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# Concentrations of Polychlorinated Biphenyls (PCBs) in Suspected Receptacles and Their Vicinity Soils

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## Abstract:

PCBs are versatile and synthetic chlorinated compounds, though its production was banned years ago, the continual use of PCBs in transformer oil and printing ink still persists. PCBs in the environment cause soil contamination and pollution. This study focus on the determination of PCBs in different sources and their vicinity soils in Makurdi Nigeria. GC-MS analysis of PCBs in the soils revealed concentrations in the range of 0.18 - 151.31 ppm. The trend in abundance of PCBs (ppm) and total Cl are as follows; tPCBs (ppm) of WS1 (14.63) > RP2 (3.84) > RS2 (2.88) > DS4 > (2.76) > US6 (2.61) > MS3 (1.35) > CS7 (0.18) > 0.02 (permissible limit). The concentration of transformer oil PCB (TO8 is 151.31 ppm) > 50 ppm (threshold limit). tPCBs with BZ number 138 (31.02 ppm) in TO8 is the most abundant. PCBs with BZ number 153 (0.01 ppm) and BZ number 138 (0.01ppm) in RS2 has the least value. in the long run chronic exposure may cause casinoma in the liver and malignant melanoma. The trend of total number of Cl in the PCB compounds (tCl) follows the order of TO8 (80) > WS1 (67) > RP5 (62) >RS2 (52) > US6 (43) > DS4 (29) > MS3 (18) >5-10 (toxic). They are all toxic and above permissible limit. Chlorine numbers in the range of 5-10 > CS7 (4) is non-toxic. Analysis of variance revealed a significant difference in the concentration of tPCBs and total number of Cl across the study area. Generally, the significant levels/difference ($p < 0.05$) of ∑PCBs in the analytical sample when compared to the control soil samples calls for concern.

## Keywords:

PCB, Transformer, Soil, Printing Press, Chlorine, Biphenyls

## 1. Introduction

Polychlorinated biphenyls (PCBs) are class of persistent organic pollutants (POPs) used as dielectric fluids because of their chemical and physical stability and electrical insulating properties [1]. They are compounds synthesized from the substitution of

hydrogen atoms by chlorine atoms in the biphenyls. The general chemical formula of PCBs can be represented as $C_{12}H_{10-n}Cl_n$, where n is a number of chlorine atoms within the range of 1-10 (i.e. *n* ranges from 1 to 10) [2]. The relative molecular weight of this compound depends on the degree of chlorination. Theoretically, a total of 209 possible PCBs congeners that have been synthesis under laboratory condition exist, but only about 130 of these are likely to occur in commercial products [3,4].

The number and position of the chlorine atoms on the biphenyl molecule determine the congener's nomenclature as well as govern its environmental fate and toxicity [2]. Individual congeners are identified by the number and position of the chlorine atoms around the biphenyl rings (PCBs Congeners). The congeners that are toxic carry between 5-10 chlorine atoms, mostly in the *Para* and *Meta* positions. Meanwhile, the congener's that substitute at the 3, 4-*ortho* positions are considered the most toxic. It is known that *ortho* substitution increases toxicity, therefore properties of every PCB congener depend entirely on the degree of its chlorination [5].

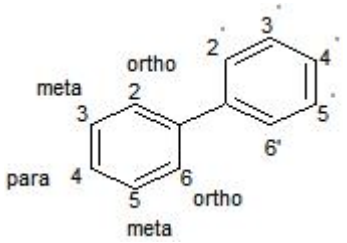


***Figure 1.*** *Structure of PCB showing the number and location of Cl group.*

Occurrence of PCBs in remote areas, far from their original sources is thought to be the result of long range atmospheric transport and precipitation [6]. PCB in the environment altered their compositions through various processes such as volatilization and partitioning, chemical or biological transformation, and bioaccumulation. PCBs adsorb strongly to soil, where they tend to persist due to their characteristic properties [7]. Soil acts as a good indicator of Pollution and environmental risk. Many cleaning agents, pesticides and pharmaceutical products rely on the chemical properties of the chlorine atom attached to a hydrocarbon backbone or ring structure [8].

No evidence has supported the natural occurrence of PCBs although they continue to exist in many environmental matrices [9]. Majority of the PCBs in the environment finds its way during their manufacture, usage as well as during disposal [1]. Human activities influence the concentration of PCBs especially close to shorelines and in water [9].

PCB attaches strongly to soil and may remain there for several years as a result of its lipophilicity it is for this reason that environmental cycling is expected in disposal and spill sites [10]. It also occurs during the disposal of PCB-containing materials by breathing contaminated air and by making contact with materials containing PCBs [1]. Old appliances and electrical equipment are also believed to be the primary Source of household contamination. Today PCBs usually reach the environment as a result of transformer oil leakage caused by transformer failures, poor handling of damaged electrical equipment, spilling during oil changes and improper waste disposal [11].

The chemical properties of PCBs (low water solubility, high stability and semi-volatility) favour their long-range transport in the environment, making them detectable in remote areas like in the arctic air, water and organisms. Due to their physical and chemical properties, PCBs are highly persistent in the environment and

tend to accumulate progressively in soils, plants and animals and proportionally to the trophic level in the food chain and are classified as probably carcinogenic [12]. PCBs contaminates soil via PCBs sources (including electrical transformer and printing ink) is of increasing concern, hence the need to continually monitor PCBs levels in different receptacles and their vicinity soils. In this study, we focus on comparative determination of PCB concentrations in soils within the environments of electrical transformer, dumpsites and printing ink.

## 2. Materials and Methods

All chemicals used for this research were obtained and used without further Purification. Acetone and hexane solvents used in extraction were procured from Merck, India. Silica gel (100-200 mesh) was procured from Sigma-Aldrich. PCBs standard solutions 2000 ppm, containing 14 PCBs congeners was purchased from Accu-standard. Agilent 7820A Gas chromatograph coupled to 5975C inert mass spectrometer (with triple axis detector) and electron-impact source (Agilent Technologies) was used. Transformer oil (TO8) was graciously donated by PHCN Electrical transformer handlers.

