 32$, extremely high degree of contamination

$mC_d > 32$, exceedingly high degree of contamination

2.9 Data analysis

All data obtained in the study were subjected to analysis of variance (ANOVA) for spatial and seasonal variations , with the level of significance set at $P < 0.05$. The statistical analysis of the data was performed using SPSS v.25 software, including mean, standard deviation and other calculations for the data acquired.

3. RESULTS AND DISCUSSION

3.1 Results of Heavy Metals in Soils

The results of heavy metal analyses in soils of Ikot Abasi obtained during the dry season are presented in Table 1, while the results of heavy metal analyses in soils of Ikot Abasi obtained during the wet season are presented in Table 2. Iron had concentration range from 790.0 mg/kg to 5421 mg /kg during the dry season ; lead had concentration range of below detection limit (BDL) to 0.005 mg/kg at station 2; cadmium was below detection limit at all stations ; zinc (15.69 – 56.41 mg/kg) ; chromium (0.956 – 2.741 mg/kg) ; copper (1.764 – 5.993 mg/kg); nickel (0.266- 4.087) ; vanadium (BDL – 0.004 mg/kg); mercury (BDL at all stations) . The concentrations of the metals determined were lower than the permissible limits set by WHO and background concentrations of shale (Onjefu et al., 2016; WHO 2010; Helen et al, 2022). In a similar study on the outcrops rock samples of the Benue trough, Nigeria, the was an anomalous concentrations of lead (Pb) and cadmium above average crustal abundance of 30 mg/kg , which was not health for agro-systems (Etesin et al., 2015). During the wet season, the metals concentrations were, iron (504 – 4951 mg/kg); lead (0.001 – 0.003 mg/kg); cadmium (BDL); zinc (13.96 – 52.91); chromium (0.458 – 2.713 mg/kg); copper (1.204 – 5.282 mg/kg); nickel (0.197 – 2.742 mg/kg); vanadium (BDL – 0.002 mg/kg); mercury (BDL) . Equally, the concentrations of the metals determined during the wet season were lower than the permissible limits set by WHO and background concentrations of shale (Onjefu et al., 2020; WHO, 2010).

Table 1: Concentrations of Heavy Metals in Soils in Ikot Abasi during the Dry Season

Sample Site	Location	Depth	Fe	Pb	Cd	Zn	Cr	Cu	Ni	V	Hg
			mg/kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg
Station 1	Ikpetim	< 15 cm	845	0.003	< 0.001	15.88	1.567	2.965	0.622	0.003	< 0.001
		> 20 cm	490	0.002	< 0.001	23.06	2.086	2.286	0.854	0.001	< 0.001
Station 2	Utaewa	< 15 cm	1127	0.005	< 0.001	45.21	1.563	3.954	0.923	0.003	< 0.001
		> 20 cm	765	0.002	< 0.001	32.87	1.256	2.723	1.045	0.002	< 0.001
Station 3	Conveyor Belt	< 15 cm	1025	0.002	< 0.001	30.08	2.055	4.067	1.764	0.001	< 0.001
		> 20 cm	854	0.001	< 0.001	23.44	1.567	3.518	1.543	< 0.001	< 0.001
Station 4	Berger Camp	< 15 cm	985	< 0.001	< 0.001	56.41	1.965	1.764	2.076	< 0.001	< 0.001
		> 20 cm	622	< 0.001	< 0.001	47.33	1.028	1.211	2.754	< 0.001	< 0.001
Station 5	Ikot Abasi	< 15 cm	921	0.001	< 0.001	42.98	0.956	4.865	1.765	0.004	< 0.001
		> 20 cm	1200	< 0.001	< 0.001	31.76	0.522	3.976	2.173	0.002	< 0.001
Station 6	Ikot Abasi Village	< 15 cm	5421	0.002	< 0.001	37.54	1.346	4.912	4.087	0.001	< 0.001
		> 20 cm	3277	0.003	< 0.001	29.78	0.976	4.045	4.167	0.003	< 0.001
Station 7	Ikot Obong Village	< 15 cm	2190	0.002	< 0.001	15.69	1.845	3.775	2.675	0.002	< 0.001
		> 20 cm	1654	0.001	< 0.001	12.95	1.382	2.865	2.169	0.001	< 0.001
Station 8	Ikot Ukpoindu	< 15 cm	877	< 0.001	< 0.001	29.75	1.675	3.218	0.854	< 0.001	< 0.001
		> 20 cm	642	< 0.001	< 0.001	20.66	1.245	2.734	0.674	< 0.001	< 0.001
Station 9	Ikot Etetuk	< 15 cm	790	0.003	< 0.001	56.34	1.875	4.672	0.226	0.002	< 0.001
		> 20 cm	1096	0.001	< 0.001	41.76	1.025	4.127	0.459	0.001	< 0.001
Station 10	Ikot Akpanata	< 15 cm	1378	< 0.001	< 0.001	27.94	2.451	5.993	1.848	0.002	< 0.001
		> 20 cm	965	0.001	< 0.001	21.75	0.975	5.431	2.026	0.001	< 0.001
Station 11	Market Square	< 15 cm	2170	0.003	< 0.001	18.66	2.741	3.673	1.754	< 0.001	< 0.001
		> 20 cm	1562	0.002	< 0.001	27.92	1.452	2.856	1.452	< 0.001	< 0.001
Station 12	Ata Udo Usung	< 15 cm	899	< 0.001	< 0.001	40.56	1.156	5.753	2.765	0.002	< 0.001
		> 20 cm	753	< 0.001	< 0.001	39.79	0.845	5.357	2.911	0.001	< 0.001

