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Toxic Metals in Soils of Mechanic Village Abakaliki, Nigeria and their Health Implications

Oti, Wilberforce J. O

Department of Industrial Chemistry, Ebonyi State University, Private Mail Bag 053, Abakaliki, Ebonyi State, Nigeria. E-mail: drwilberforceoti@gmail.com

ABSTRACT

Composite samples of soil were collected between June 2013 and May 2014 from different sections of mechanic village Abakaliki such as mechanic, welder, electrician and panel beater workshop. A control sample was collected from a farm 100m to the mechanic village 500m away. Orion 920A pH meter and X-ray Fluorescence spectrophotometer were used to determine the pH and different concentrations of metal in the soil. In addition, Walkley and Black method was used to determine the percentage of organic matter while Hydrometer method was used to determine the percentage of sand, silt, and clay in the soil samples. The results showed average pH of 6.2$\pm$ 0.82 and metal concentration (in mg/Kg) ranged from (0.12 $\pm$ 0.2 – 84.41$\pm$ 6.4) for As; (6.41 $\pm$ 0.2 – 116.02$\pm$ 12..2) for Cd; (8.12 $\pm$ 1.2 – 80.72$\pm$12.2) for Co (764.32 $\pm$ 112.4 – 444.14 $\pm$ 16.14) for Cu; (1.14 $\pm$ 0.12 – 6.18 $\pm$ 0.18) for Cr; (1212.8$\pm$ 24.1 – 525.12 $\pm$ 44.2) for Fe; (822.0$\pm$ 72 – 620.18 $\pm$ 66.2) for Mn; (82.4 $\pm$ 8.0 – 228 $\pm$ 8.6) for Ni; (268.12 $\pm$ 46.8 – 664.62 $\pm$ 52) for Pb and (788.24 $\pm$ 84.2 – 1420 $\pm$ 142) for Zn. Percentage (%) of organic matter, sand, silt, and clay respectively were of the range 1.12 $\pm$ 3.4 – 1.68 $\pm$ 3.4; 54 $\pm$ 22 – 58.12; 9.31 $\pm$ 0.92 – 18.8 $\pm$ 1.22 and 26.48 $\pm$ 2.81 – 32.18 $\pm$3.22. The concentrations of the investigated heavy metals were higher in the top soil than in the soil and this suggest that source of pollution was anthropogenic. Elevated concentrations of Ni >Pb>Cd> As above the US-EPA Regulatory Limits in that order were observed in the samples collected from, while variations in the heavy metal levels were generally observed between and within groups. Regular monitoring of heavy metal in the soil is expedient for safety of environment and human health.
Keywords: Toxic Metals, Pollution Index, X-ray Fluorescence, Mechanic Village

INTRODUCTION

As urbanization continues in Nigeria, there was a developmental need to concentrate artisans and automobile engineers that work on vehicles to a common place and that led to the formation of mechanic villages. According to [1], mechanic village is an area of open land allocated to automobile repair workers in the vicinity of an urban centre. Most Nigerian cities have between one and four mechanic villages depending on the population of the city.

Soil is a repository for anthropogenic wastes from human impact on the environment. Heavy metals in soil come from two major sources namely nature and human activities. Naturally, metals in the soil can result from dust and leached particles from rocks and volcanic ash. Anthropogenic source of metal in soil include metalliferous mining and smelting; agricultural and horticultural materials; fossil fuel combustion; chemical and other manufacturing industries and waste disposal. In general, soils are often contaminated by emission from industrial areas, pesticides, waste water irrigation, coal combustion residues, leaded gasoline, oil spill, animal manure, mine tailings, sewage sludge, atmospheric deposition and disposal of high metal wastes. In the mechanic village, soils are often contaminated by the accumulation of heavy metals and metalloids through waste generated from activities of mechanics, panel beaters, electricians, welders. Heavy metal pollution is not only toxic to plants and deteriorates soil optimal bio-productivity but is a severe threat to human health especially at elevated level. Heavy metals are accessed by man via direct ingestion or contact with contaminated soil, the food chain (man being a tertiary consumer in the food chain) and drinking of contaminated ground water. Some metals such as Pb, Hg and As are known carcinogens and their presence in human body cause a long term damaging effect on the central nervous system. Unlike other pollutants, heavy metals are non-biodegradable and they have the tendency to bio-accumulate and bio-magnify from one trophic level to another [2]. While organic contaminants are easily oxidized to carbon (IV) oxide by microbial action, metals do not undergo microbial or chemical degradation. Consequently the total concentration of metals in the soils remains unchanged for a long time after their introduction although their speciation and bioavailability may changes in over a period of time [3]. The presence of toxic metals in soil is known to severely inhibit the biodegradation of organic contaminants. Heavy metals studies have been conducted in soils with differing levels of anthropogenic influences such as in mining activities [4], automobile mechanic waste dump [5]; agricultural land [6];urban cities [7]; industrial areas [8];automobile traffic [9], and in sediments of inland waters [10] [11].