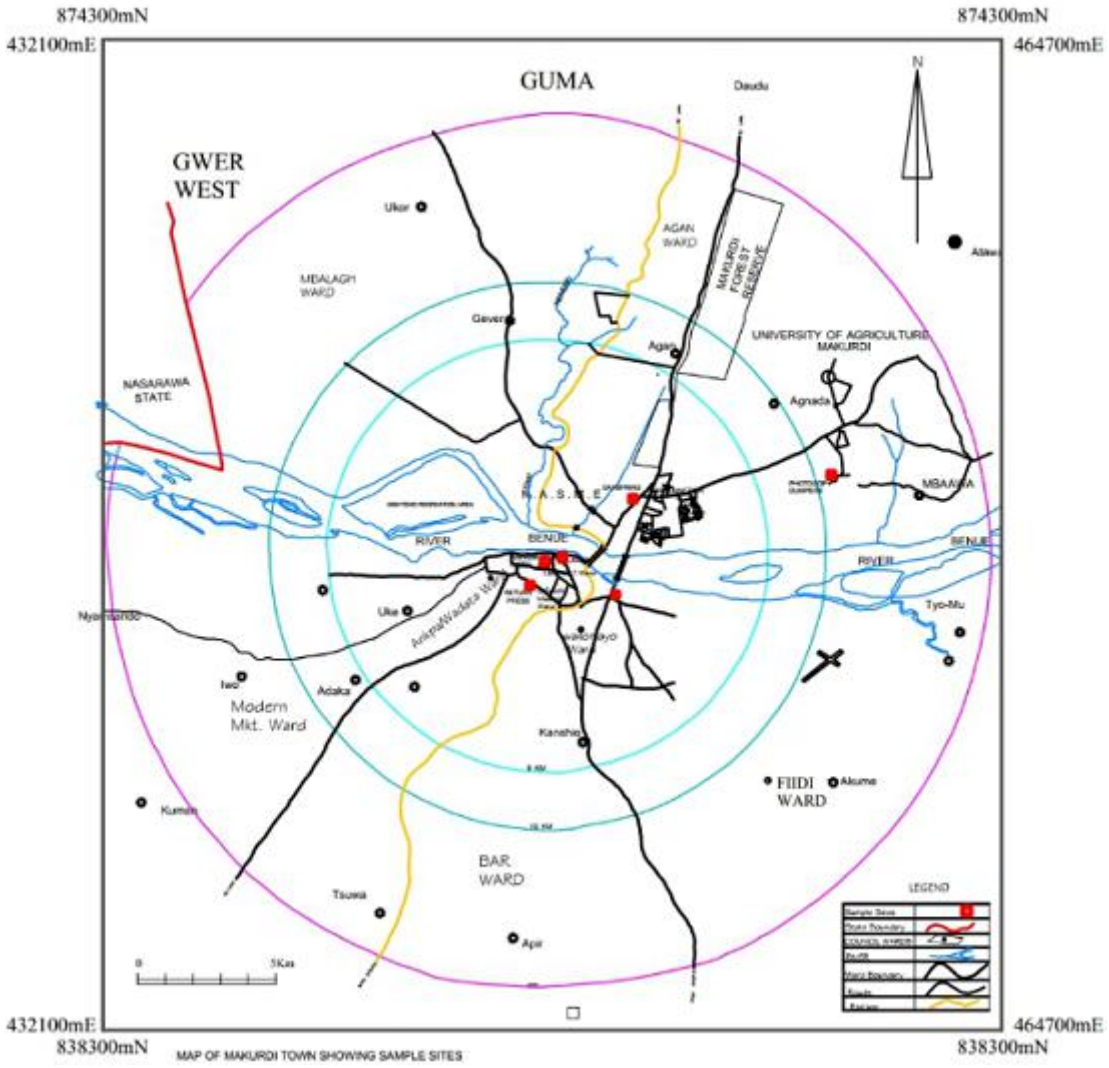


***Figure 2.*** *Map Showing Study Area and Sampling Locations.*

### *2.1. Sampling*

A documented soil sampling technique [13] was adopted. The Soil samples, coded in Table 1 were collected from the vicinities of four Electricity transformers, printing press and dump sites in Makurdi -Benue state of Nigeria. Composite sample were collected with a garden hand towel (washed and rinsed with distilled water) at depth of 10 – 15 cm. Each composite sample was weighed between 20 - 25 g, and consist of four core samples from north, east, west and south around the vicinity at a distance of 10 m. A control sample $C_1$ was used. The composite sample was air dried, and each sample was sieved using 250 µm mesh sieve. The samples were placed in labelled polythene bags and sent to the laboratory for further treatment. Preliminary physico-chemical investigation, the pH, conductivity and total organic carbon of samples were investigated.

***Table 1.*** *Sample Codes and Locations.*

| S/No. | Code | Sample type/Location |
|---|---|---|
| 1 | WS1 | Soil at the vicinity of transformer at Wurukum roundabout |
| 2 | RS2 | Soil at the vicinity of transformer at Rahama Hotel |
| 3 | MS3 | Soil at the vicinity of transformer at MLS |
| 4 | DS4 | Soil at the vicinity of transformer at Day spring |
| 5 | RP5 | Soil at the vicinity of Return Press |
| 6 | US6 | Soil at the vicinity of FUAM Business centre dumpsite. |
| 7 | CS7 | Control Experimental soil sample –Ankpa word |
| 8 | TO8 | Commercial Transformer oil |

MLS- ministry of land & survey

### *2.2. Preparation of Soil Sample*

The soil sample (10 g) was mixed thoroughly with anhydrous sodium sulphate, and transferred into a beaker and added 40 mL hexane: acetone (1:1) and placed into an ultrasonic bath and sonicate for twenty minutes, the solvent layer was allowed to settle and the solvent layer was decanted and concentrated down to 2 mL using a rotary evaporator and ready for Extraction. Protocol of USEPA 3665A [12] was adopted for the preparation of transformer oil sample. PCBs standards and calibration curves were prepared following standard laboratory practices.

