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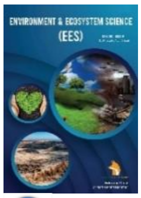

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RESEARCH ARTICLE

ASSESSMENT OF HEAVY METALS CONCENTRATION LEVEL IN SOIL SAMPLES FROM POWER TRANSFORMERS IN SELECTED PARTS OF IBADAN, OYO STATE, NIGERIA

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ABSTRACT

Trace elements with bio-importance are presence in some heavy metals but adverse effects of these elements called for concern in human system. Hence, the parameters involved must be put into consideration, such as the environment, health effects, and concentrations. The occurrences of the substance to our immediate environment, leaching processing, and their sources must be known. It is generally known that these substances are input into our immediate environment by both natural and anthropogenic means. The substance are imported into the subsurface water, flowing through water directions and finally depositing in the aquifer, or transported by erosion and end up in water and subsequently soil pollution. Heavy metals concentration level presence in soil samples from transformer oil was determined in Sango and Orita-Challenge, Ibadan, Oyo State, Nigeria using Inductively Coupled Plasma (ICP). The heavy metals determined were: (Pd, Ni, Cd, Mn, Cu, Fe, Zn, Ca, Co, K, Mg, Na, and Cr). It was affirmed from the results that some high level of heavy metals concentration from the transformer sites differs from one another, as a result of heavy metals content in the transformer oil released to the surrounding soil, while the analysis of some samples shows that the heavy metals fall below the detection limit or absent.

KEYWORDS

Heavy Metals, Soil Sample, transformer, pollution, Sango

1. INTRODUCTION

The mineral constituents in soil are very significance to our well-being and human health. The most major environmental threat that poses high risk to human health is the presence of heavy metal in soil (Opaluwa et al., 2012; Yusuf et al., 2015; Alabi et al., 2019; Adebo et al., 2023a). Soils in our environment consist of difference composition as a result of human influences and practically contain greater percentage of contaminants (Coby and Xiangdong, 2015). Human activities have caused high concentration of heavy metal in our immediate environment through thermal power stations, waste disposal, soil amendments, transformer oil leakage, vehicle, traffic, emissions from industrial plants, and road infrastructures (Fernando et al., 2017, Adebo et al., 2023b). Generally, the climatic conditions and nature of the parent material influence heavy metal distribution on soil parameters and their relative movement such as mineralogy, texture, and classification of soil (Echem, 2014). Heavy metals stayed in the environment for a long period and it doesn't degrade even when the pollution sources have been removed.

The transfer of electrical energy between two or more circuits through electromagnetic induction in a static electrical device is called a Transformer (Agron, 2016, Elbagermi et al., 2013; Ejoh, et al., 2018). A stable oil at has high temperatures with excellent electrical insulating properties is known as transformer oil or insulating oil (Ashwini et al., 2014; Wodaje and Alemayehu, 2018). The transformer oil is mostly used in high-voltage capacitors, switches, circuit breakers, and fluorescent lamp ballasts (Dagne, 2019). The main purpose is to serve as a coolant, insulate, and suppress corona discharge and arcing. It is based on mineral oil, but alternative formulations with better engineering or environmental properties are growing in popularity (Stojić et al., 2014; Geoffrey et al., 2020). PCBs normally get to our immediate environment due to oil leakage from the transformer as results of faulty transformer, improper handling of faulty electrical tool, oil spilling during changes, and uncultured waste disposal (Nassef et al., 2006).

Copper, lead, iron, silver, aluminum, tin, and zinc metals are found in transformer oils (Bala et al., 2008; Godswill et al., 2019). Oil pits are used to collect oil leakage from the devices (Rafiquel et al., 2015; Firmi et al., 2015). They are located below the transformers (Raymond et al., 2011; Nasirudeen and Amaechi, 2015; Gabrielyan et al., 2018). This study was carried out to assess soil pollution levels around transformers in Ibadan by heavy metals. Heavy metals concentration in soil samples can be measured using nuclear analytical techniques. For this study, Inductively Coupled Plasma (ICP) will be used to evaluate the presence of heavy metals in the soil samples. Reports on previous studies have shown that accumulation beyond a specific threshold of heavy metals becomes hazardous to the human body and also one of the pathways of soil contamination is through spillage or leakage of transformer oil. This research aims to determine the environmental impact of oil leakages around transformers in Sango and Orita-challenge communities in Ibadan, Oyo state, Nigeria.