Simple Pollution Index (PI) is used to determine the level of the pollutant in the environment by comparing the concentration of the pollutant to the regulatory limit [12]. In this present work, PIwas employed in measuring the extent of pollution in all the soil samples. When is greater than one (PI > 1), it indicates that the soil or plant is contaminated by the metal, when PI = 1, it indicates a critical state and when PI < 1, there is no pollution [13]. Mathematically, it is expressed as

$$PI = C_{\text{soil or plant}} / C_{\text{USEPA-standard}}$$

Where PI is the individual pollution index of study metal; $C_{\text{plant or soil}}$ is the Concentration of the metal in soil or plant. $C_{\text{USEPA-standard}}$ is the value of the regulatory limit of the heavy metal by US EPA [11]. The overall Pollution status of the soil was determined with the formula

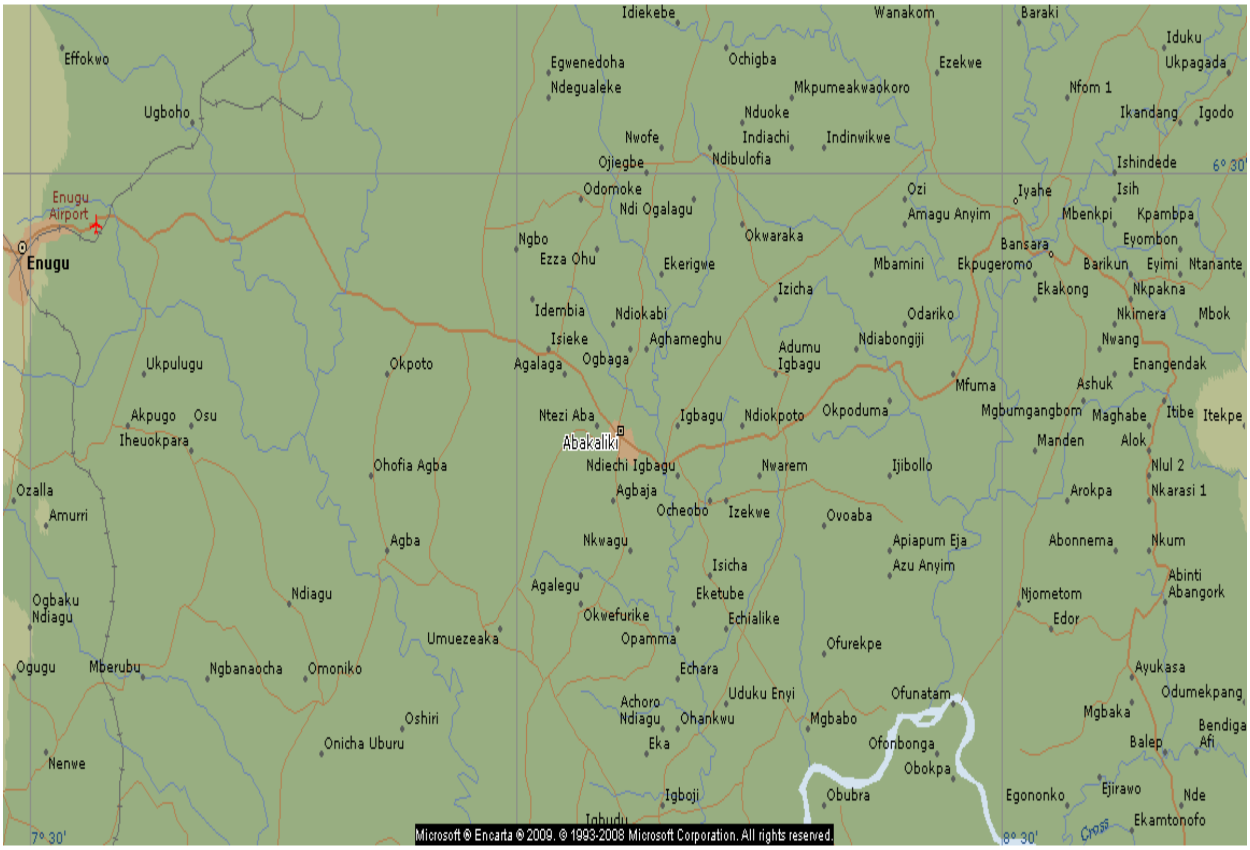
$$PI_{Soil} = \sqrt{\frac{(PI\,ave)^2 + (PI\,max)^2}{2}}$$