### *2.3. Extraction of PCBs*

Standard procedures [2,14] were adopted. 5 g of the sample was weighed into 50 mL conical flask, 10 mL of dichloromethane (DCM) was added and was sonicated for about 30 min. The clear portion was decanted into a clean beaker and kept separately. To the residue in conical flask, another 10 mL of DCM was added and followed the same process. Finally, 10 mL of n-Hexane was added to the residue and sonicated for about 20 min to complete the extraction process before collection of the clear portion into the initial baker containing the extract; the extract was centrifuged and later cleans up by packing of column. The cleaned extract was dried over anhydrous sodium sulphate. It was concentrate to about 1mL before injection for GC-MS analysis. For the extraction of PCBs from transformer oil, 0.5 g of oil was diluted with 5 mL of hexane and was transferred to a separation funnel. The container was rinsed several times with hexane until the final volume in the separation funnel was 20 mL. 20 millilitres (20 mL) of concentrated tetaoxosulphate (vi) acid (H2SO4) was added to a separation funnel and shaken vigorously for 2 minutes. Acid treatment of oil

oxidizes most polyaromatic hydrocarbons (PAC) and other organic double bonds, PCBs and aliphatic compounds are not prone to oxidation with acidic treatment. The mixture was allowed to separate for 15 minutes and the excess acid was drained. Any remaining acid was removed by washing the extract with 5 mL deionised water

### *2.4. Clean-up process for Extracted PCBs*

Clean up method [15,16] were followed. Briefly, the concentrated extract (1 mL) was dissolved in 2 mL of n-hexane and transferred into a reparatory funnel. 2 mL of sulphuric acid (98%) was added slowly to the extract and shaken vigorously for 2 minutes. The inorganic layer was decanted off. Several portions of sulphuric acid were used until the acid layer remained colourless. The organic extracts were passed through anhydrous sodium sulphate and concentrated to 1 mL. However, an acid clean-up alone does not usually remove all of the interfering substances that are present in the samples. An additional clean-up was the use of adsorption column chromatography to separate target analytes from other interfering compounds using Florisil (60–100 mesh). A glass column was packed with 10 g of activated Florisil (130°C for 12 h) and 2 g of anhydrous $Na_2SO_4$ was added on the top for removal of any trace of water. The column was pre-eluted with 40 mL of hexane. The extract (1 mL) was loaded into the column and the elution of analyte was carried out using 80 mL of hexane. The elutes was concentrated by rotary evaporator and under a gentle stream of pure nitrogen. The residue fraction was dissolved into 1 mL of hexane.

### *2.5. Physicochemical Analysis*

The soil pH was determined following standard method [16], using pH meter (HI 8424 by HANNA). electrical conductivity was read using a conductivity meter (by JENWAY 4520) while the total carbon was determined, following NS-EN 159358 method.

$$TOC\,(\%) = \frac{100-100\ NWAA}{NWBA}$$

NWAA and , NWBA is net weight After and before ashing respectively. Net weight is weight obtained by deducting the filter weight from sum of sample and filter weight.

## 3. Results and Discussion

### *3.1. Physiochemical Parameters*

Physiochemical Analysis was carried out to determine the pH level, conductivity and organic matter, of the soil and transformer oil. This was performed in triplicate and reported mean values of three determinations (Table 2). Values of the total organic carbon are indication of the presence of organic pollutants (including PCBs) in the samples. The pH (5.69-7.67) and conductivity (108.7-135.8) values were within range for slightly contaminated soils.

***Table 2.*** *Physiochemical Parameters of Samples.*

| Sample code | pH | Conductivity (µS/cm) | Total Organic carbon (%) |
|---|---|---|---|
| WS1 | 7.54 ± 0.04 | 221.6 ±0.01 | 3.85± 0.01 |
| RS2 | 5.69 ± 0.05 | 158.2 ±0.02 | 1.65± 0.03 |
| MS3 | 5.72 ± 0.02 | 124.6 ±0.02 | 0.98 ± 0.01 |
| DS4 | 6.36 ± 0.02 | 116.0 ±0.11 | 2.47± 0.02 |

| | | | |
|---|---|---|---|
| RP5 | 6.05 ± 0.01 | 108.7 ±0.02 | 2.63± 0.1 |
| US6 | 7.67 ± 0.03 | 245.8 ±0.10 | 2.35± 0.01 |
| CS7 | 7.35 ± 0.02 | 135.8 ±0.02 | 0.15± 0.02 |
| TO8 | 6.14 ± 0.04 | 0.001 ±0.00 | 3.83± 0.02 |

### *3.2. Gas Chromatography - Mass Spectrometry Analysis*

GC-MS analysis was carried out to determine the concentrations of polychlorinated biphenyls (PCBs) in WS1, RS2, MS3, DS4, RP5, US6, CS7 and TO8 as shown in Tables 3-9. The sample was tested for the presence of the following PCB congeners, with BZ number 18, 28 +31, 20, 52, 44,105, 149, 118, 153, 101, 138, 180, 170 and 196. Comparison of total PCBs concentration (ppm) and total number of chlorine in different samples are shown in Figure 3 and Figure 4 respectively while Figures 5-8 represents the comparative study of tPCBs concentration (ppm) in the soil samples of different land use compared with results of the control soil and commercial PCB. In Figure 9, mean PCBs concentrations were reported for soils, re-grouped into those around electrical transformer (STR), printing press (PP) and Dumpsites (DS).

***Table 3.*** *GC-MS Concentrations of PAHs in WS1.*

| PCBs BZ Number | IUPAC Name of PCBs Congeners | Number of Cl | Concentration (ppm) |
|---|---|---|---|
| 18 | 2,2′,5-TriCB | 3 | 0.60 |
| 28+31 | 2,4,4′-TriCB + 2,4′,5-TriCB | 6 | 0.65 |
| 20 | 2,3,3′-TriCB | 3 | 1.44 |
| 52 | 2,2′,5,5′-TetraCB | 4 | 2.23 |
| 44 | 2,2′,3,5′-TetraCB | 4 | 2.27 |
| 105 | 2,3,3′,4,4′-PentaCB | 5 | 0.72 |
| 149 | 2,2′,3,4′,5,6-HexaCB | 6 | 0.48 |
| 118 | 2,3′,4,4′,5-PentaCB | 5 | 0.80 |
| 153 | 2,2′,4,4′,5,5′-HexaCB | 6 | 0.64 |
| 101 | 2,2′,4,5,5′-PentaCB | 5 | 2.19 |
| 138 | 2,2′,3,4,4′,5′-HexaCB | 6 | 0.99 |
| 180 | 2,2′,3,4,4′,5,5′-HeptaCB | 7 | 0.08 |
| 170 | 2,2′,3,3′,4,4′,5-HeptaCB | 7 | 1.54 |
| 196 | 2,2′,3,3′,4,4′,5,6′-OctaCB | | ND |

*tCl = 52; tPCBs = 2.88 ppm; BZ=Ballschmiter and Zell, ND=not detected, WS1- Soil at the vicinity of transformer at Wurukum roundabout*

