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GEO- AND PHYTO-MONITORING OF ENVIRONMENTAL IMPACT OF SMELTING INDUSTRY IN IKIRUN, NIGERIA

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ABSTRACT
This research monitored the level of some heavy metals in soil and a plant species around iron smelting industry. The soil in different depths D1 (0 -10 cm), D2 (10 – 20 cm) and D3 (20 -30 cm) and plant (Tithonia diversifolia) known as Mexican sunflower were sampled in four soil sampling points (SSP) and plant sampling points (PSP) which are 50, 100, 150 and 200 m away from the industry. The concentrations of Cr, Cu, Fe, Pb and Zn in the soil and plant digest were determined using Atomic Absorption Spectroscopy (AAS). Some physicochemical properties like pH, electrical conductivity and organic matter were also measured. The result of the analysis of the heavy metals in the soil was in the sequence Fe > Zn > Cu >Pb> Cr at SSP1 SSP2 and SSP4 while Fe > Zn > Cu > Cr > Pb at SSP3. In the plant, the result showed the presence of these heavy metals except Pb which was not present in any sampling points. The concentration of iron (Fe) in the plant decreased away from PSP1 to PSP4 around the industry. The physicochemical properties like pH which influenced the availability of metals in soil were found to increase away from SSP1 to SSP4 and consequently its effect on the concentration of these heavy metals in plants, particularly for Fe and Zn. Although, heavy metals monitored were within the permissible limit of WHO except Fe in soil, the trend of their presence in the soil and plant suggested the impact of the industry on the environment.

KEYWORDS: Environmental impact, Phyto- and Geo-monitoring, Heavy metals, Smelting

INTRODUCTION

The environmental impact of industrialization has been a major concern of environmentalists. Karataş (2016) posited that environmental problems in recent times mostly arise from human activities. There is no doubt that industrialization is the key to wealth and better living through technological innovations, economics and social transformations (Mgbemene *et al.*, 2016). This industrialization is however associated with environmental alteration and its impact on biodiversity poses a threat to human existence through life necessities, recreation and ecological functions (Shailender *et al.*, 2009). In this era of high municipal solid waste generation, recycling has received much interest in which iron smelting is a fast-growing industry. Iron and steel smelting industries are sources of metals entering the environment in terms of particulate matter during their various production processes (Ogundele *et al.*, 2017; Zheng *et al.*, 2010). The practice of iron and steel smelting is the same in Nigeria with about 17 of such industries across the nation.

Soil is a basic component of the ecosystem which serves as a reactor, transformer, integrator and storage (Oketayo *et al.*, 2019), a medium of plants growth (Gangadhar, 2014) and plays an important role in the regulation of pollutants in the environment (Mohan and Sajayan, 2015). It serves as a major recipient of any substance that we throw or dispose of as a waste product in the environment (Sarkar *et al.*, 2017), this poses direct pollution on the soil. Indirect pollution of soil may also occur as a result of air pollutants that fall as wet or dry deposition and settle on land (Aelion, 2004). Consequently, soil properties change and adversely affect the health of living organisms (plants and animals) living on it. Soil pollutants can contaminate water through water infiltration from the soil surface into the soil profile (Ranieri *et al.*, 2016). The pollution caused by heavy industries enters plants which then passes into the food chain and eventually affects human health (Krishna and Govil, 2007). Therefore, soil and plants are good analytical tools for monitoring environmental pollution. These environmental indicators are used to assess the environmental health and level of pollutants in the environment. The level of contamination in numerous polluted environments has been reportedly monitored using soil as an indicator. The ability of plants to accumulate heavy metals into their organs may hence be used to monitor soil pollution and in particular the concentration of heavy metals (Malizia *et al.*, 2012).

Many researchers have reported assessment of pollution around iron smelting industry using soil alone (Bello *et al.*, 2015; Oketayo *et al.*, 2019; Uduma *et al.*, 2019), plants alone (Oketayo *et al.*, 2017) or both soil and plants (Isola *et al.*, 2015; Olayiwola, 2013). However, the available literature did not put common medicinal plants into consideration. In this study, Mexican sunflower (*Tithonia diversifolia*) which is commonly used as a medicinal plant and soil were employed in monitoring the impact of the smelting industry on its environment. Mexican sunflower is commonly used in folk medicine for the treatment of various ailments in the most western part of Nigeria. Its anti-malaria and repellant activities were reported by Oyewole *et al.* (2008). It is found in Nigeria on road-sides, crop fields and waste areas (Wokem *et al.*, 2015). The physicochemical properties and heavy metals in these indicators were assessed for monitoring pollution.