Where PI_{soil} is the Pollution Index of the soil, PI_{ave} is the average Pollution indices while PI_{max} is the maximum PI recorded. PI_{Soil} is the overall pollution status of the soil [14].

The major aims of this work was to investigate the levels of heavy metals accumulated in the soils of mechanic, welder, electrician and panel beater workshops due to human activities. The pollution index was used to establish the pollution status of the soil.

STUDY AREA

Abakaliki, is in the mid of the South Eastern, Nigeria (latitudes 4°20'and 7°00'N and longitudes 5°25' and 9°35'). It is the Capital City of Ebonyi State of Nigeria is located at latitudes 6°19'N, 6° 21'N and longitudes 8°05'E, 8°07'E [5]. The study area Mechanic Village is located 1500m from the central part of the town about 200m to Rice Mill Industry. The mechanic village is characterized by beehive activities from 8.00 am in the morning to 6.00pm in the evening. A section known as Motor parts is where people buy and sell different parts of vehicles. The remaining section is occupied basically by the four major identifiable groups such as mechanics, welders, electricians and panel beaters. The mechanics and electricians focus on repairing the mechanical and electricalaspect of the vehicles respectively. The welders and panel fix damaged parts of vehicleand weld metals together. All these activities result to introduction of metals into the environment due to poor waste management.



METHODOLOGY

Collection of Soil Samples: From the selected workshops, composite top-soil and sub-soil samples were collected at 0-30 cm (n=6) and at 60-90 cm (n=6) depths respectively [15]. The soil samples were air-dried, ground mechanically with stainless steel soil grinder and sieved to obtain < 2 mm fraction. 30 g sub-sample was drawn from the bulk (< 2 mm fraction) and reground with laboratory mortar and pestle to obtain < 200 µm fraction. The sample was further dried in an open inert vessel in a muffle furnace at 105 ^{o}C for 2 hours so as to remove soil moisture, after which the samples were cooled in desiccators [16].

Determination of metal concentration: The procedure begins with pelletization of the soil samples and this was done by the use of CAVER model manual palletizing machine at a pressure of 6 - 8 torrs. Standard procedure for XRF was followed in accordance with [5] and Standard Operating Procedure (2007). XRF uses X-rays from decaying source (Am-241) to excite the target atoms. A voltage of 25KV and current of 50µA produced from X-ray tube was used to bombard the sample in XRF system for 18 minutes at 1000 counts. Si-Li detector was used to detect the characteristic X-ray of the metals and their corresponding concentrations were computed in the read out device. The X- rays generated from the target were measured with two Si/Li detectors and the corresponding metal concentration was ascertained by means of incorporated computer device. The device gives the concentrations (in mg/Kg) of As, Cd, Cu, Co, Fe,Mn, Ni,Pb and Zn.

Determination of Soil pH: 50 ml deionized water was added to 10 ml dry soil sample, and stirred with a glass rod. Each sample preparation was left to stand overnight and measurement was made with an Orion 920A pH meter with deionized water as the solvent [17].