***Table 4.*** *GC-MS Concentrations of PAHs in RS2.*

| PCBs BZ Number | IUPAC Name of PCBs Congeners | Number of Cl | Concentration (ppm) |
|---|---|---|---|
| 18 | 2,2′,5-TriCB | - | ND |
| 28+31 | 2,4,4′-TriCB + 2,4′,5-TriCB | 6 | 0.35 |
| 20 | 2,3,3′-TriCB | 3 | 0.32 |
| 52 | 2,2′,5,5′-TetraCB | 4 | 0.09 |
| 44 | 2,2′,3,5′-TetraCB | 4 | 0.71 |
| 105 | 2,3,3′,4,4′-PentaCB | 5 | 0.17 |
| 149 | 2,2′,3,4′,5,6-HexaCB | 6 | 0.37 |
| 118 | 2,3′,4,4′,5-PentaCB | - | ND |
| 153 | 2,2′,4,4′,5,5′-HexaCB | 6 | 0.01 |
| 101 | 2,2′,4,5,5′-PentaCB | 5 | 0.70 |
| 138 | 2,2′,3,4,4′,5′-HexaCB | 6 | 0.01 |
| 180 | 2,2′,3,4,4′,5,5′-HeptaCB | - | ND |
| 170 | 2,2′,3,3′,4,4′,5-HeptaCB | 7 | 0.15 |

| | | | |
|---|---|---|---|
| 196 | 2,2′,3,3′,4,4′,5,6′-OctaCB | - | ND |

*tCl = 52; tPCBs = 2.88 ppm; BZ=Ballschmiter and Zell, ND=not detected; RS2- Soil at the vicinity of transformer at Rahama Hotel*

***Table 5.*** *GC-MS Concentrations of PAHs in MS3.*

| PCBs BZ Number | IUPAC Name of PCBs Congeners | Number of Cl | Concentration (ppm) |
|---|---|---|---|
| 18 | 2,2′,5-TriCB | - | ND |
| 28+31 | 2,4,4′-TriCB + 2,4′,5-TriCB | 6 | 0.28 |
| 20 | 2,3,3′-TriCB | 3 | 0.27 |
| 52 | 2,2′,5,5′-TetraCB | | ND |
| 44 | 2,2′,3,5′-TetraCB | 4 | 0.42 |
| 105 | 2,3,3′,4,4′-PentaCB | - | ND |
| 149 | 2,2′,3,4′,5,6′-HexaCB | - | ND |
| 118 | 2,3′,4,4′,5-PentaCB | | ND |
| 153 | 2,2′,4,4′,5,5′-HexaCB | - | ND |
| 101 | 2,2′,4,5,5′-PentaCB | 5 | 0.38 |
| 138 | 2,2′,3,4,4′,5′-HexaCB | - | ND |
| 180 | 2,2′,3,4,4′,5,5′-HeptaCB | - | ND |
| 170 | 2,2′,3,3′,4,4′,5-HeptaCB | - | ND |
| 196 | 2,2′,3,3′,4,4′,5,6′-OctaCB | - | ND |

*tCl = 18; tPCBs = 1.35 ppm; BZ=Ballschmiter and Zell, ND=not detected; MS3-Soil at the vicinity of transformer at Ministry of Lands and Survey*

***Table 6.*** *GC-MS Concentrations of PAHs in DS4.*

| PCBs BZ Number | IUPAC Name of PCBs Congeners | Number of Cl | Concentration (ppm) |
|---|---|---|---|
| 18 | 2,2′,5-TriCB | - | ND |
| 28+31 | 2,4,4′-TriCB + 2,4′,5-TriCB | 6 | 0.28 |
| 20 | 2,3,3′-TriCB | 3 | 0.39 |
| 52 | 2,2′,5,5′-TetraCB | 4 | 1.11 |
| 44 | 2,2′,3,5′-TetraCB | 4 | 0.40 |
| 105 | 2,3,3′,4,4′-PentaCB | - | ND |
| 149 | 2,2′,3,4′,5,6-HexaCB | - | ND |
| 118 | 2,3′,4,4′,5-PentaCB | | ND |
| 153 | 2,2′,4,4′,5′,5 ′-HexaCB | - | ND |
| 101 | 2,2′,4,5,5′-PentaCB | 5 | 0.43 |
| 138 | 2,2′,3,4,4′,5′-HexaCB | - | ND |
| 180 | 2,2′,3,4,4′,5,5′-HeptaCB | - | ND |
| 170 | 2,2′,3,3′,4,4′,5-HeptaCB | 7 | 0.15 |
| 196 | 2,2′,3,3′,4,4′,5,6′-OctaCB | - | ND |

*tCl = 29; tPCBs = 2.76 ppm; BZ=Ballschmiter and Zell, ND=not detected; DS4- Soil at the vicinity of transformer at Day spring*

***Table 9.*** *GC-MS Concentrations of PAHs in RP5.*

| PCBs BZ Number | IUPAC Name of PCBs Congeners | Number of Cl | Concentration (ppm) |
|---|---|---|---|
| 18 | 2,2′,5-TriCB | 3 | 0.04 |
| 28+31 | 2,4,4′-TriCB + 2,4′,5-TriCB | 6 | 0.31 |
| 20 | 2,3,3′-TriCB | 3 | 0.52 |
| 52 | 2,2′,5,5′-TetraCB | 4 | 0.10 |
| 44 | 2,2′,3,5′-TetraCB | 4 | 0.18 |
| 105 | 2,3,3′,4,4′-PentaCB | 5 | 0.17 |
| 149 | 2,2′,3,4′,5,6-HexaCB | 6 | 0.32 |

| | | | |
|---|---|---|---|
| 118 | 2,3′,4,4′,5-PentaCB | - | ND |
| 153 | 2,2′,4′,4′,5,5′-HexaCB | 6 | 0.42 |
| 101 | 2,2′,4,5,5′-PentaCB | 5 | 0.79 |
| 138 | 2,2′,3,4,4′,5′-HexaCB | 6 | 0.53 |
| 180 | 2,2′,3,4,4′,5,5′-HeptaCB | 7 | 0.02 |
| 170 | 2,2′,3,3′,4,4′,5-HeptaCB | 7 | 0.44 |
| 196 | 2,2′,3,3′,4,4′,5,6′-OctaCB | - | ND |

*tCl = 62; tPCBs = 3.84 ppm; BZ=Ballschmiter and Zell, ND=not detected; RP5- Soil at the vicinity of Return Press*

