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Assessment of some heavy metals in the surrounding soils of an automobile battery factory in Ibadan, Nigeria

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The levels of heavy metals (Pd, Zn, Cr, Cd, Fe and Cu in mg/kg) in soils were assessed with respect to distance in different directions around an abandoned battery company in Ibadan, Western Nigeria by using flame atomic absorption spectrophotometry method. The results generally show a decrease of lead (Pb) concentrations with increase in distance away from the company in all the four different directions (Northwest, Northeast, Southwest and Southeast). The other heavy metals assessed do not show any clear trend with distance away from the factory. The mean concentrations of Pb, Zn, Cr, Cd, Fe and Cu were 59.13±48.9 (range 5.00 - 182.00 mg/kg), 2.68±1.1 (range 0.4 - 5.2 mg/kg), 1.62±2.4 (range ND - 8.7 mg/kg), 0.08±0.09 (range ND - 0.24 mg/kg), 49.44±16.5 (range 12.5 - 70 mg/kg) and 4.94±2.6 mg/kg (range 0.5 - 10.5 mg/kg), respectively. The mean concentration of Pb was far above (four times higher than) the normal crustal average for soils while the other heavy metals were below the normal background level. The concentration of Pb is also the highest at the distance closest to the factory which indicate that Pb is the major heavy metal impacted on soils by the company which elevate the normal background level and thereby contaminate the soils and make it unfit for agricultural purposes as plant take up the leached metals and ultimately find its way into animals and human body through the food chain.

Key words: Food chain, Battery Company, lead pollutant, assessment, agricultural purposes, anthropogenic sources

INTRODUCTION

Heavy metals or trace elements had been reported to have come from weathering of rock (natural) minerals which may be increased substantially by anthropogenic activities such as industrial and agricultural activities and

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enter our environment (Kabata-pendias, 2000). The soil serves as a long term 'save' sink for heavy metals such as lead, cadmium, zinc, copper and nickel. Heavy metals such as copper and zinc in the soil are essential trace elements for plants and animals but excessive concentrations through external additions can damage the overall soil fertility and agricultural productivity. These metals are toxic at soil concentration above normal level (Inuwa et al., 2007).

Heavy metals such as lead and cadmium can have adverse effects on human and animal health if allowed to accumulate in the food chain. Contamination of soils by heavy metals through anthropogenic activities from the vicinity of industrial areas have been reported by some workers (Onianwa and Fakayode, 2000; Adegoke et al., 2009; Tamunobereton-ari et al., 2011; Maina et al., 2012; Iyaka and Kakulu, 2012; Babatunde et al., 2014). Increase in industrialization and urbanization gives rise to the pollution of environment in the whole world which is responsible for discharging effluents that contain heavy metals such as lead, cadmium, chromium, mercury, etc in the environment (Chen and Chen, 2001; Filazi et al., 2003).

Metals can be used as raw materials for numerous industrial products or as catalysts in chemical processes and constituents of fertilizers and pesticides (Blum et al., 2005). Some of these metals are extracted, purified and processed for industrial use and thereby released to the environment again (Merian, 1991). Heavy metals contamination has been a serious concern in the world, and the governments, through various regulatory agencies in their efforts to prevent further addition of these metals have launched possible methods of remediation (Ahmad et al., 2011; Etim and Onianwa, 2013). Heavy metals have been known to come from many different sources in urban areas which include industrial discharges and vehicular emissions (Harrison et al., 1981). Waste from automobile battery factory sites has been shown to contain high percentage of lead in the surrounding soils (FOEFL, 1987) which in turn pollute the environment. Evanhoe (2006) reported a high level of heavy metals pollution at medieval metallurgical work-shop in southern France; and the lead, copper and other heavy metals left behind many years back still pose a potential health risk.