2. SITE DESCRIPTION

Ibadan is situated in southwestern region of Nigeria with eleven (11) Local Govt. areas. It is the largest city in Nigeria and second largest after the capital city of Egypt, Cairo, in the South Saharan. The most lucrative investment in Ibadan has been targeted to land being the major assets. The study area is geographically enclosed within Latitude 7°14'27.97'N to 7°14'50.64''N and longitudes 5°10'5.03"E to 5°10'27.95"E. that is, (805100 to 805900 Northings and 740200 to 740600 Eastings) using the Universal Traverse Mercator (UTM). The study area covers about 28,454 km^2. The

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towns and villages in the study area were linked with each other through minor and major roads. Some regions are accessible through footpath where there are neither minor nor major roads. Generally, the topography is flat and undulated in some regions by hilly ridges and gentle steeps. The area enjoys a tropical climate with two distinct seasons comprising of rainy seasons (April to October) and Dry season (November to March). The temperature throughout Oyo State ranges between $23^{0}C$ to $27^{0}C$. The area falls within the rainforest consisting of tall trees mainly Iroko intermingled with palm trees thick undergrowth and tall grasses (Oladejo et al., 2015).

3. Research Methodology

Soil samples were taken around six (6) selected transformer sites in the study area (Figure 1) and Table 1 shows the sample sites and codes. The soil samples were acquired during the dry season period within two days. The heavy metal concentration in the soil during the dry season is higher compare to rainy season where the run-off and percolation is high. Most of the heavy metal concentration will infiltrated during the rainy season and absent in dry season. The soil samples collected around the transformers were soil samples that have mixed with the oil dripping from the transformers. The soil samples were obtained at the base of the transformer. Wearing hand gloves, each sample was collected directed at the base of the transformer, and an auger was used to collect the samples into an air-tight labeled polythene bag. The following apparatus were used for the soil analyses; Pipette, Digestion block (Q- BLOCK), Weighing balance, Digestion tube (50mls), AAS Buck Scientific Device, and Beaker, while the Reagents used are; Hydrochloric Acid and Nitric Acid. Figure 2 shows the cross-section of soil samples.

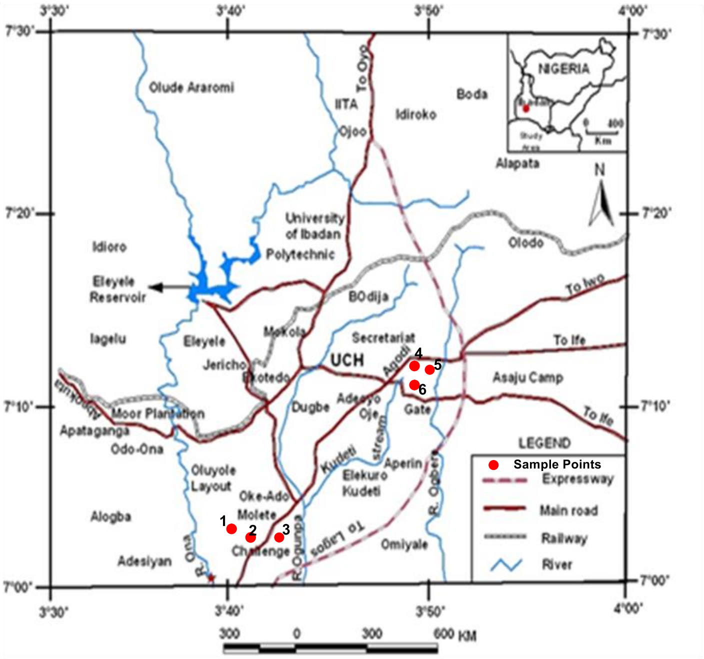

Figure 1: Map of Ibadan Showing the Sample Points

Table 1: Sample Site location and Sample Code			
S/N	SAMPLE SITES	SAMPLE CODE	DRAINAGE
1	ORITA-CHALLENGE MARKET	OCM	NO
2	PODO-CHALLENGE	PC	NO
3	PODO-CHALLENGE(CONTRONL SAMPLE	PC-C	YES
4	POLYTHENIC IBADAN NORTH CAMPUS	PLY-NC	YES
5	ALARO JUNCTION SANGO	ALJ-S	NO
6	POLYTHENIC IBADAN NORTH CAMPUS (CONTROL SAMPLE)	PLY-C	YES