***Table 7.*** *GC-MS Concentrations of PAHs in US6.*

| PCBs BZ Number | IUPAC Name of PCBs Congeners | Number of Cl | Concentration (ppm) |
|---|---|---|---|
| 18 | 2,2′,5-TriCB | 3 | 0.15 |
| 28+31 | 2,4,4′-TriCB + 2,4′,5-TriCB | 6 | 0.28 |
| 20 | 2,3,3′-TriCB | 3 | 0.58 |
| 52 | 2,2′,5,5′-TetraCB | 4 | 0.09 |
| 44 | 2,2′,3,5′-TetraCB | 4 | 0.36 |
| 105 | 2,3,3′,4,4′-PentaCB | 5 | 0.17 |
| 149 | 2,2′,3,4′,5,6-HexaCB | - | ND |
| 118 | 2,3′,4,4′,5-PentaCB | - | ND |
| 153 | 2,2′,4,4′,5,5′,-HexaCB | - | ND |
| 101 | 2,2′,4,5,5′-PentaCB | 5 | 0.38 |
| 138 | 2,2′,3,4,4′,5′-HexaCB | 6 | 0.45 |
| 180 | 2,2′,3,4,4′,5,5′-HeptaCB | - | ND |
| 170 | 2,2′,3,3′,4,4′,5-HeptaCB | 7 | 0.15 |
| *196* | *2,2′,3,3′,4,4′,5,6′-OctaCB* | - | *ND* |

*tCl = 43; tPCBs = 2.61 ppm; BZ=Ballschmiter and Zell, ND=not detected; US6- Soil at the vicinity of FUAM Business centre dumpsite*

***Table 8.*** *GC-MS Concentrations of PAHs in CS7.*

| PCBs BZ Number | IUPAC Name of PCBs Congeners | Number of Cl | Concentration (ppm) |
|---|---|---|---|
| 18 | 2,2′,5-TriCB | - | ND |
| 28+31 | 2,4,4′-TriCB + 2,4′,5-TriCB | - | ND |
| 20 | 2,3,3′-TriCB | - | ND |
| 52 | 2,2′,5,5′-TetraCB | - | ND |
| 44 | 2,2′,3,5′-TetraCB | 4 | 0.18 |
| 105 | 2,3,3′,4,4′-PentaCB | - | ND |
| 149 | 2,2′,3,4′,5,6-HexaCB | - | ND |
| 118 | 2,3′,4,4′,5-PentaCB | - | ND |
| 153 | 2,2′,4′,4′,5,5′-HexaCB | - | ND |
| 101 | 2,2′,4,5,5′-PentaCB | - | ND |
| 138 | 2,2′,3,4,4′,5′-HexaCB | - | ND |
| 180 | 2,2′,3,4,4′,5,5′-HeptaCB | - | ND |
| 170 | 2,2′,3,3′,4,4′,5-HeptaCB | - | ND |
| 196 | 2,2′,3,3′,4,4′,5,6′-OctaCB | - | ND |

*tCl = 4; tPCBs = 0.18 ppm; BZ=Ballschmiter and Zell, ND=not detected; CS7- Control Experimental soil sample at Ankpa ward*

***Table 9.*** *GC-MS Concentrations of PAHs in TO8.*

| PCBs BZ Number | IUPAC Name of PCBs Congeners | Number of Cl | Concentration (ppm) |
|---|---|---|---|
| 18 | 2,2′,5-TriCB | 3 | 1.66 |

| | | | |
|---|---|---|---|
| 28+31 | 2,4,4′-TriCB + 2,4′,5-TriCB | 6 | 2.o3 |
| 20 | 2,3,3′-TriCB | 3 | 6.73 |
| 52 | 2,2′,5,5′-TetraCB | 4 | 28.92 |
| 44 | 2,2′,3,5′-TetraCB | 4 | 0.82 |
| 105 | 2,3,3′,4,4′-PentaCB | 5 | 3.75 |
| 149 | 2,2′,3,4′,5,6-HexaCB | 6 | 10.82 |
| 118 | 2,3′,4,4′,5-PentaCB | 5 | 2.57 |
| 153 | 2,2′,4,4′,5,5′-HexaCB | 6 | 24.06 |
| 101 | 2,2′,4,5,5′-PentaCB | 5 | 5.52 |
| 138 | 2,2′,3,4,4′,5′-HexaCB | 6 | 31.02 |
| 180 | 2,2′,3,4,4′,5,5′-HeptaCB | 7 | 15.13 |
| 170 | 2,2′,3,3′,4,4′,5-HeptaCB | 7 | 18.85 |
| 196 | 2,2′,3,3′,4,4′,5,6′-OctaCB | 8 | 1.43 |

*tCl = 80; tPCBs = 153.31 ppm; BZ=Ballschmiter and Zell, ND=not detected; TO8- Commercial Transformer oil*