Table 2: Concentrations of Heavy Metals in Soils in IkotAbasi during the Wet Season

Sample Site	Location	Depth	Fe	Pb	Cd	Zn	Cr	Cu	Ni	V	Hg
			mg/kg	mg/kg	mg/Kg	mg/Kg	mg/kg	mg/kg	mg/kg	mg/kg	(mg/Kg
Station 1	Ikpetim	< 15 cm	817	0.002	< 0.001	13.96	1.267	1.765	0.512	0.002	< 0.001
		> 20 cm	504	0.002	< 0.001	20.17	1.862	1.976	0.653	0.001	< 0.001
Station 2	Utaewa	< 15 cm	1250	0.003	< 0.001	41.22	1.283	3.672	0.733	0.002	< 0.001
		> 20 cm	659	0.001	< 0.001	33.45	1.172	2.459	1.205	0.001	< 0.001
Station 3	Conveyor Belt	< 15 cm	1041	< 0.001	< 0.001	31.19	1.922	3.948	1.453	< 0.001	< 0.001
		> 20 cm	911	< 0.001	< 0.001	20.14	1.248	2.994	1.699	< 0.001	< 0.001
Station 4	Berger Camp	< 15 cm	958	< 0.001	< 0.001	52.91	1.673	1.493	1.065	< 0.001	< 0.001
		> 20 cm	541	< 0.001	< 0.001	42.88	1.161	1.204	1.662	< 0.001	< 0.001
Station 5	Ikot Aba	< 15 cm	842	< 0.001	< 0.001	40.13	0.734	4.384	1.612	0.002	< 0.001
		> 20 cm	1248	< 0.001	< 0.001	32.56	0.458	4.113	2.022	0.002	< 0.001
Station 6	Ikot Abasi Village	< 15 cm	4951	0.002	< 0.001	33.78	1.278	3.845	3.875	0.001	< 0.001
		> 20 cm	3112	0.001	< 0.001	27.26	1.024	3.359	3.992	0.001	< 0.001
Station 7	Ikot Obong Village	< 15 cm	1763	0.001	< 0.001	16.22	1.578	2.654	2.118	0.002	< 0.001
		> 20 cm	1489	0.001	< 0.001	12.54	1.211	2.357	2.317	0.001	< 0.001
Station 8	Ikot Ukpoinua	< 15 cm	734	< 0.001	< 0.001	27.44	1.548	2.118	0.764	< 0.001	< 0.001
		> 20 cm	578	< 0.001	< 0.001	21.58	1.374	2.051	0.449	< 0.001	< 0.001
Station 9	Ikot Etetuk	< 15 cm	765	0.002	< 0.001	50.25	1.655	4.387	0.197	0.001	< 0.001
		> 20 cm	821	0.001	< 0.001	38.93	1.173	4.141	0.321	0.001	< 0.001
Station 10	Ikot Akpanata	< 15 cm	1265	< 0.001	< 0.001	26.05	2.331	4.713	1.331	0.001	< 0.001
		> 20 cm	1107	0.001	< 0.001	22.48	1.103	4.276	1.794	0.001	< 0.001
Station 11	Market Square	< 15 cm	1977	0.001	< 0.001	16.78	2.722	3.445	1.532	< 0.001	< 0.001
		> 20 cm	1511	0.001	< 0.001	21.94	2.023	2.648	1.763	< 0.001	< 0.001
Station 12	Ata Udo Usung	< 15 cm	741	< 0.001	< 0.001	39.44	1.328	5.283	2.318	0.001	< 0.001
		> 20 cm	726	< 0.001	< 0.001	37.86	1.127	5.117	2.742	< 0.001	< 0.001