Heavy metals contaminations in surface soils around an isolated lead smelter in southern Australia decrease with distance from the source depending on the direction of the wind (Cartwright et al., 1977). Some manufacturing industries in Nigeria constitute a major source of environmental pollution which contaminates the country's environment (Kakulu and Osibanjo, 1992). Basel Convention (2004) reported that the slag, a by-product formed from thermal reduction of a metallic ores in the smelting plant in Nigeria contain more than 6% of lead. Apart from slag, another source of lead in battery industries are the particulates that accompany the smoke during smelting operations which settle back on the soil, and also Pb that leaches from scrap battery dumpsites (Adie and Osibanjo, 2009). The aim of this study therefore is to determine the level of concentrations and distribution of lead, zinc, chromium, cadmium, iron and copper in relation to the normal background level in the vicinity of an automobile battery factory in Ibadan, Nigeria.

MATERIALS AND METHODS

Study area description

The study location is an abandoned automobile battery company located in a vast land around Wofun along Kute road, Ibadan, Nigeria (Figure 1). The company is surrounded by developing sites and villages for residential settlements with portions of land used for agricultural purposes. The annual rainfall in the area ranges between 145-250 cm with high humidity (Etim and Adie, 2012).

Sampling and analysis

Fifty-two soil samples of topsoil (0-15 cm) were collected with the aid of plastic materials in order to avoid contamination from twenty-three locations around the battery factory in different directions (Northeast, Northwest, Southeast, Southwest). At least two soil samples were collected in different points at a location and pooled together to form composite samples for that location. The soil samples were collected in a new clean polythene bags, sealed and properly labeled for easy identifications. The samples were oven-dried at 105°C for 2 h in the laboratory and ground using mortar and pestle, sieved with 0.5 mm nylon mesh size, sieve in order to remove big stones, small sticks and to make the soil smooth and homogenized.

Analytical grade reagents were used for all analysis. All reagents were standardized against primary standards to confirm their actual concentrations. All glassware and plastic containers used were soaked in 10% HNO_3 solution overnight (Onianwa, 2001) and rinsed thoroughly with distilled water before used.

About 5 g each of the dried soil samples were accurately weighed into a beaker and 50 ml of 2 M HNO_3 was added into the beakers, mixed properly and covered with watch glass before transferring the beakers with their contents into a water bath maintained at 100°C and allowed to boil for 2 h with intermittently shaking at 15 min intervals. The resulting solutions were allowed to cool and then filtered using Whatman's filter papers No 42 into 50 ml standard volumetric flask and diluted to the mark with distilled water (Anderson, 1976). The filtrates were then analyze for lead, zinc, chromium, cadmium, iron and copper using atomic absorption spectrophotometer (Buck Scientific 200A model). A blank sample was analyzed for every batch of 10 soil samples processed. Duplicate samples were analyzed to check for precision of the instrument and method used. All instruments were also calibrated before used.

The range, mean and standard deviation were calculated for descriptive statistical analysis using Microsoft excel 2007.