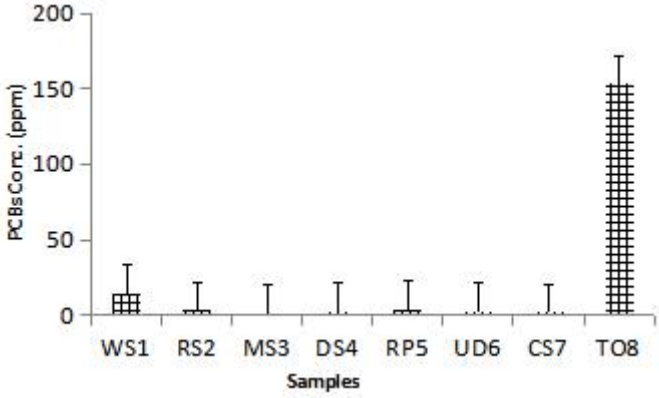


***Figure 3.*** *Total PCBs Concentration in Samples.*

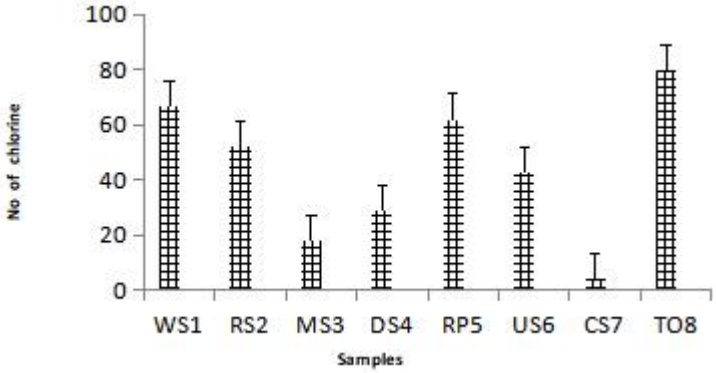


***Figure 4.*** *Total Number of Chlorine in Different Samples.*

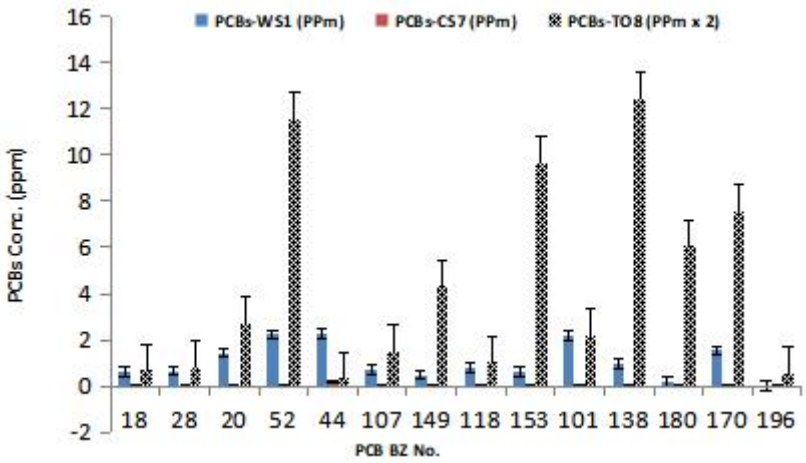


***Figure 5.*** *Comparative PCBs Levels (ppm) in WS1, CS7 and TO8.*

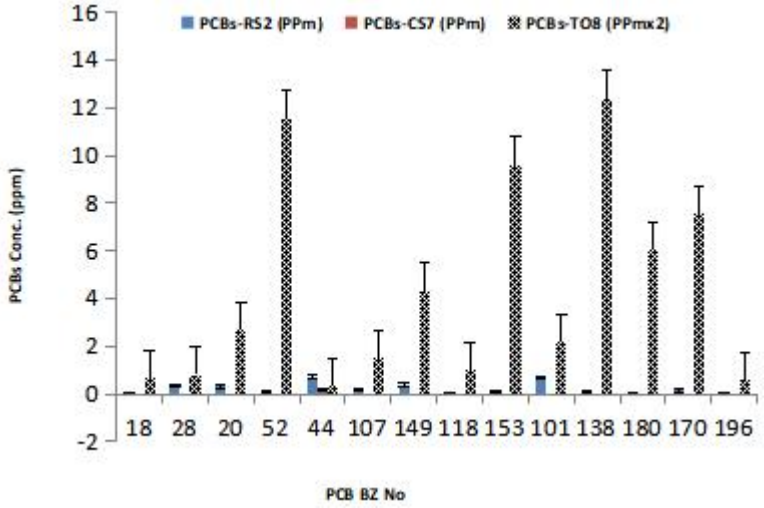


***Figure 6.*** *Comparative PCBs Levels (ppm) in RS2, CS7 and TO8.*

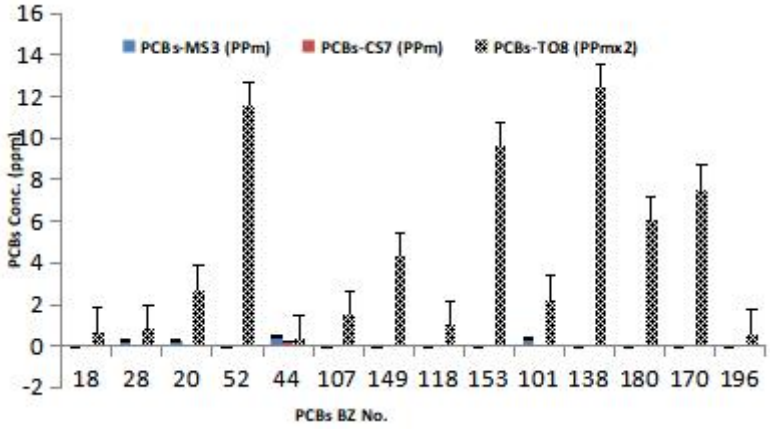


***Figure. 7.*** *Comparative PCBs Levels (ppm) in MS3, CS7 and TO8.*

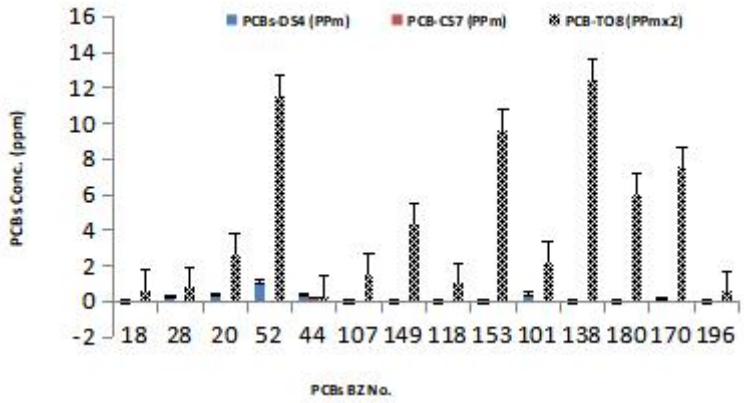


***Figure 8.*** *PCBs Concentrations (ppm) in DS4, CS7 and TO8.*

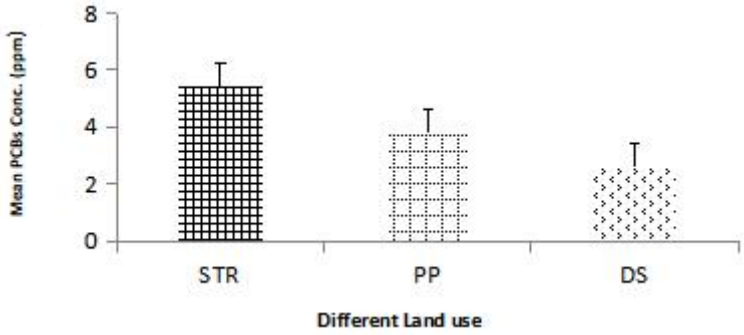


***Figure 9.*** *PCBs in Soil Samples of Different Land Use.*

### *3.3. Soil PCBs and Cl in the Vicinity of Electrical Transformers*

The tPCBs of sample, SW1 is 14.63 ppm of, this exceed the permissible limit of 0.02 ppm and the contaminated value of 1.00 ppm, The soil sample have PCBs content higher than the permissible limit and the contamination limit value as defined by the soil regulation [11]. The total number of Cl in SW1 is 67 which also exceed the legal limit of 5-10 [2]. Sw1 is therefore contaminated with PCBs.