Figure 2: Cross Section of Soil Samples

3.1 Heavy Metals Determination in Soil Sample Preparation

3.1.1 Wet Acid Digestion

The digestion 5ml of HNO_3 (70%) and 1.5ml of $HClO_4$ (60%) from HNO_3 /$HClO_4$ were added to 0.5g of the sample, and the solution was heated until the disappearance of the brown fumes. It was cooled, 5ml of diluted (1:1) HCL (density 1.18gml^{-1}) added, and finally diluted with H_2O_2 (33%) up to 25ml solution

3.1.2 Modified HNO_3/ HCL_4 Digestion

The procedure was the same as the previous but modified laboratory by the addition of 7ml H_2O_2 (33%)

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3.1.3 HNO_3 / H_2O_2 Wet Digestion

0.5g of the sample were added to 8 ml of HNO3 and let stand overnight. The solution was subjected to 120°C of heat for an hour on the hot plate. 4ml 33% H_2O_2 was added to the heated solution until the digest was calorie. The residue was taken to dryness at low heat (80°C), cooled, and diluted with (1:10) HCL (Density 1.18g ml^{-1})

3.1.4 Improved HNO_3/H_2O_2 Digestion

5.0ml of HNO_3 was added to 0.50g of sample in a 250.0ml dry flask and stirred, and all the material was wet. 4.0ml of 33% H_2O_2 was gently added in a ventilated area and patiently mixed after addition. The solution was giving time to cool after the brown fumes have been reduced (7-8 minutes). A little white quantity and yellow dissolution in the solution remained. The solution was filtered, washed with 5ml of (1:1) HCL (density 1.18g ml^{-1}), and diluted up to 25ml with distilled H_2O.

3.2 Heavy Metals Concentration in Soil Samples

Many approaches were tested: conventional wet digestion; a technique on classical HNO3/HClO4 wet procedure was changed slightly in the lab., by adding 7ml H_2O_2 and approach similar to the previous (Improved HNO_3/H_2O_2 Digestion) but using different proportion 0f HNO3 (5ml) and H_2O_2 (4mL), also modifying the sequence of addition regents, the period of concentration and digestion is centered on dry matter of macro and microelements. The outcome of the results was correlated with the traditional dry ashing results for organic matter destruction. This method is normally taken as references because it has been widely considered/use in the laboratory. In digestion (Modified HNO_3/ HCL_4 Digestion) and (Improved HNO_3/H_2O_2 Digestion), a little amount of white solid presence in suspension, independently of the quantity of H_2O_2 added, and when the period of digestion was higher, it does not disappear or with the increased addition of HNO_3 or $HClO_4$. The concentrations of the heavy metals (Cu, Pb, Mg, Cd, Na, Fe, Ni, Ca, Mn, Zn, K, Cr, Co) presence in the soil sample from the selected transformers were assessed, and the degree of heavy metal pollution presence in the soils was determined.

4. Results and Discussion

The heavy metals concentration in the soil samples collected from the six transformer sites was shown in Table 2. Calcium has the highest concentration in the soil sample OCM (2365.5 ppm) with the lowest concentration in the soil sample PLY-C (200.2 ppm) (Figure 3a). The Manganese has the highest concentration in the soil sample OCM (1639.65 ppm) with the lowest concentration in the soil sample PLY-C (74.65 ppm) (Figure 3b). Potassium has the highest concentration in the soil sample OCM (311.25 ppm) with the lowest concentration in the soil sample PLY-C (148.3 ppm) (Figure 3c). Sodium has the highest concentration in the soil sample PC-C (116.15 ppm) with the lowest concentration in the soil sample PLY-C (40.85 ppm) and OCM (40.85 ppm) (Figure 3d). Magnesium has the highest concentration in the soil sample PC (43.15 ppm) with the lowest concentration in the soil sample OCM (16.1 ppm) (Figure 3e). The sample PC, Iron has highest concentration in the soil sample (1131.55 ppm) with the lowest concentration in the soil sample OCM (546 ppm) (Figure 3f).