RESULTS AND DISCUSSION

Heavy metal concentrations in the topsoil within the

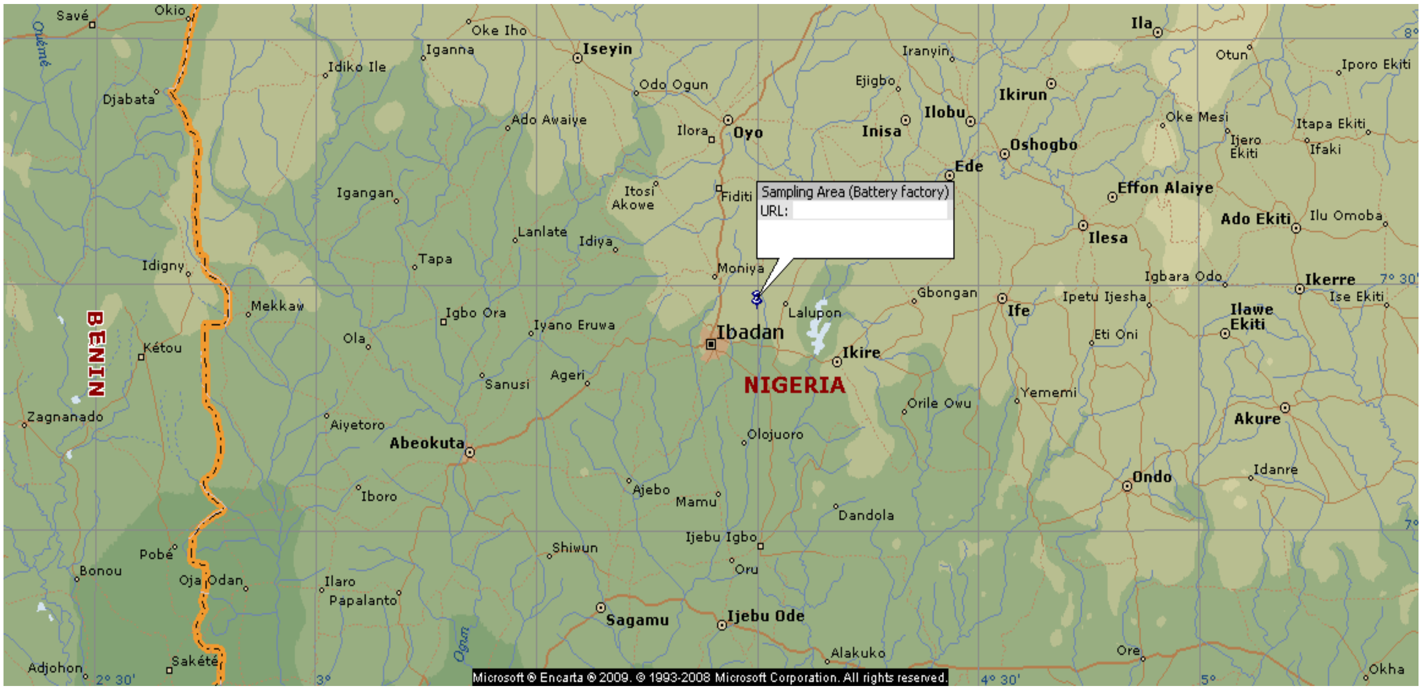

Figure 1. Map of Ibadan showing the study area.

vicinity of the battery factory in different directions are presented in Table 1. The Pb concentration ranged from 5.0 mg/kg in southwest direction (500 m) to 182.0 mg/kg also in the same direction (0 m) with an overall mean concentration of 59.13 mg/kg Pb which is above the normal crustal average (15 mg/kg) of uncontaminated soils (Kabata-Pendias and Pendias, 2011) and higher than the normal background value of 10 mg/kg reported by Alloway (1990).

The highest concentration (182.00 mg/kg) in the southwest direction (0 m) was obtained at the location closest to point of source of pollution from the factory which is even far below the highest Pb concentration obtained by Onianwa and Fakayode (2000) and Ogundiran and Osibanjo (2009) in the surrounding soils of battery factories in Ibadan, Nigeria. The mean Pb concentration (59.13 mg/kg) in soil obtained in this study area falls within the Pb concentration range (38-102 ppm) obtained in the soil around a car battery manufacturing site in Nigeria by Orisakwe et al. (2004), 17.07-8469 mg/kg by Yaylali-Abanuz (2011) obtained in surface soil around Gegze industrial area, Turkey but higher than the mean Pb concentrations of 14.13 mg/kg reported by Babatunde et al. (2014) in soil in the vicinity of an oil depot in Jos, Nigeria and 47.8 mg/kg by Srinivas et al. (2009) in soil within an industrial area, and 18 mg/kg reported by Iyaka and Kakulu (2012b) around a ceramic and pharmaceutical industrial sites in Suleja and Minna, Nigeria. The observed mean Pb level is however much lower than 181 µg/g reported by Iyaka and Kakulu (2012a) from the soil of the vicinity of a local brass industrial area in Bida, Nigeria and 4904 mg/kg reported by Adie and Osibanjo (2009) in soil from an automobile battery company in Ota, Nigeria.