RS2 has a total concentration level of 2.8 ppm and a total number of chlorine of 52. The 2.8 ppm is also above the permissible limit of 0.02 ppm and the contamination limit of 1.00 ppm as stipulated by existing legislation. The high concentration of PCBs and a high number of chlorine in RS2 could Pose serious danger in the environment, owing to their persistency and toxicity.

MS3, has a total PCB concentration of 1.35 ppm with a total number of chlorine (18). The concentration of 1.35 ppm is above the permissible limit of 0.02 and the contamination limit of 1.00 ppm. The total number of chlorine in MS3 is 18, this exceed the permissible limit of 5-10 (toxic).

The PCB levels in DS4 is 2.76 ppm, and a total of 29 numbers of chlorine. PCBs limit exceeds 0.02 threshold limit and 1.00 contaminations limit. This implies that DS4 is contaminated with high level of PCBs. The number of chlorine present in the PCBs is also above the permissible limit of 5-10 (toxic).

### *3.4. PCBs in Soil Around Printing Press*

RP5 has the highest value of PCBs contamination (3.84 ppm). This concentration level is above the permissible limit of 0.02 ppm and the contamination limit of 1.00

ppm. This level of PCBs released into the environment could pose serious threat, owing to their persistency and toxicity. The toxicity is as a result of a high number of chlorine (62). The congeners that are toxic carries between 5-10 chlorine atoms, mostly in the *Para* and *Meta* positions. Meanwhile, the congener's that substitute at the 3, 4-*ortho* positions are considered the most toxic. It is known that *ortho* substitution increases toxicity, therefore properties of every PCB congener depend entirely on the degree of its chlorination [5]

### *3.5. Polychlorinated Biphenyls (PCBs) in Soil Around Dumpsite*

US6 with a PCBs concentration level of 2.61 ppm and tCl of 43 total (above the permissible limits of 0.02 and the 1.00 ppm respectively). The reported levels raise concern and appropriate measures have to be taken to prevent the environment. Apparent half-lives of some PCB congeners in a set of different studies in humans, in rhesus monkey and in rats were reported [17].

The persistence of PCBs combined with their high lipophilicity provides the necessary conditions for them to bioaccumulate in living organisms. Previous studies revealed that all congeners of PCBs are lipophilic but different congeners sometimes act differently from one another and water solubility decreases as the degree of chlorination increases [18].

### *3.6 Polychlorinated Biphenyls (PCBs) in Control Sample*

From Table 7, Only one PCB congener (BZ 44; 2,2′,3,5′-TetraCB) is detected in the control sample. BZ 44 in CS7 is lower, compared to the same congeners of all analytical soil samples. This value of PCB is however above the permissible limit value of 0.02 ppm [11]. CS7 have a total number of 4 Chlorine which is within the permissible limit of 5 to 10. Note that the PCB quantification limit value of 0.02 ppm, is calculated as the total of 7 congeners and defined by the Soil Regulation [11].

### *3.7. Polychlorinated Biphenyls (PCBs) in Transformer Oil*

From Table 9, TO8 shows a value of 153.3 ppm of PCBs. The benchmark level for PCBs in transformer oil is considered as 50 mg $kg^{-1}$ (50 ppm) in many countries [19]. PCB concentrations in TO8 exceeds the set legal limit of 50 ppm[18] and was considered a hazardous waste and must be treated accordingly. The reported levels raise concern and appropriate measures have to be taken to prevent TO8 environmental dispersion. In a similar fashion, tCl of TO8 summed at 80 is above the permissible limit of 5-10. The toxicity of PCBs depends greatly on the number of total chlorine.

### *3.8. Total PCBs (tPCBs)*

The level of soil contamination by PCBs for SW1 (14.63) is the highest when compared to RS2 (2.88), DS4 (2.76) and MS3 (1.35) for the soil samples from the electrical transformer vicinities. The dumpsite (US6) also records a high PCBS concentration (2.61), above the permissible limit of 0.02 and contamination limit of 1.00 ppm. The Printing press (RP5) have a value of 3.84 above the permissible limit and contamination limit of 1.00 ppm. T08 (153.31 ppm) which is the major known source in most receptacles have PCBs concentration far above the permissible limit of 50 ppm. Of less concern is the levels reported for control samples CS7 (0.18 ppm). The trace amount in the control sample of polychlorinated biphenyl (PCBs) possibly

occurs due to evaporate and spread to the atmosphere at latitudes with warmer climates and then condense and fall- out closer to the poles [2]. Studies by some members of this team on tPAHs – total polycyclic aromatic hydrocarbons (which are similarly carcinogenic organic pollutants) in environmental samples were reported [20,21,22,23]

### *3.9. Test of Significance*

A one way –ANOVA using SPSS (version 17) software was adopted to compare the tPCBs concentrations and tCl in the soil samples for different land use. Result revealed that there is significant difference ($P<0.05$) in the concentration of PCBs across the study area. The F-Test also confirmed that there were significant difference in the PCBs concentration across the study area (F-cal. (11.981) > F-tab. (2.33) at 95 % confidence level.

## 4. Conclusions

The GC-MS quantification of PCBs in soils within the vicinities of PCB receptacles revealed that the various soils and TO8 are contaminated with PCBs of different congeners, with values above the permissible limits. Only one PCB congeners, in trace amounts is detected in the control sample (CS7). The trend in abundance of PCBs (ppm) follows the order of; tPCBs (ppm) WS1 (14.63) > RP2 (3.84) > RS2 (2.88) > DS4 > (2.76) > US6 (2.61) > MS3 (1.35) > CS7 (0.18) > 0.02 (permissible limit). TO8 (151.31) > 50 (permissible limit). PCBs with BZ number 138 (31.02 ppm) in TO8 is the most abundant with the highest value while PCBs with BZ number 153 and PCBs with BZ number 105 (0.01 ppm) in RS2 have the lowest value . The trend of total Cl is as follows, tCl –TO8 (80) > WS1 (67) > RP5 (62) >RS2 (52) > US6 (43) > DS4 (29) > MS3 (18) >5-10 (toxic). They are all toxic and above the permissible limit. Overall, Soils in the vicinity of Electrical transformers, printing press and dumpsites are prone to PCB contamination, hence could be potential PCB receptacles.

## Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this article.

## Author Contributions

Conceptualization: A.U.I., S.A.; A.U; Methodology: A.U.I.; A.J.O.; Formal analysis: A.J.O; Investigation: A.J.O.; Resources: A.U.I.; A.J.O.; S.A.; A.U; Data Curation: A.U.I.; Writing – original draft preparation: A.J.O.; Writing – review and editing: A.U.I, S.A.; A.U; Visualization: A.U.I.; S.A.; Project administration: A.U.I.