MATERIALS AND METHODS

STUDY AREA

The study area is an iron smelting industry located at Ikirun, along Ikirun – Osogbo road (07°55'N and longitude 04°41'E), Osun State in the southwest region of Nigeria. The industry was established in 2009 and since then carrying out smelting of scrap iron for the production of steel. The site is a tropical area with two seasons, dry and rainy seasons.

Sample and sampling

The samples used for the monitoring were soil and plant, *Tithonia diversivolia* (Mexican sunflower). The soil and plant samples for the monitoring were taken from four different sampling points, which are 50, 100, 150 and 200 m away from the industry during the dry season. Each of the soil sampling points was also taken at three different depths, D1 (0-10 cm), D2 (10-20 cm) and D3 (20-30) into polyethylene bags and labeled as soil sampling points (SSP) 1 to 4 with their respective depth (D) 1 to 3. For the plant, the leaves and stems were removed into polyethylene bags and labeled as plant sampling points (PSP) 1 to 4.

Method

Sample preparation

The soil samples were crushed using a clean mortal, sieved, homogenized and stored for subsequent analysis. The plant samples (leaves and stems) were freed of soil, air dried, pulverized and also stored for analysis.

Physicochemical analysis

The pH of both the soil and plant samples were taken in water in a ratio of 1:2.5 using a pH meter (Abdus-Salam and Bello, 2015). Similarly, the soil conductivity was measured in distilled water in a ratio of 1:2.5 using a conductivity meter (Hanna HI 8633). The organic matter in the soil was measured using the titration method of Walkley and Black (1934).

Heavy metals analysis

Both soil and plant samples were digested for heavy metal analysis (Chen and Ma, 2001) and the metals concentrations were determined using Atomic Absorption Spectroscopy (Buck Scientific model 210VGP). A 2 g of each soil sample was measured into 250 ml glass beakers and digested with 8 ml of aqua regia on a hot plate for 30 min. After evaporation to dryness, the samples were re-dissolved with 10 ml of 2% nitric acid, filtered and then diluted to 50 ml with distilled water. For the plant samples, the method of Jones Jr and Case (1990) was adopted in which 0.5 g of the sample was placed in a 250 ml digestion tube and 3.5 ml of concentrated H_2SO_4 was added. The mixture was allowed to stand for 30 min at room temperature after which 3.5 ml of 30% H_2O_2 was added to the digestion tube and the sample was then heated for 30 min. The digestion tube was removed and cooled. A 1 ml of 30% H_2O_2 was added until the digest was clear upon cooling and then filtered. The filtrate was made up to 25 ml in a volumetric flask by distilled water.

RESULTS AND DISCUSSION

Soil

Physicochemical properties

The physicochemical properties and heavy metals analysis of the soil samples around the iron smelting industry is presented in Tables 1a and b. The pH of the soil in SSP1 and SSP2 was slightly acidic in a range between pH 5.3 and 6.2. The acidity in these two sampling points (50 m and 100 m away from the industry) increased down the depth. However, from SSP3 to SSP4, the acidity decreased down the depth to neutrality and slightly alkaline (pH 7.8) at depth 3 of SSP4 which is 200 m from the industry. The soil pH for the three depths of SSP3 (150 m away from the industry) and SSP4 (200 m away from the industry) ranges from 6.5 to 7.8. This result indicates that the immediate environment of the industry (SSP 1 and SSP2) is slightly acidic. The mean pH values of the three depths from each sampling point range from 5.6 to 7.6 for SSP1 to SSP4 respectively, showing a decrease in the acidity of the soil away from the industry. Consequently, there will be an increase in micronutrient solubility and mobility of heavy metals in the acidic area (Bhattacharya *et al.*, 2002). At a low pH, the nutrients are usually soluble due to high desorption and low adsorption rate (Neina, 2019).