Determination of percentages of Sand, Silt, and Clay in Soil: Hydrometer method was used to determine the percentage of sand, silt, and clay in the soil samples [6]. 50 g sample of the soil was weighed and disperse the soil in 1L of water. The dispersionmedium used was 40 g of $[Na_3PO_3]_{13}$ and 10 g of Na_2CO_3 in deionized water. Amyl alcohol was used to disperse froth in determination of silt percentage. After suspending the soil, the hydrometer reading at 40 sec and at 2 hours was taken and correction factor was applied. Using the hydrometer readings, percentages of sand, silt, and clay was calculated. Textural triangle was used to find the texture of the soil.

Determination of percentages of Organic Matter: Percentage of organic matter was determined using Walkley and Black method as described by White [18]. The mass of empty, clean, and dry porcelain dish were determined and a part of or the entire oven-dried soil sample was placed in the porcelain dish and the mass was recorded. The dish was placed in a muffle furnace and the temperature was gradually increase to 440ºC and was left in the furnace overnight. The mass difference was calculated and that represents the organic matter percentage.

RESULTS AND DISCUSSIONS

The results of the total mean heavy metal concentrations from the top-soil and sub-soils of the investigated sections are presented in Tables 1 and 2, the soil properties from the locations are presented in Table 3.

Table 1: XRF Mean Concentrations (mg/kg) of Heavy Metals in Top Soil from different Sections of Abakaliki Mechanic Village and their Pollution Indices (n = 3)

Metal	MS	PI	WS	PI	ES	PI	PBS	PI	CS	PI	US-EPA*
As	12.81 ± 4.1	0.17	76.20 ± 4.8	1.02	84.41 ± 6.4	1.12	20.81 ± 9.6	0.3	6.12 ± 1.2	0.1	75*
Cd	102.14 ± 11.2	1.2	69.40 ± 4.2	0.82	96.34 ± 0.2	1.1	116.02 ± 12.2	1.4	27.44 ± 0.2	0.3	85
Co	48.70 ± 3.2	0.1	80.76 ± 12.2	0.1	60.4 ± 1.2	0.1	62.41 ± 5.3	0.1	24.28 ± 2.4	0.01	660
Cu	982.2 ± 84.1	0.2	1322.2 ± 92	0.3	772.92 ± 62	0.2	860.6 ± 81.1	0.2	500.47 ± 47	0.11	4300
Cr	1116.99± 24	0.4	1212.8±20	0.4	881.8 ±79.1	0.3	1006.18± 24	0.3	722.12± 78.1	0.2	30000
Fe	1100.22±10	–	898.2+76.2	–	900.86±82.1	–	442.4 ± 3.6	–	312.4 ± 4.2	–	
Mn	822.0 ± 72	–	690.0 ± 34.0	–	646.0 ± 42.1	–	628.6 ± 49.4	–	590.18 ± 50.4	–	18300
Ni	118.6 ± 60	1.6	206.8 ± 72	2.8	228 ± 8.60	3.0	186.2 ± 4.81	2.5	84.4 ± 72	1.1	75
Pb	419.8 ± 41.2	1.0	451.7 ± 43.7	1.1	664.62 ± 52	1.6	712.21 ± 61	1.7	318.12 ± 37.6	0.8	420
Zn	1020 ± 112.4	0.14	822.0 ± 62.4	–	869.8 ± 22	0.12	942.4 ± 16.1	0.13	788.2 ± 84	0.13	7500

*** Values refer to metal concentration in typical soils (Miroslav& Vladimir, 1999),**
PI = Pollution index.
ND = Not detectable
MS = Mechanic Sample
WS = Welder Sample
ES = Electrician Sample
PBS = Panel beater Sample
CS = Control Sample

Table 2: XRF Mean Concentrations (mg/kg) of Heavy Metals in Sub-Soil from different Sections of Abakaliki Mechanic Village and their Pollution Indices (n = 3)