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## References

[1] Anyasi, R.O.; Atanga, H.I. Biological remediation of polychlorinated biphenyls (PCB) in the environment by microorganisms and plants. *African Journal of Biotechnology,* 2011, 10 (82), 18916-18938.

[2] Kamba, E.A.; Itodo, A.U.; Ogah, E. A test for solid phase extracted polychlorinated biphenyls (PCBs) levels in transformer oil. *American Journal of Electrical Power and Energy System,* 2013, 2(3), 57-65.

[3] UNEP. Chemicals guideline for the identification of PCBs and materials containing PCBs, First issue, Inter-organization program for the sound management of chemicals, 1999; pp. 562-563.

[4] Martinez, H.A.; Rodriquez, G.C.; Castillo, D.H. Determination of PCBs in transformers oil using gas chromatography with mass spectrometry and aroclors. *Journal of Mexico Chemical Society, 2005,* 4, 263-270.

[5] Bernhard, T.; Petron, S. Analysis of PCB Congeners vs. Arcolors in Ecological Risk Assessment. *PCB Congeners in Ecological Risk Asssessment*, 2001, 1-7, AR103112-AR103118.
Available online: https://clu-in.org/download/contaminantfocus/pcb/analysis-of-pcb-congeners.pdf (accessed on 31 January 2020).

[6] Wang. S. Y.; Hu, J. Determination of dioxin-like polychlorinated biphenyls in soil and moss from Fildes Peninsula, Antarctica. *Chinese Science Bulletine,* 2012, 57, 992-6.

[7] Bhupander, K.; Virendra, K. V.; Satish, K. S.; Sanjay, K.; Chandra, K.; Sharma, A. B. Assessment of polychlorinated biphenyls and organochlorine pesticides in water samples from the Yamuna River. *Journal of Xenobiotics,* 2012, 2(1), e6.

[8] Vicent, T.; Caminal, G.; Eljarrat, E.; Barceló, D. Emerging Organic Contaminants in Sludge's: Analysis, Fate and Biological Treatment. *Handbook of Environmental Chemistry,* 2013, 24, 1-30.

[9] Borja, J.; Marie-Teleon, D.; Auresenia, J.; Gallardo, S. Polychlorinated Biphenyls and their biodegradation. *Process Biochemistry*. 2005, 40, 1999-2013.

[10] Yang, M.; Park, M.S; Lee, H.S. Endocrine disrupting chemicals: Human exposure and health risks. *Journal of Environmental Science Health,* 2006, 24, 183- 224.

[11] Stojić, N.; Pucarević, M.; Mrkajić, D.; Kecojević, I. Transformers as a potential for soil contamination. *Metabk,* 2014, 53(4), 689-692.

[12] Motladiile, S.; Kwaambwa, H.M.; Sichilongo, K. Development and Validation of a Gas Chromatography-Mass Spectrometry Method for the Determination of PCBs in Transformer Oil Samples-Application on Real Samples from Botswana. *Journal of Chromatograph Separation Technique,* 2011, 2(4), 4172-2157.

[13] Bentum, J.K.; Dodoo, D.K.; Kwakye, P.K. Accumulation of Metals and Polychlorinated Biphenyls (PCBs) in Soils around Electric Transformers in the Central Region of Ghana. *Advances in Applied Science Research,* 2012, 3(2), 634-643.

[14] Díaz-Moroles, N.E.; Garza-Ulloa, H.J.; Castro-Ríos R.; Ramírez-Villarreal, E.G.; Barbarín-Castillo, J.M.; dela Luz Salazar-Cavazos, M.; Waksman-de Torres, N.

A comparison of the performance of two chromatographic and three extraction techniques for the analysis of PAHs in sources of drinking water. *Journal of chromatographic science,* 2007, 45(2), 57-62.

[15] Bi, X.; Chu, S.; Men, Q.; Xu, X. Movement and retention of Polychlorinated biphenyls in a paddy field of WenTai area in China. *Agricultural Ecosystem Environment*, 2002, 89 (3), 241-252.

[16] Olayinka, O; Akande, O; Bamgbose, K.; Adetunji, M.T. Physicochemical Characteristics and Heavy Metal Levels in Soil Samples obtained from Selected Anthropogenic Sites in Abeokuta, Nigeria. *J. Appl. Sci. Environ. Mgt*., 2017, 21 (5), 883-891.

[17] Christian, J.; Larsen E.; Nielsen J.; Boberg M.; Axelstad P. Evaluation of health hazards by exposure to PCB and proposal of a health-based quality criterion for soil. The Danish Environmental Protection Agency, 2014, 1485. ISBN: 978-87-93026-17-9.
Available online: https://www2.mst.dk/Udgiv/publications/2014/03/978-87-93026-17-9.pdf (accessed on 31 January 2020).

[18] Pelitli, V.; Doağn, Ö.; KÖroğlu, H. J. Transformer oils potential for PCBs Contamination. *International Journal of Metallurgical and Material Engineering,* 2015, 1(114), 2455-2372.

[19] Bogdevich, O.P.; Cadocinicov, O.P. PCBs determination in transformer oil by SPE and GC Analysis. *Journal of the Physical Sciences,* 2004, 3(2), 226.

[20] Itodo, A.U.; Akeju, T.T., Itodo H.U. PAHs in Crude Oil Contaminated Water from Ese-Odo Offshore, Nigeria. *Annals of Ecology and Environmental Science*, 2019, 3(1), 12-19.

[21] Arowojolu, M.I.; Tongu, S.M.; Itodo, A.U.; Yinusa, S.T.; Yinusa. Basheeru, K.A.; Mejida, S. PAHs in water samples from a Nigerian bitumen seepage: Gas chromatography- mass spectrometry quantification. *Chemical Science International Journal,* 2018, 22(2), 1-10.

[22] Itodo, A.U.; Sha'Ato, R.; Arowojolu M.I. Distribution of Polycyclic Aromatic Hydrocarbons (PAHs) in Soil Samples from Regions around Loda-Irele Bitumen Field, Nigeria. *Pakistan Journal of Analytical and Environmental Chemistry,*2018, 19(1), 71-78.

[23] Itodo, A.U.; Sha'Ato, R.; Arowojolu, M.I. Polycyclic aromatic hydrocarbons in water samples from a Nigerian bitumen seepage: Gas chromatography- mass spectrometry quantification. *Bangladesh Journal of Scientific and Industrial Research,* 2018, 53(4), 319-326.