Electrical conductivity is used to estimate the soluble salt concentrations in soil and is commonly used as a measure of salinity. The mean soil electrical conductivity (EC) in the soil sampling points ranges from 0.4 to 3.10 μS/cm with the highest value at SSP1. In SSP1, the soil EC increased with depth and the highest value of 4.6 μS/cm indicates an extremely high EC. However, EC at each depth of SSP2 up to SSP4 is non-saline. Soil with EC below 0.4 μS/cm is considered marginally or non-saline, while soil above 0.8 μS/cm is considered severely saline (Wagh *et al.*, 2013).

Table 1a: Some physicochemical parameters and heavy metals of the soil samples

Sampling Points	Depth	pH	OM (%)	EC (μS/cm)	Cr (mg/kg)	Cu (mg/kg)	Fe (mg/kg)	Pb (mg/kg)	Zn (mg/kg)
SSP 1	1	6.1	2.76	0.4	0.22	1.26	540	0.50	6.90
	2	5.4	5.86	4.3	0.08	0.48	350	0.30	4.30
	3	5.3	7.31	4.6	0.48	1.22	3100	0.60	2.50
SSP2	1	6.2	1.38	0.55	0.37	0.87	4400	0.30	3.40
	2	5.6	4.42	0.33	0.42	1.25	790	0.40	2.30
	3	5.5	2.83	0.36	0.14	0.78	920	0.30	1.80
SSP 3	1	6.5	1.59	0.36	0.99	1.29	1900	0.60	5.30
	2	6.7	0.76	0.35	0.18	0.77	850	0.40	2.40
	3	7.0	1.45	0.36	0.27	1.07	1800	0.40	2.40
SSP 4	1	7.7	6.42	0.49	0.07	0.07	2700	0.10	1.13

2	7.7	7.45	0.49	0.43	1.10	1000	0.40	5.00
3	7.8	7.89	0.51	0.11	0.55	280	0.40	4.60

Table 1b: Statistical summary of physicochemical parameters and heavy metals of the soil sampling points

Parameters / Sampling Points		pH	OM (%)	EC (µS/cm)	Cr (mg/kg)	Cu (mg/kg)	Fe (mg/kg)	Pb (mg/kg)	Zn (mg/kg)
SSP1	Min.	5.3	2.76	0.40	0.08	0.48	350	0.30	2.50
	Max.	6.1	7.31	4.60	0.48	1.26	3100	0.60	6.90
	Mean	5.6	5.31	3.10	0.26	0.99	1330	0.47	4.67
SSP2	Min.	5.5	1.38	0.36	0.14	0.78	790	0.30	1.80
	Max.	6.2	4.42	0.55	0.42	1.25	4400	0.40	3.40
	Mean	5.8	2.88	0.40	0.31	0.97	2036	0.33	2.50
SSP3	Min.	6.5	0.76	0.35	0.18	0.77	850	0.40	2.40
	Max.	7.0	1.59	0.36	0.99	1.29	1900	0.60	5.30
	Mean	6.7	1.27	0.40	0.48	1.04	1516	0.47	3.37
SSP4	Min.	7.6	6.42	0.49	0.07	0.07	280	0.10	1.13
	Max.	7.8	7.89	0.51	0.43	1.10	2700	0.40	5.00
	Mean	7.7	7.25	0.50	0.20	0.57	1326	0.30	3.57
WHO/FEPA maximum permissible Limits		NS	NS	NS	100*	36*	400**	85*	50*

NS means not specified; * WHO and ** FEPA

The organic matter (OM) ranges from 0.76% at D2 of SSP3 to 7.89% at D3 of SSP4 with the highest mean value of 7.25% in SSP4. The lowest value obtained for each sampling point was at the upper depth (D1) except SSP3 which was in the middle (D2). Liu *et al.* (2006) stated that soil organic matter is usually lower at the surface due to soil erosion and degradation resulted from sparse vegetation and cultivation. Although the highest value was obtained in SSP4 (200 m away from the industry) but the result did not correlate with sampling distance and depth. Many factors affect the soil organic matter among which are climatic condition, temperature, soil texture, soil depth, land use (Azlan *et al.*, 2012; Chibsa and Ta, 2009).