3.2 Pollution Load Index (PLI)

The PLI calculated (Table 3) were 0.007 – 0.01 during the dry season, while the value of PLI during the wet season were 0.006 – 0.011, which indicated no pollution to baseline pollutant level in the soils of the study area and falls within the category of PLI of zero, which is excellence with no metal pollutant contamination. Thus, the seasonal variation was not significant at $P < 0.05$.

3.3 Potential ecological risks index (RI)

The potential ecological risks index (RI) of metals in soils of the study area calculated during the dry season ranged between 0.348 to 0.962, which by the RI classification falls in the category of less than 150, signifying low risk. While the RI of metals in soils of the study area calculated during the wet season ranged between 0.315 to 0.771, which by the RI classification falls in the category of less than 150, signifying low ecological risk of metal contamination (Table 3).

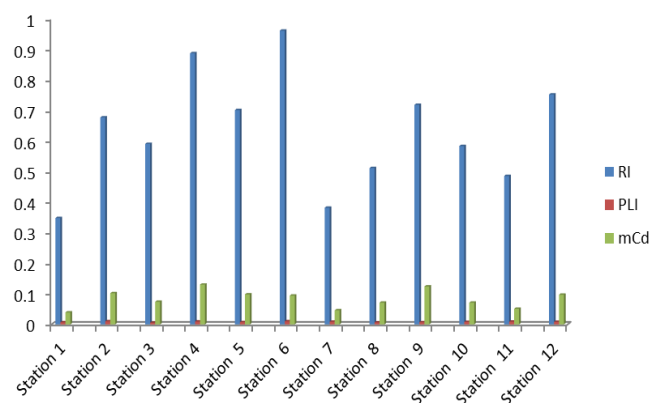
3.4 Modified degree of contamination (mCd) in soils

The modified degree of contamination (mCd) in soils of the study area calculated during the dry season ranged between 0.039 to 0.13, while the values obtained during the wet season ranged between 0.034 to 0.119. The mCd calculated for both seasons falls into the category of less than 1.5, which is nil to very low degree of contamination of the soils of the study area (Table 3) and represented graphically in Figures 2 and 3, with the highest RI value of 0.962 at Station 6. The low levels of metals in the study area delegates towards absence of both anthropogenic and lithogenic sources of metal pollution in the area. The regulated limits of metals in soils by the European Union (EU, 2010) are, Cd (3.00 mg/kg), Cu (140 mg/kg), Ni (75 mg/kg), Pb (300 kg/kg), Zn (300 mg/kg). In comparison to this study, all the stations had metal values far lower than the regulated metal concentrations for any degree of metal contamination.

However, Fe, Zn, Cr, Cu, and Ni show significant ($P < 0.05$) spatial variation in the soils of the study area determined from the twelve sampling stations as reflected in Tables 1 and 2, depending on the closeness of the stations to areas of industrial and agricultural activities. In their study, Bunzl *et al.* (2001) investigated the transfer of heavy metals like, Cu, Pb and Zn from soils to plants and found that vegetables grown at environmentally contaminated soils in Addis Ababa, Tanzania, have the possibility to accumulate metals at levels that are toxic to human health.