Generally, Pb concentration decreased with increased distance from the factory (Figures 2 to 5), which suggests dispersion of pollutants from the point of source. This study agreed with previous reports on similar environments (Ogundiran and Osibanjo, 2008; Iyaka and Kakulu, 2012b). The unexpected high Pb concentration obtained southeast of the factory at distance of about 250 m (Figure 4) might be connected with local activities such as spillage of leaded fuel and oil from mechanic workshop and block industry. Furthermore, high Pb levels have also been reported in roadside soil along sampling points with heavy vehicular emissions (especially patronizing the mechanic and block industry) by various researchers (Othman et al., 1997; Al-Chalabi and Hawker, 2000; Onianwa, 2001; Olukanni and Adeoye, 2012; Ubwa et al., 2013; Olayiwola et al., 2013). Lead exposure causes health effects which include headache, vomiting, concentration and memory problems (mental retardation), high blood pressure, fertility problems in men, miscarriage in women, developmental delay and damage to nervous system in children (Agusa, 2006; Needleman, 1990).

No definite patterns or trends are observed in the concentrations distribution of zinc (Zn), chromium (Cr),

Table 1. Heavy metal concentrations (mg/kg) in soil samples around the battery factory.

Sample direction	Distance from factory (m)	Pb	Zn	Cr	Cd	Fe	Cu
Northeast	0	142.00	3.80	BDL	BDL	20.90	3.85
Northeast	20	80.00	5.20	0.65	BDL	16.70	6.80
Northeast	50	36.00	2.80	0.65	0.19	62.00	5.00
Northeast	100	32.00	2.40	BDL	0.20	57.00	2.10
Northeast	250	16.00	3.00	BDL	0.04	60.00	5.49
Northeast	350	15.00	1.40	BDL	0.02	50.00	4.85
Northwest	0	133.60	3.10	BDL	0.02	37.50	7.10
Northwest	20	58.00	3.40	BDL	0.18	50.00	3.40
Northwest	50	29.00	2.80	0.65	0.20	29.00	2.25
Northwest	100	21.20	2.40	0.65	BDL	12.50	3.85
Northwest	250	26.50	2.80	0.65	BDL	37.50	0.80
Northwest	500	16.70	2.84	0.65	BDL	57.00	0.50
Southeast	0	101.00	3.40	8.70	0.24	65.00	3.40
Southeast	20	100.00	3.10	4.00	0.04	65.00	6.80
Southeast	50	67.00	2.80	2.70	0.07	58.00	5.25
Southeast	100	44.50	4.10	0.65	0.04	58.00	3.85
Southeast	250	112.00	2.10	5.35	BDL	57.00	2.25
Southeast	500	24.90	2.40	6.00	BDL	57.00	10.00
Southwest	0	182.00	1.40	4.00	0.20	70.00	10.50
Southwest	50	80.00	2.90	0.65	0.07	58.00	7.20
Southwest	200	23.20	0.70	BDL	0.03	65.00	7.70
Southwest	450	14.50	2.40	0.65	0.23	57.00	6.40
Southwest	500	5.00	0.40	0.65	0.06	37.5	4.35
Minimum		5.00	0.40	BDL	BDL	12.50	0.50
Maximum		182.00	5.20	8.70	0.24	70.00	10.50
Mean±SD		59.13±48.9	2.68±1.1	1.62±2.4	0.08±0.09	49.44±16.5	4.94±2.6

BDL = Below detected limit; SD = standard deviation.