Heavy metals

The level of some heavy metals (Cr, Cu, Fe, Pb and Zn) in the four sampling points with depth is presented in Table 1 (a and b) and depicted in Figure 1. The heavy metals were in the order of Fe > Zn > Cu > Pb > Cr in the sampling points except for SSP3 where an order of Fe > Zn >Cu>Cr > Pb was observed. Iron was found to be the most available heavy metals among the other heavy metals analyzed in the soil. The level of Fe concentration in the SSP1 to SSP3 is lesser at D2 (10-20 cm) as compared with D1 (0-10 cm) and D3 (20-30 cm). This is likely due to the mobility of the ion from the surface to the inner depth of the soil. The mobility of iron around the industry agrees with the position of Bhattacharya *et al.* (2002) and Neina (2019) that heavy metals become more mobile as acidity increases. However, the levels of Fe concentration in SSP4 decreased down the depth with the lowest concentration in all the sampling points. The mean concentrations of the sampling points range from 1326 mg/kg in SSP4 to 2036 mg/kg in SSP2.

Copper, chromium, lead and zinc were also present in varying concentrations as distributed at different depths of the soil sampling points around the industry. The variation in the level of concentrations of these heavy metals at different depths of a particular sampling point is due to different mobility patterns. This mobility is affected by pH, organic matters, soil texture and leachability (Fijałkowski *et al.*, 2012; Sherene, 2010; Violante *et al.*, 2010).

The concentrations of Cu range from 0.07 mg/kg to 1.29 mg/kg. The highest concentration was observed in D1 of SSP3 and the lowest in D1 of SSP4. From the mean values of each sampling point, the lowest concentration was observed in SSP4. In the case of chromium, the highest concentration (0.99 mg/kg) was observed at D1 of SSP3 and the lowest concentration (0.07 mg/kg) at D1 of SSP4. The least mean concentration (0.20 mg/kg) was obtained in SSP4. The lead level in soil ranges from 0.10 mg/kg to 0.60 mg/kg in all the sampling points. The mean concentrations of each of the sampling points showed the highest value (0.47 mg/kg) in SSP1 and SSP3 while the least value (0.30 mg/kg) was obtained in SSP4. Zinc level decreased down the depth in SSP1 to SSP3 but in SSP4, the concentration was higher at D1 and D3. The concentrations range from 1.13 mg/kg to 6.90 mg/kg with SSP1and SSP4 having the highest and the lowest concentrations respectively. The least mean concentration (2.50 mg/kg) was obtained in SSP2 and the highest (4.67 mg/kg) was observed in SSP1.

From the mean concentrations of each sampling point for the heavy metals analyzed (Table 1b), it is observed that SSP4 which is the farthest sampling point had the least values except for Zn where it was in SSP2. Also, the mean concentrations of these heavy metals except Fe are all below the WHO/FEPA's permissible limits reported by Ogundele *et al.* (2015) and Mohammed and Folorunsho (2015) in all the sampling points. The higher level of Fe concentration may be attributed to the geochemical nature of parental soil materials (Kacholi and Sahu, 2018).