From the soil sample, Copper has the highest concentration in the soil sample ALJ-S (158.3 ppm) with the lowest concentration in the soil sample PC-C (3.2 ppm) (Figure 3g). Zinc has the highest concentration from the soil samples in ALJ-S (116.1ppm) with the lowest concentration in the soil sample PLY-C (30.3 ppm) (Figure 3h). Lead has the highest concentration from the soil samples in ALJ-S (17.2 ppm) with the lowest concentration in the soil sample PC (0.65 ppm) (Figure 3i). Nickel has the highest concentration from the soil samples in PC-C (17.2 ppm) with the lowest concentration in the soil sample PC, PLY-C, and ALJ-S (0.25 ppm) (Figure 3j). Chromium has the highest concentration from the soil samples in PLY-NC (1.35 ppm) with the lowest concentration in the soil sample PC (0.15ppm) (Figure 3k). Cobalt has the highest concentration from the soil samples in OCM (1.9 ppm) with the lowest concentration in the soil sample PC-C (0.1ppm) (Figure 3l). Cadmium has the highest concentration from the soil samples in OCM, PC-C, PC, and PLYNC (0.05 ppm) with the lowest concentration in the soil sample PLY-C and ALJ-S (0 ppm) (Figure 3m).

Table 2: Heavy Metals Concentration in the Soil Samples

Sample	Ca	Mg	K	Na	Mn	Fe	Cu	Zn	Pb	Ni	Cr	Co	Cd
OCM	2365.5	1639.65	311.25	40.85	16.1	546	4.35	45.65	1.65	0.25	0.3	1.9	0.05
PC-C	204.15	108.2	264.65	116.15	38.5	712.15	3.2	31.6	2.3	0.6	0.2	0.1	0.05
PC	1021.35	132.8	280.25	50.6	43.15	1131.55	90.85	67.9	0.65	0.25	0.15	0.9	0.05
PLY-C	200.2	74.65	148.3	40.85	28.5	598.55	3.8	30.3	1.65	0.25	1.05	0.8	0
ALJ-S	1509.1	104.7	193.95	44.75	30.9	935.25	158.3	116.1	17.2	0.25	1.05	0.7	0
PLY-NC	261.2	104	203.85	42.8	38.35	764.05	5.85	38	1.95	0.4	1.35	0.8	0.05

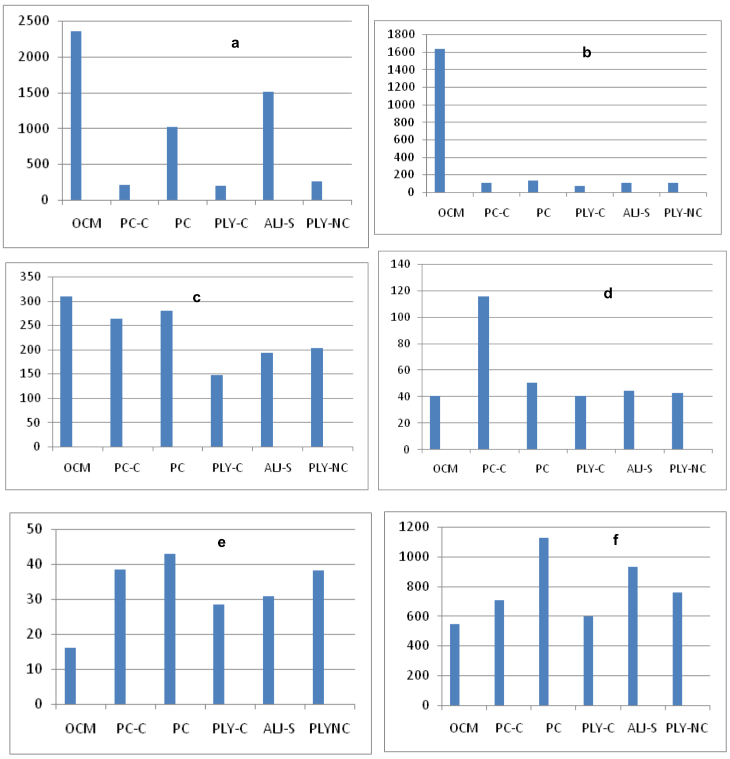

Figure 3: Graphical Representation of the Concentration of Heavy Metal in the Tested Samples (a) Calcium (b) Manganese (c) Potassium (d) Sodium (e) Magnesium (f) Iron