Metal	MS	PI	WS	PI	ES	PI	PBS	PI	CS	PI	US-EPA*
As	3.81 ± 1.1	0.05	6.20 ± 0.8	0.83	4.42 ± 1.4	0.06	0.28 ± 0.6	0.4	0.12 ± 0.2	–	75*
Cd	12.44 ± 1.2	0.15	9.20 ± 0.2	0.11	6.41 ± 0.2	0.08	12.02 ± 1.2	0.14	7.44 ± 0.2	0.09	85
Co	9.12 ± 1.2	0.01	10.21 ± 12.2	0.01	10.4 ± 0.2	0.02	12.8 ± 0.3	0.02	8.12 ± 1.4	0.01	660
Cu	764.2 ± 32.1	0.17	322.2 ± 12.2	0.07	542.32 ± 62	0.12	610.6 ± 8.4	0.14	444.14 ± 34	0.10	4300
Cr	916.42± 24.1	–	902.8±20.1	–	621.8 ±19.1	–	906.18± 24.1	–	525.12 ± 18.1	–	3000
Fe	261.42 + 24.2	–	198.02+20.2	–	220.1±12.2	–	234.4 ± 8.6	–	82.4 ± 24.2	–	
Mn	542.0 ± 62	–	530.0 ± 44.0	–	516.0 ± 42.1	–	588.6 ± 49.4	–	620.18 ± 50.4	–	18300
Ni	88.6 ± 8.0	1.2	84.8 ± 7.2	1.1	92.8 ± 8.6	1.2	86.2 ± 4.8	1.1	82.4 ± 8.0	1.1	75
Pb	382.8 ± 41.2	0.9	391.7 ± 43.7	0.9	464.62 ± 62	1.1	450.21 ± 51	1.1	268.12 ± 43.6	0.6	420
Zn	1420 ± 142	0.2	1022.0 ± 62	0.1	989.8 ± 22	0.1	1002.4 ± 16.1	0.1	986.2 ± 84	0.13	7500

Table 3: Properties of Soil from Different Sections of Abakaliki Mechanic Village (n =3)

Properties	MS	WS	ES	PBS	CS
Sand (%)	60.22± 6.2	58.96 ± 4. 6	63.44± 6.2	64.27± 6.2	66.28 ± 6.6
Silt (%)	7.12 ± 0.8	16.44 ± 1.2	12.32 ± 1.7	14.12 ± 1.8	8.12 ± 1.4
Clay (%)	33.60 ± 2.9	29.90 ± 2.8	31.82±3.1	28.44± 2.7	31.64± 2.9
Organic Matter (%)	1.26± 0.8	1.12 ± 0.7	1.33± 08	1.04 ± 0.6	1.56± 1.1
Ph	6.4± 0.92	6.1± 0.88	6.5± 0.64	6.2 ± 0.64	6.8± 0.82

The concentrations of studied metals were higher in top-soil than in sub-soil which suggests that the source of metal in the investigated environment was from anthropenic origin. From Tables 1 and 2, the Pollution Indices of Co, Cu, Cr, Fe, Mn and Zn in the sampleswere generally low. Some of these metals areessentialmicroelements to human health and their concentrations were significantly lower when compared to toxic metals such as As, Cd Ni and Pb. The PI <1 was observed for all the essential microelement such as Cu, Co, Fe, Mn and Zn. They play vital roles in the metabolism of plants and animals. However at excessive concentration, they possess phytotoxic potentials which can inhibit biomass production through the deterioration of soil fertility and can become harmful to humans [19].The concentrations ofNi and Pb exceeded the US-EPA Regulatory Limits in both the top and sub soil samples,while the concentrations ofAs and Cd exceeded only in the top-soil.Non-essential metals such as

As, Cd, Ni and Pb, even at low concentration, constitute environmental threat as they are toxic toplant and animal including humans. In solution, some group of metals exhibit synergism. Thus Ni/Zn, Cu/Cd, Cd/Zn and Cu/Zn present a more hazardous effect than the individual metals [8].

Arsenic: High PI > 1 of As was observed in the top-soil collected from welder and electrician sections which obviously resulted from materials and activities used in these sections (Tables 1 and 2). Low PI<1 observed in samples from sub-soil means that the source of As came as a result of human activities.Occupational exposure of arsenic poisoning is known to occur in persons working in industries involving the use of inorganic arsenic and its compounds, such as nonferrous metal alloys, and electronic semiconductor manufacturing. Arsenic ions have the ability to interact with protein thiols, hence it is notoriously poisonous to multicellular life [20]. Arsenic occurs both in various organic and inorganic forms in the environment. European Union under directive 67/548/EEC has classified elemental arsenic and arsenic compounds as "toxic" and "dangerous for the environment". Moreover, International Agency for Research on Cancer (IARC) recognizes arsenic and arsenic compounds such as arsenic trioxide, arsenic pentoxide and arsenate salts as group 1 carcinogens. Long-term exposure to arsenic has been linked to bladder and kidney cancer in addition to cancer of the liver, prostate, skin, lungs and nasal cavity [21].