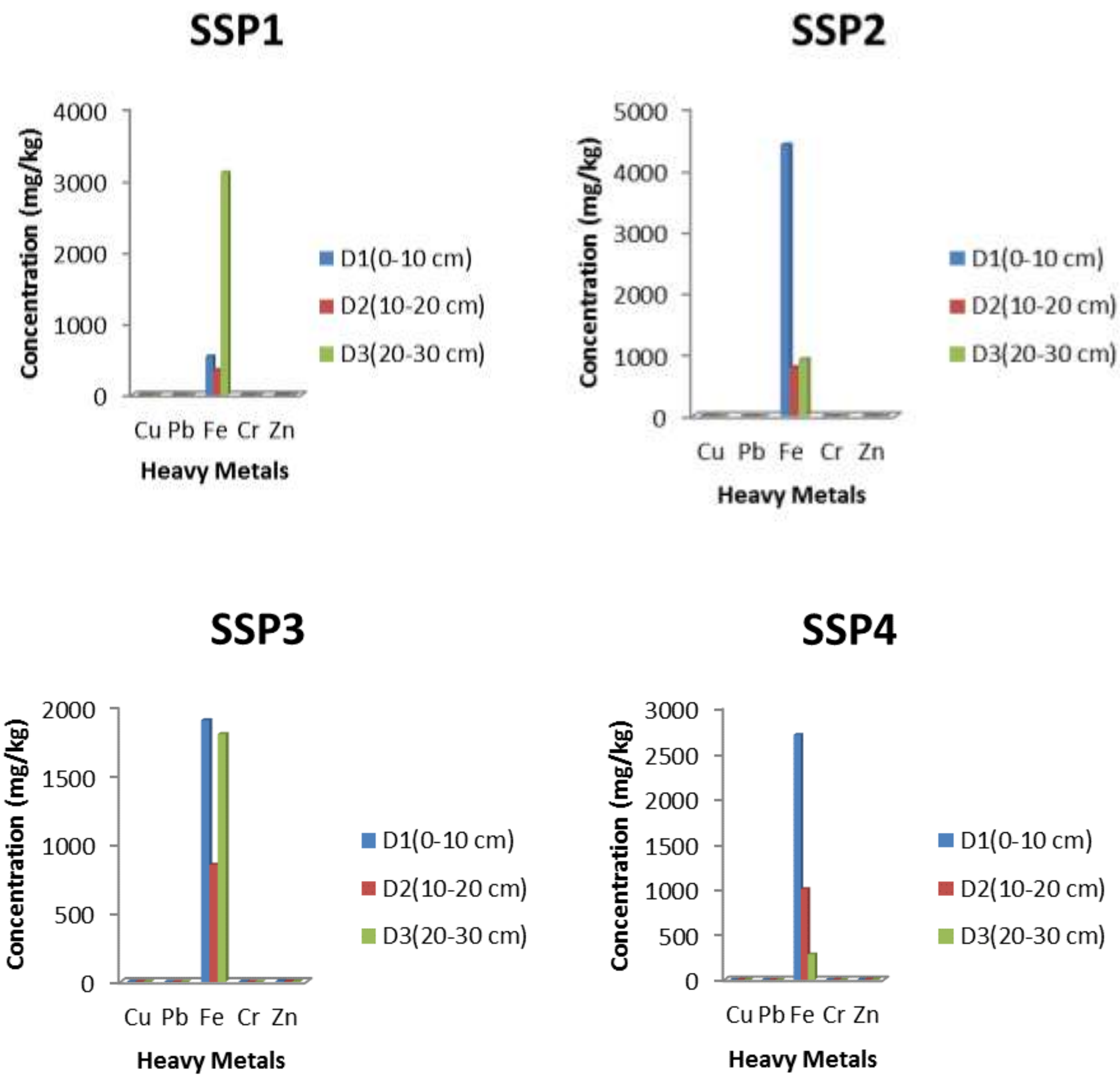

Fig. 1: Concentrations of heavy metals in the four soil sampling points with depth

Plant

pH

The result of the pH value in the plant sample, Mexican sunflower (*Tithonia diversifolia*) from four sampling points is presented in Table 2. The pH values are alkaline, ranging from 7.6 to 9.0. It is also observed from the result that the alkalinity of the plant increases with distance away from the industry except that of PSP4 where there is a slight fall in the pH after PSP3.

Table 2: The pH values and heavy metals concentrations of the plant sample in four sampling points

Parameters	pH	Cr (mg/kg)	Cu (mg/kg)	Fe (mg/kg)	Pb (mg/kg)	Zn (mg/kg)
Sampling Point						
PSP1	7.6	N.D	0.03	4.7	N.D	0.38
PSP2	8.0	0.01	0.03	3.9	N.D	0.24

PSP3	9.0	N.D	0.04	3.2	N.D	0.23
PSP4	8.6	N.D	0.03	2.0	N.D	0.19
WHO Limits	N.G	1.50	10	20	2	50

N.D means Not Detected; N.G means Not Given

Heavy metals

The bioavailability of heavy metals in Mexican sunflower (*Tithonia diversifolia*) is presented in Table 2 and depicted in Figure 2. The presence of the heavy metals is in the order of Fe< Zn < Cu. While chromium was detected in a very minute quantity in Mexican sunflower at SSP2, lead was not detected all in all the four sampling points. This may be due to the low level of the Pb and Cr at their respective soil sampling points and the absorption capacity of the plant. The presence of one heavy metal also poses an antagonistic effect on the availability of another in the soil and plant (Chibuike and Obiora, 2014).