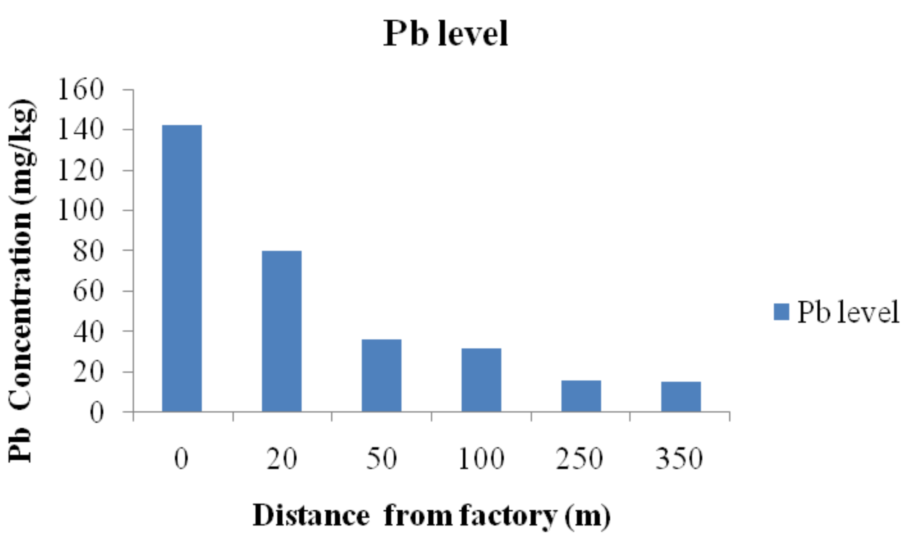

Figure 2. Pb concentrations variation in soils with distance from factory in northeast direction.

cadmium (Cd), iron (Fe) and copper (Cu) (Table 1). Zn concentration in soil samples ranged from 0.4 mg/kg in southwest direction (500 m) direction to 5.2 mg/kg northeast direction (20 m) with a mean of 2.68 mg/kg; Cr

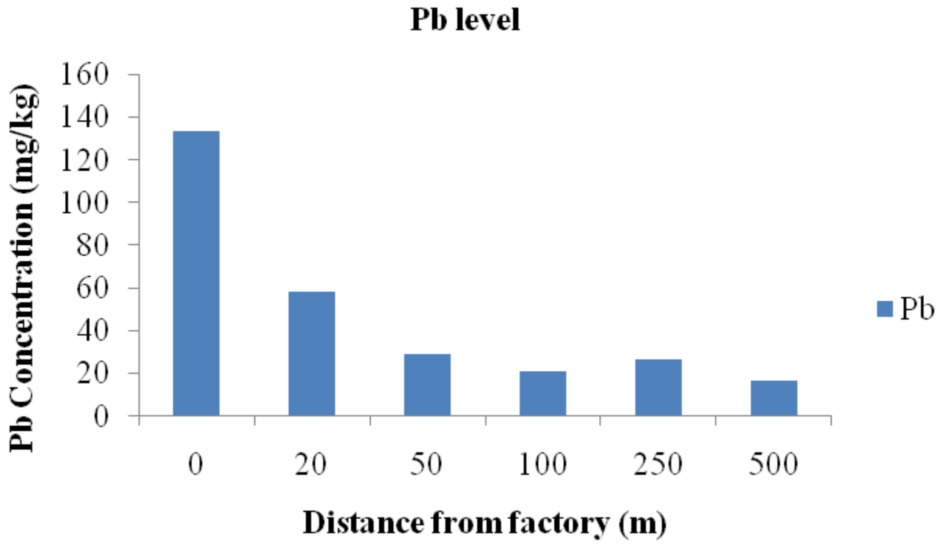

Figure 3. Pb concentrations variation in soils with distance from factory in northwest direction.

