

Accumulation of Polychlorinated Biphenyls (PCBs) in Soil and Water from Electrical Transformers Installation Sites in Selected Locations in Jos Metropolis, Plateau State, Nigeria

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Received: March 03, 2018; Accepted: April 09, 2018; Published: April 15, 2018

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Abstract

Soil and water samples from surroundings of selected Electricity Transformer installations belonging to the Jos Electricity Distribution (JED) Plc, Jos were analyzed for different congeners of polychlorinated biphenyls (PCBs) widely used as coolants. The EPA 3550 and 3510 methods were used for the sampling, preparation and extraction of the soil and water samples respectively. The extracts were cleaned up using column chromatography packed with silica gel (120 mesh). Thereafter, it was concentrated for characterization and quantification using Gas Chromatography coupled with Mass Spectroscopy Detector (GC-MSD). Fifteen (15) congeners were identified and quantified in the soil samples. The result obtained shows C₅₂ to have the highest concentration with the value of 5.84 mg/kg. The range for the concentrations of the various congeners identified are: C₁₈ (0.00-0.05 mg/kg), C₂₀ (0.27-0.70 mg/kg), C₂₈ (0.28-0.39 mg/kg), C₂₉ (0.28-0.39 mg/kg), C₄₄ (0.15-0.54 mg/kg), C₅₂ (0.09-5.84 mg/kg), C₁₀₁ (0.38-0.51 mg/kg), C₁₃₇ (0.45-1.79 mg/kg), C₁₄₂ (0.00-0.55 mg/kg), C₁₅₃ (0.37-1.20 mg/kg), C₁₇₀ (0.15-1.59 mg/kg), C₁₈₀ (0.00-0.47 mg/kg) and C₁₉₄ (0.00-0.32 mg/kg). Similarly, for the water samples only C₂₀, C₂₈, C₂₉, C₁₀₁, C₁₀₅ and C₁₅₃ were identified and quantified. The result shows C₁₅₃ having the highest concentration with the value of 0.57 mg/l followed by C₁₀₅ (0.48 mg/l), C₁₀₁ (0.37 mg/l), C₂₈ and C₂₉ have same concentration of 0.28 mg/l. From thirty samples analyzed, the result of the soils is below the Canadian Reference maximum allowable limit while that of water has some values higher than the recommended allowable limit. The studies showed various concentrations are link with ages of Transformer installation, as those installed earlier had more congeners with higher concentrations than the recent ones.

Keywords: PCBs; Congener; Transformer; GC-MSD

Introduction

Polychlorinated Biphenyl (PCBs) are industrial chemical that were manufactured under the trade name Aroclor for use in transformers, electrical equipment, motor oils, paint and numerous other application. They are large class of compounds produced by partial or complete chlorination of biphenyls molecules with a general molecular formula of C₁₂H_{10-n}Cl_n where n ranges from one to ten [1,2]. Although banned thirty-five years ago, these contaminants are still widely detected in humans and the environment [3]. They were first synthesized in 1864 [4] and were commercially produced in the United States in 1929 in response to the electrical industry's need [5] but the production was banned in the United States in 1977 due to potential health hazard such as disturbances in the liver, nausea, vomiting, jaundice, fatigue, alteration of lipid metabolism, hormonal changes, respiratory tract infection and they are also known to be carcinogen [6]. There has been a global concern of PCBs because of their potential adverse on various organism including humans such as endocrines disrupting capacities, tendency to accumulate in living organism because of their love for fat [7]. Polychlorinated biphenyls primarily accumulate in soil and sediments as a result of spills, leaking toxic landfill or contamination from products containing the chemicals. PCBs do pollute air via volatilization and dispersion, the contaminants are most problematic in soil and sediments where they adhere to

organic and are very slow to degrade. The primary route of exposure for humans and wildlife is through the ingestion of contaminated dietary items. PCBs are highly lipophilic and dissolve in fatty tissue and bioaccumulate over an organism's life span. PCBs are broad category compounds consisting of 209 individual congeners differentiated by the position and number of chlorine that makes up the molecules [8].

The degree of lipophilicity increases with increase in chlorination. The use of PCBs in electrical transformers is the single largest sources of PCBs in vast majority of developing countries, additional sources of PCBs may come from the illegal dumping of toxic wastes containing these chemicals. For instance, in 1987 an Italian company slipped and dumped illegal 8000 drums of PCBs in a small-town Koko in the Nigerian Delta [9] PCBs are not produced in Nigeria, but its source has been attributed mainly to the importation and use of transformers and capacitors containing PCBs transformer oils [10]. Studies have also shown that PCBs are present in Nigeria environment [11,12], this may be as a result of poor handling of damaged electrical equipment, leakages, spillage during refilling and indiscriminate dumping of PCBs containing wastes [13]. Therefore, this study seeks to investigate and assess the concentration of PCBs in soil and water from some selected soil of PHCN transformers in Jos metropolis, Plateau state.

Materials and Methods

Study area

Jos is a city in the center of Nigeria, the city has a population of about 900,000 resident based on 2006 census [14]. It is the administrative capital of plateau state. The city is located on the Jos plateau at an elevation of about 1,238 meters or 4,062 feet high above

sea level. During British colonial rule, Jos was an important center for tin mining. This city is situated at an altitude of 1,217 m (3,993 ft) above sea level. Jos enjoys a more temperate climate than much of the rest of Nigeria. Average monthly temperature ranges from 21-25°C (70-77°F) and from mid-November to late January, night time temperature drops as low as 11°C (52°F). Jos receives about 1,400 millimeters (55 inches) of rainfall annually (Figures 1-3).