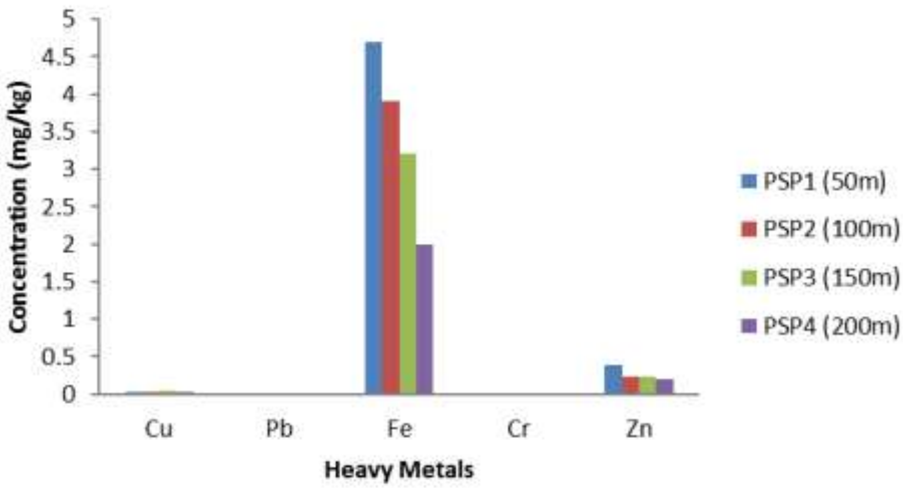

Fig. 2**:** Concentrations of heavy metals in plant sample with distance

Copper was detected in all the samples at a very low concentration with the highest concentration of 0.04 mg/kg in PSP3. Zinc is one of the essential micronutrients. Although, it is needed by plants in small amounts, but crucial to plant development. However, it could be detrimental to plant in higher concentrations. Zinc is found in the four samples with its concentrations range from 0.19 mg/kg in PSP4 to 0.38 mg/kg in PSP1. This trend shows that zinc concentrations in the plant samples decreased from PSP1 to PSP4 away from the industry (Fig. 2). WHO's recommended limit of zinc in plants is 50 mg/kg (Shah *et al.*, 2013). The concentrations of zinc in the four samples were below the threshold limit. Iron was present in the plant sample as the heavy metal with the highest concentration. The result revealed that the concentrations range from 2.0 mg/kg in PSP4 to 4.7 mg/kg in PSP1. This indicates that iron concentration in the plant samples decreased from PSP1 to PSP4 away from the industry (Fig. 2). However, the four plant samples contained iron concentration below the WHO maximum permissible limit of 20 mg/kg in medicinal plants reported by Shah *et al.* (2013). Considering the mean soil pH value of these sampling points (Table 1b), the result obtained for Fe and Zn agrees with the position of Bhattacharya *et al.* (2002) and Neina (2019) that nutrients are usually soluble and available at low pH due to high desorption and low adsorption rate of metals.

CONCLUSION

Herein, soil and a medicinal plant (Mexican sunflower) around an iron smelting industry were used to assess its environmental impact. Physicochemical properties and heavy metal concentrations in these environmental indicators (soil and plant) taken within the surroundings of the industry were determined. Except for the pH that correlates with the immediate environment, there was no significant correlation of other physicochemical properties on the environment. The least mean concentrations of these heavy metals in soil were obtained in the farthest sampling point (SSP4) except for Zn which was in SSP2. The soil pH affects the availability of the heavy metals in the plant sample especially Fe and Zn which their concentrations also decreased away from the industry. Pb was not present in any of the sampling points for plant samples. The results indicated that this industry impacted on its immediate environment. However, all the heavy metals except iron in soil were within the permissible limit of WHO for soil and medicinal plants. A constant routine impact assessment is therefore recommended around such an industrial environment.

REFERENCES:

Abdus-Salam, N., & Bello, M. (2015). Kinetics, thermodynamics and competitive adsorption of lead and zinc ions onto termite mound. *International journal of environmental science and technology, 12*(11), 3417-3426.