Table 3: Ecological Risk Indices

Location	Dry Season			Wet Season		
	RI	PLI	mCd	RI	PLI	mCd
Station 1	0.348	0.0067	0.039	0.315	0.006	0.034
Station 2	0.678	0.0099	0.102	0.615	0.008	0.092
Station 3	0.591	0.0054	0.074	0.577	0.006	0.075
Station 4	0.888	0.0092	0.13	0.771	0.008	0.119
Station 5	0.702	0.0073	0.098	0.657	0.007	0.0914
Station 6	0.962	0.01	0.094	0.768	0.011	0.086
Station 7	0.382	0.0085	0.046	0.461	0.007	0.044
Station 8	0.512	0.0065	0.071	0.478	0.006	0.064
Station 9	0.719	0.007	0.124	0.681	0.006	0.111
Station 10	0.584	0.008	0.071	0.523	0.007	0.065
Station 11	0.486	0.009	0.051	0.429	0.007	0.047
Station 12	0.753	0.0081	0.097	0.713	0.008	0.093

**Figure 2: Ecological Risk indices during dry season**

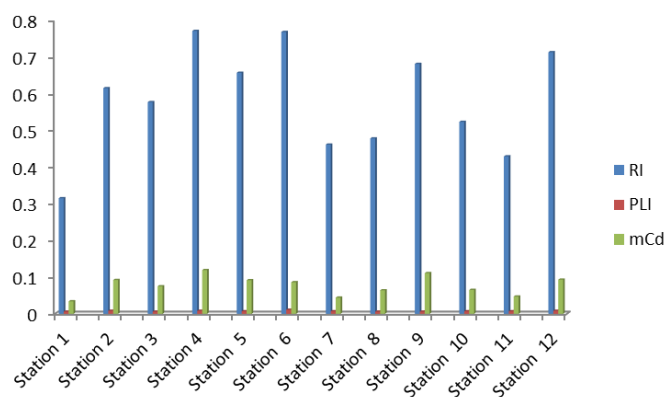


Figure 3: Ecological Risk indices during wet season

4. CONCLUSION

Heavy metals (Cr, Fe, V, Ni, Cu, Zn, Hg, Cd, Pb) were determined in the surface (0 – 15 cm) and sub-surface soils (15 – 30 cm) from Ikot Abasi during the dry and wet seasons. The mean concentrations of heavy metals during the dry and wet seasons were in the order: Fe > Zn > Cu > Cr > Ni > Pb > V > Cd > Hg. There was no significant variation of metal concentrations in the dry and wet seasons ($P < 0.05$) in the study area. However, there was significant ($P < 0.05$) spatial variations of metal concentrations in the study area. To investigate the contamination degree, ecological risk, and human health risk of heavy metals in the soil of the study area, contamination factor (CF), pollution load index (PLI), modified degree of contamination (mCd), potential ecological risk index (RI), and geo-accumulation index (Igeo), were determined based on the data obtained from the soil analyses, to assess the pollution degree. The results showed that the degree of heavy metals contamination decreased in the order; Fe > Zn > Cu > Cr > Ni > Pb > V > Hg. The potential ecological risk indices and geo-accumulation index indicated very low contamination, with no potential ecological and health risk.

The geo-accumulation index (Igeo) determined for all the metals studied were less than one, which falls in the Class 0, implying that the soils of the study area is practically unpolluted; the potential ecological risk (RI) were less than one, which was in the class of no potential ecological risk; modified degree of contamination (mCd) calculated for both seasons falls into the category of less than 1.5, which falls in the class of nil to very low degree of contamination of the soils of the study area; pollution load index (PLI), falls in the category of PLI of zero, which is excellence with no metal pollutant contamination. The public concern in respect of the security of the agricultural products derivable from the heavy metal contaminated soil, seem not to be applicable in the soils of Ikot Abasi, based on the outcome of this study, but the recommendation will be regular monitoring to check any deviation subsequently.

ACKNOWLEDGEMENT

The authors wish to express their gratitude to all persons, including the Laboratory staff and field sampling personnel, who played different roles in the execution of this study.

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