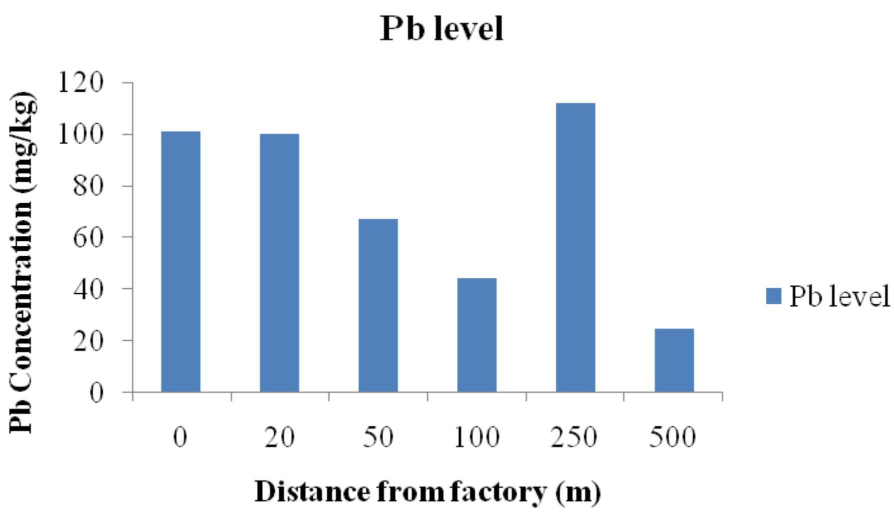

Figure 4. Pb concentration variation in soils with distance from the factory in southeast direction.

in southeast concentration was not detected in soils of some sampling locations from northeast, northwest and southwest directions and the highest concentration (8.7 mg/kg) was detected direction (0 m) with average of 1.62 mg/kg.

Cd contents were also below the detection level in some soil samples of surrounding soils from northeast, northwest and southeast directions. However, maximum concentration (0.24 mg/kg) in southeast direction (0 m) with overall mean of 0.08 mg/kg was recorded. Fe concentration ranged between 12.5 mg/kg in northwest direction (100 m) and 70 mg/kg in southwest direction (0 m) with a mean of 49.44 mg/kg; while Cu content ranged between 0.5 mg/kg in northwest direction (500 m) and 10.5 mg/kg in southwest direction (0 m) with a mean of 4.94 mg/kg.

The mean concentrations of these heavy metals except Pb were far below the soils crustal background average (Figure 6) of 70, 100, 0.1 and 55 mg/kg for Zn, Cr, Cd, Cu, respectively (Kabata and Pendias, 2011). These may suggest that the company did not impact these metals on the surrounding soil, and that the concentrations determined comes from natural soil parent rock geochemistry. Similar low concentration level of Cr and

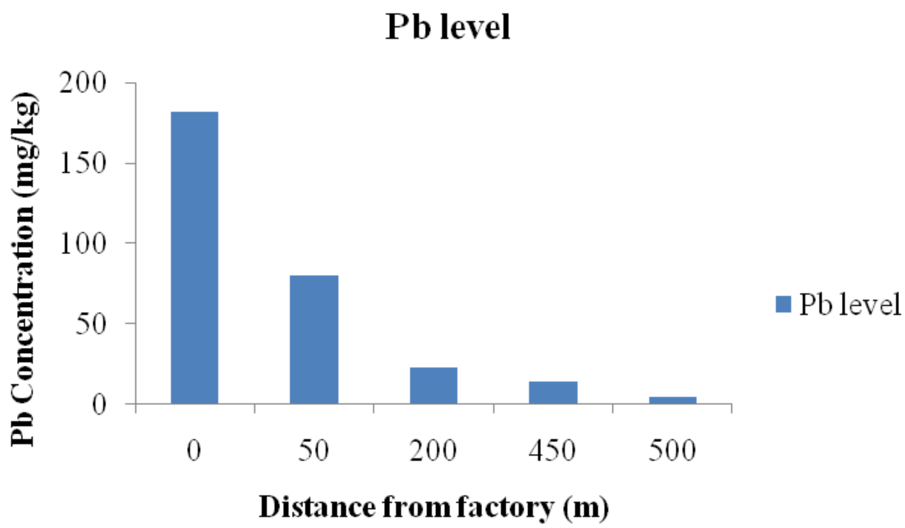

Figure 5. Pb concentration variation in soils with distance from the factory in southwest direction.