Aelion, C. (2004). Soil contamination monitoring. *Environmental monitoring, Encyclopedia of life support systems (EOLSS), developed under the auspices of the UNESCO, EOLSS Publishers, Oxford. http://www. eolss. ne t*.

Azlan, A., Aweng, E., Ibrahim, C., & Noorhaidah, A. (2012). Correlation between soil organic matter, total organic matter and water content with climate and depths of soil at different land use in Kelantan, Malaysia. *Journal of applied sciences and environmental management, 16*(4).

Bello, S., Zakari, Y., Ibeanu, I., & Muhammad, B. (2015). Evaluation of heavy metal pollution in soils of Dana steel limited dumpsite, Katsina state Nigeria using pollution load and degree of contamination indices. *American journal of engineering research, 4*(12), 161-169.

Bhattacharya, P., Mukherjee, A. B., Jacks, G., & Nordqvist, S. (2002). Metal contamination at a wood preservation site: characterisation and experimental studies on remediation. *Science of the Total Environment, 290*(1-3), 165-180.

Chen, M., & Ma, L. Q. (2001). Comparison of three aqua regia digestion methods for twenty Florida soils. *Soil science society of America Journal, 65*(2), 491-499.

Chibsa, T., & Ta, A. A. (2009). Assessment of soil organic matter under four land use systems in the major soils of Bale Highlands, South East Ethiopiab. Factors affecting soil organic matter distribution. *World Applied Sciences Journal, 6*(11), 1506-1512.

Chibuike, G. U., & Obiora, S. C. (2014). Heavy metal polluted soils: effect on plants and bioremediation methods. *Applied and Environmental Soil Science, 2014*.

Fijałkowski, K., Kacprzak, M., Grobelak, A., & Placek, A. (2012). The influence of selected soil parameters on the mobility of heavy metals in soils. *Inżynieria i Ochrona środowiska, 15*, 81-92.

Gangadhar, Z. S. (2014). Environmental impact assessment on soil pollution issue about human health. *International Research Journal of Environment Sciences, 3*, 78-81.

Isola, E. F., Olatunji, O. A., Afolabi, A. M., & Omodara, A. A. (2015). Heavy metal accumulation in the above-ground vegetation and soil around an iron smelting factory in Ile-Ife, southwestern Nigeria. *Sciences in Cold and Arid Regions, 7*(2), 121-127.

Jones Jr, J. B., & Case, V. W. (1990). Sampling, handling, and analyzing plant tissue samples. *Soil testing and plant analysis, 3*, 389-427.

Kacholi, D. S., & Sahu, M. (2018). Levels and health risk assessment of heavy metals in soil, water, and vegetables of Dar es Salaam, Tanzania. *Journal of Chemistry, 2018*.

Karataş, A. (2016). Environmental impacts of globalization and a solution proposal. *American International Journal of Contemporary Research, 6*(2), 64-70.

Krishna, A., & Govil, P. (2007). Soil contamination due to heavy metals from an industrial area of Surat, Gujarat, Western India. *Environmental monitoring and assessment, 124*(1-3), 263-275.

Liu, D., Wang, Z., Zhang, B., Song, K., Li, X., Li, J., . . . Duan, H. (2006). Spatial distribution of soil organic carbon and analysis of related factors in croplands of the black soil region, Northeast China. *Agriculture, Ecosystems & Environment, 113*(1-4), 73-81.

Malizia, D., Giuliano, A., Ortaggi, G., & Masotti, A. (2012). Common plants as alternative analytical tools to monitor heavy metals in soil. *Chemistry Central Journal, 6*(S2), S6.

Mgbemene, C. A., Nnaji, C. C., & Nwozor, C. (2016). Industrialization and its backlash: focus on climate change and its consequences. *Journal of Environmental Science and Technology, 9*(4), 301-316.

Mohammed, S., & Folorunsho, J. (2015). Heavy metals concentration in soil and Amaranthus retroflexus grown on irrigated farmlands in the Makera Area, Kaduna, Nigeria. *Journal of Geography and regional Planning, 8*(8), 210-217.

Mohan, A., & Sajayan, J. (2015). Soil pollution-A Momentous Crisis. *International Journal of Herbal Medicine, 3*(1 Part A), 45-47.