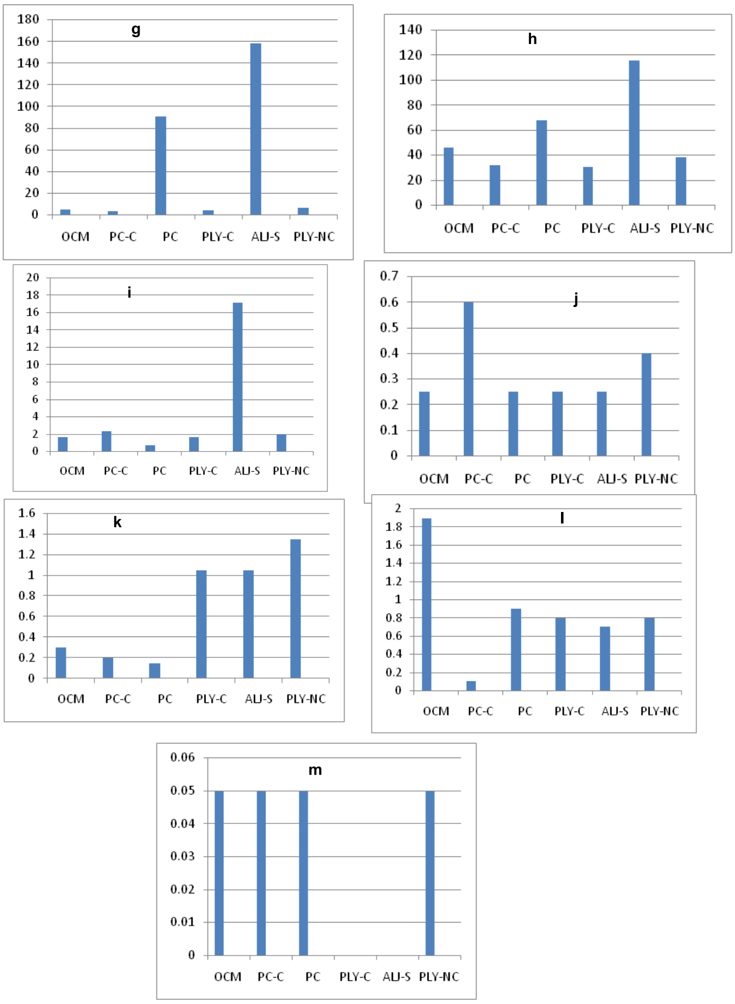

Figure 3: Graphical Representation of the Concentration of Heavy Metal in the Tested Samples (g) Copper (h) Zinc (i) Lead (j) Nickel (k) Chromium (l) Cobalt (m) Cadmium

5. Conclusion

Investigation of heavy metals concentration (Pd, Ni, Cd, Mn, Cu, Fe, Zn, Ca, Co, K, Mg, Na, and Cr) presence in the soil samples within sole selected transformers in Sango and Orita-Challenge was carried out. The concentration of these heavy metals (Pd, Ni, Cd, Mn, Cu, Fe, Zn, Ca, Co, K, Mg, Na, and Cr) was not shown in all the soil samples. The results was able to identify the presence of high heavy metals concentration in soil samples within a selected location compared to others, which maybe as a result of heavier quantity of heavy metals deposited in the soil samples. There is presence of low concentrations of these heavy metals in other sites, which maybe as a result of low concentration of the heavy metals due to human activities. Traces of heavy metals concentration could be delineated in some soil samples around the transformer, which is an indicative that the heavy concentration fall below the detection limit or not present at all.

The heavy metal concentration in the soil samples within the selected transformers fall within the permissible recommended limit, which may not endanger the environment at the moment. However, continuous storage of heavy metals levels is a major concern which may cause health challenges. The heavy metals contamination (Pd, Ni, Cd, Mn, Cu, Fe, Zn, Ca, Co, K, Mg, Na, and Cr) from the selected soil samples around the transformer sites in Sango and Orita-Challenge was compared with the control point. The heavy metals concentration presence in the soil is in accordance with EPA Target and Intervention 2008 Recommendation values and the results show that most of the soil is contaminated. The concentrations of (Pd, Ni, Cd, Mn, Cu, Fe, Zn, Ca, Co, K, Mg, Na, and Cr) in transformer sites are higher than the values in the control sites.

The pollution problem in Sango and Orita-Challenge is a pressing one as some parts of these polluted regions are lived in by population, therefore heavy metals can enter the human body through soil-plant-human or soil-plant-animal-human chains and cause various diseases. It is therefore recommended that; there should be proper monitoring and quick repair of the transformer to avoid the release (spillage) of transformer oil which contains these heavy metals. Designated better ways of controlling waste from transformers (transformer oil) and soils from transformers surrounding should be treated before use, especially for cultivation. Since the induced pollution poses serious threats to public health, further investigations should be carried out on farm products sold in the market located in the study areas, and transformers should be located in isolated 3areas and far from residential areas. Drainage around transformers should be constantly checked for possible contamination with heavy metal release from transformer oil spillage.

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