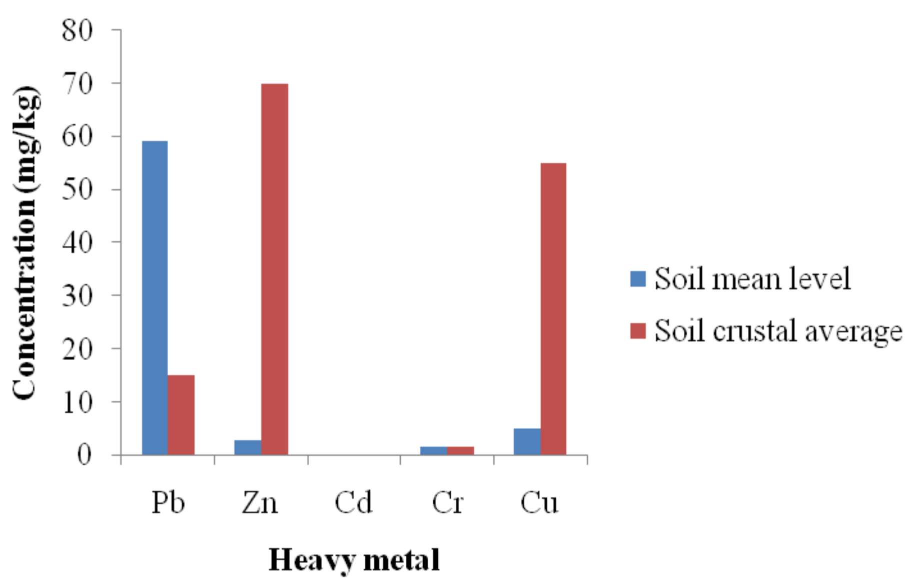

Figure 6. Comparison of soil mean heavy metals concentration obtained with soil crustal average.

Cd, have also been observed in surrounding soils of open battery waste dumpsite (Adegoke et al., 2009); in surface soil of waste dumpsite (Nwajei et al., 2007); in soils around cassava processing mills (Iwegbue et al., 2013).

However, higher mean concentrations of Zn, Cr, Cd and Cu have been reported in soils from some industrial areas (Onianwa and Fakayode, 2000; Iwegbue et al., 2006; Krishna and Govil, 2007; Ogundiran and Osibanjo, 2009; Iyaka and Kakulu, 2012a). Fe content in the soil has a natural concentration level ranging between 3000 - 5000 mg/kg (Awokunmi et al., 2010). The highest concentration of Fe in the study area is far lower than these values which suggest no anthropogenic input of Fe but rather natural origins.

Conclusion

Pb concentrations in the soils from the vicinity of the battery factory studied were substantially higher than the normal crustal average (about four times) in soil when compared with Zn, Cd, Cr, Fe and Cu levels. This suggests that activities of the company may have elevated the level of Pb in the soil of the study area due to many years of free discharge of effluents and indiscrimate dumping of wastes containing majorly Pb materials. This finding suggests that the study area is not safe for human to live and for agricultural purposes as these metals accumulate with time and can get into the food chain through plants uptake. They can also contaminate groundwater as a result of leaching. Therefore, the random dumping of wastes and release of effluents on the ground in the study area should be checked by relevant government agencies to reduce the potential threat that may be caused by these heavy metals contaminants. There should also be public awareness on the danger of heavy metals in food chain.

Conflict of Interests

The authors have not declared any conflict of interests.

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