Neina, D. (2019). The role of soil pH in plant nutrition and soil remediation. *Applied and Environmental Soil Science, 2019*.

Ogundele, D., Adio, A., & Oludele, O. (2015). Heavy metal concentrations in plants and soil along heavy traffic roads in North Central Nigeria. *Journal of Environmental & Analytical Toxicology, 5*(6), 1.

Ogundele, L. T., Owoade, O. K., Hopke, P. K., & Olise, F. S. (2017). Heavy metals in industrially emitted particulate matter in Ile-Ife, Nigeria. *Environmental research, 156*, 320-325.

Oketayo, O., Adeoye, A., Akinola, E., & Oyebode, A. (2019). ASSESSMENT OF HEAVY METALS IN SOILS FROM METAL RECYCLING COMPANIES IN ILE-IFE AND IKIRUN, OSUN STATE, NIGERIA.

Oketayo, O. O., Adeoye, A. O., Adegoke, A. E., Oluwatobi, O. T., Ayanda, O. S., Agbolade, O. J., & Nelana, S. (2017). Levels and field accumulation risk of heavy metals in vegetables from metal recycling companies. *Research Journal of Environmental Sciences, 11*, 94-100.

Olayiwola, O. (2013). Accumulation and contamination of heavy metals in soil and vegetation from industrial area of Ikirun, Osun State, Nigeria. *Glob J Pure Appl Chem Res [Internet], 1*(1), 25-34.

Oyewole, I., Ibidapo, C., Moronkola, D., Oduola, A., Adeoye, G., Anyasor, G., & Obansa, J. (2008). Anti-malarial and repellent activities of Tithonia diversifolia (Hemsl.) leaf extracts. *J. Med. Plants Res, 2*(8), 171-175.

Ranieri, E., Bombardelli, F., Gikas, P., & Chiaia, B. (2016). Soil pollution prevention and remediation. *Applied and Environmental Soil Science, 2016*.

Sarkar, D., Rakesh, S., Ganguly, S., & Rakshit, A. (2017). Management of Increasing Soil Pollution in the Ecosystem. *Advances in Research*, 1-9.

Shah, A., Niaz, A., Ullah, N., Rehman, A., Akhlaq, M., Zakir, M., & Suleman Khan, M. (2013). Comparative study of heavy metals in soil and selected medicinal plants. *Journal of Chemistry, 2013*.

Shailender, S., Puja, J., & Abhay, K. (2009). Impact of industrialisation on environmental pollution. *Indian Forester, 135*(9), 1259-1270.

Sherene, T. (2010). *Mobility and transport of heavy metals in polluted soil environment.* Paper presented at the Biological Forum—An International Journal.

Uduma, U. A., Omolabake, S. A., & Ogbesejana, A. B. (2019). Assessment of Metals Enrichment of Arable Soils in the Vicinity of Iron Smelting Company Using Aluminum as a Crustal Reference Element, Katsina State, Nigeria. *FUDMA Records of Chemical Sciences, 1*(1), 50-57.

Violante, A., Cozzolino, V., Perelomov, L., Caporale, A., & Pigna, M. (2010). Mobility and bioavailability of heavy metals and metalloids in soil environments. *Journal of soil science and plant nutrition, 10*(3), 268-292.

Wagh, G., Chavhan, D., & Sayyed, M. (2013). Physicochemical Analysis of Soils from Eastern Part of Pune City. *Universal Journal of Environmental Research & Technology, 3*(1).

Walkley, A., & Black, I. A. (1934). An examination of the Degtjareff method for determining soil organic matter, and a proposed modification of the chromic acid titration method. *Soil science, 37*(1), 29-38.

Wokem, G., Oyero, S., & Nwachukwu, C. (2015). Effect of methanolic extract of Mexican sunflower (Tithonia diversifolia) leaves on the histology and iron metabolism of the liver of rabbits. *Nigerian Journal of Parasitology, 36*(2), 132-136.

Zheng, N., Liu, J., Wang, Q., & Liang, Z. (2010). Health risk assessment of heavy metal exposure to street dust in the zinc smelting district, Northeast of China. *Science of the Total Environment, 408*(4), 726-733.