Cadmium: High concentrations of Cd were observed in the top-soils collected from mechanic, electrician and panel beater sections; nickel (Tables 1 and 2). Their corresponding PI > 1 were observed to generally increase in the order ES > PBS > WS > MS. Cadmium is found in the earth's crust and theoretically for every 1000Kg of a normal soil contains at least 0.2 g cadmium theoretically. Cadmiumis found in combination with zinc and they are similar in many respects such as preference to oxidation state of +2[22]. It is soluble in acids but not in alkalis. Cadmium is released through human activities, such as mining and manufacturing and uses of Ni-Cd batteries[23]. High exposures of Cd can occur with people who work with Cd metals and alloys and also with those who live near hazardous waste sites or factories that release cadmium into the air. A significantly high exposure of cadmium occurs with cigarette smokers. When people breathe in cadmium it can severely damage the lungs and may even cause death. Cadmium is first transported to the liver through the blood where it bonds to proteins to form complexes that are transported to the kidneys. Cadmium in kidneys damages filtering mechanisms and causes the excretion of essential proteins and sugars from the body and further kidney damage. It takes a very long time before cadmium that has accumulated in kidneys is excreted from a human body [24].

Nickel: From Table 1, high PI of Ni was observed in all the samples in the increasing order Es (3.0) > WS (2.8) > PBS (2.5) > MS (1.0) > CS (0.8).Values of the pollution indices shows that all the samples were already contaminated with cadmium. The presence of Cd in the control strongly suggest that all the Cd in the soil did not result from human activities because for every 1000 Kg of normal soil, there is normally at least 80 g of nickel [24].According to [25], Ni is also listed among the 25 hazardous substances thought to pose the most significant potential threat to human health. The toxicologically important routes of entry for nickel in humans are inhalation, skin absorption, ingestion, and skin and/or eye contact. Nickel salts exert their action mainly by gastrointestinal irritation and not by inherent toxicity.Nickel is listed as a class A carcinogen in another document [26]. Nickel cannot be destroyed in the environment. It can only move around, change its form, or become attached to or separated from particles. Under acidic conditions, nickel is more mobile in soil and may seep into groundwater [4]. According to [27], toxicity of Ni was associated with increased concentrations of chromium in heart and spleen, and manganese in the kidney, and decreased copper in the lung and spleen, zinc in lung, and manganese in spleen.

Lead: High concentrations of Pb were observed in the top-soil collected from all the sections of the mechanic village except the control and their corresponding PI were significantly high (Table 1). On the other hand, high concentration of lead was observed only in samples from electricians and panel beater sections. While human activities contributed to lead in the soil, it is a well known fact that lead occurs naturally in minute amounts within the Earth's crust because in every 1000 Kg of normal soil,there is 16 g of lead[28]. Industrial applications such as batteries and electrical equipments often result in the release of lead into the soil in its ionic form (Pb^{2+}) including lead oxides and hydroxides and lead-metal oxyanion complexes [29]. Lead sulphates and carbonates are predominant insoluble lead (formed at pH > 6). Lead sulphide is the most stable solid form within the soil matrix and forms under reducing conditions [30].Inhalation of lead-containing exhausts fumes or industrial emission, contaminated lead paints, soil or dust from hand-to-mouth activities of those living in lead polluted environment affects gastrointestinal tract, kidneys, and central nervous system.(Berti and Cunningham, 1994) Lead accumulates in the body organs especially the brain, which may lead to poisoning (plumbism) or even death [25].

CONCLUSION

Based on high pollution indices (PI >1) of As, Cd, Ni and Pb, the presence of these heavy metals pose a risk to the health of the workers in these sections of mechanic village. If remediation of these toxic metals is not carried out, over a period of time the adverse effect of these toxic metals could become a public health concern.

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