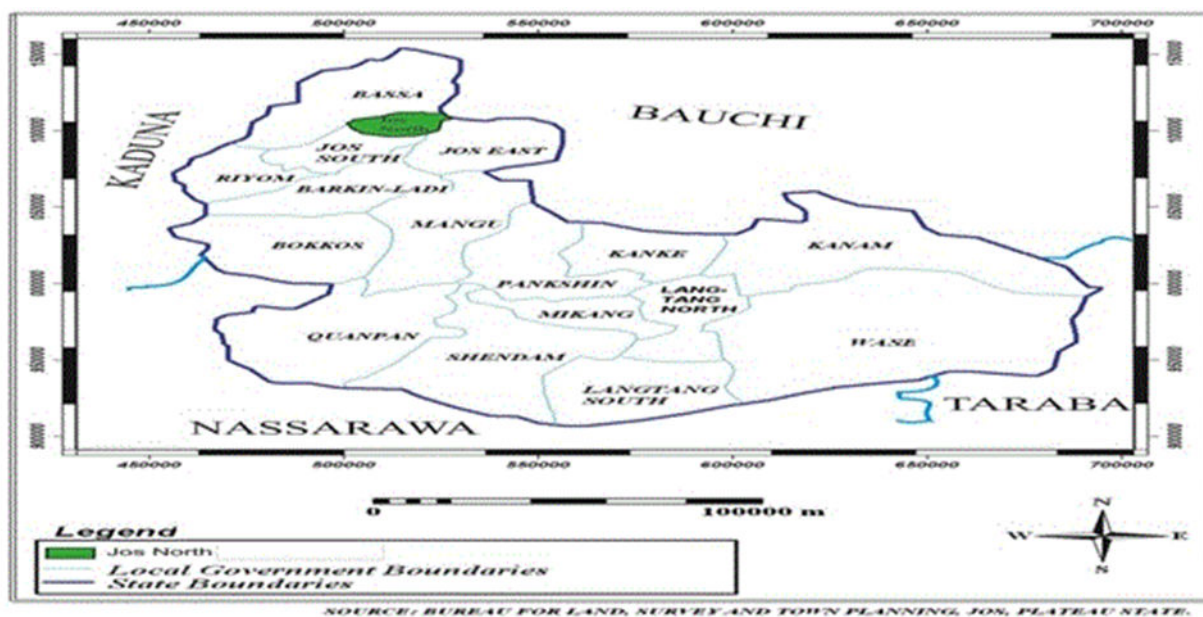


Figure 1: Map of Plateau State indicating Jos North.



Figure 2: Sampling point.



Figure 3: Transformers and the dug wells.

Sampling and sample preparation

The samples were collected in August 2017 at various locations of transformers in different site within Jos north metropolis. Soils samples were collected within Jos north metropolis. Soils sample were collected within 10-15 cm using splade that has been thoroughly

washed rinsed with distilled water into aluminum foil, sealed, labeled and placed in an ice chest cooler while the water samples were collected from dung well into pre-washed amber glass bottle preserved with 1 ml concentrated HCl bottled, sealed and put into an ice chest cooler and transported to Plateau state University Chemistry

laboratory for further treatment. At the laboratory 10 g on the soil sample was mixed thoroughly with anhydrous sodium sulphate, this was then 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 [15]. For water samples 200 ml was extracted with 10 ml of dichloromethane in separating funnel (EPA 3510) both extracts were cleaned using column chromatography and the extracts of both soil and water samples were identified and quantified using Agilent 7890 AGC coupled with 5975 MSD (Tables 1 and 2).

Results and Discussion

Table 1 and Figure 4 summarized the analytical results PCBs identified and qualified in soil with the ages of the transformers sites

SITE/CONGENER	AGE (YRS)	C ₁₈	C ₂₀	C ₂₈	C ₂₉	C ₄₄	C ₅₂	C ₁₀₁	C ₁₀₅	C ₁₁₈	C ₁₃₇	C ₁₄₂	C ₁₅₃	C ₁₇₀	C ₁₈₀	C ₁₉₄
1	20	0.01	0.47	0.37	0.37	0.34	5.84	0.89	0.36	BDL	1.79	0.55	1.20	1.59	0.47	BDL
2	5	BDL	BDL	BDL	BDL	BDL	0.09	0.38	0.17	0.00	BDL	BDL	BDL	BDL	BDL	BDL
3	9	0.00	0.39	0.34	0.34	0.22	1.16	0.47	0.18	0.00	0.53	0.31	0.53	BDL	BDL	0.00
4	40	BDL	0.27	0.28	0.28	0.17	0.25	0.43	0.17	0.00	BDL	BDL	BDL	BDL	BDL	BDL
5	3	BDL	BDL	BDL	BDL	BDL	BDL	0.38	BDL	BDL	0.45	BDL	BDL	BDL	BDL	BDL
6	25	0.05	0.86	0.39	0.39	0.54	3.86	0.55	0.21	0.00	1.21	0.45	0.78	0.19	BDL	BDL
7	7	BDL	BDL	BDL	BDL	0.15	BDL	0.54	0.26	0.00	BDL	BDL	BDL	BDL	BDL	0.00
8	2	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
9	9	0.00	0.35	0.33	0.33	0.29	3.07	1.46	0.17	0.00	0.93	0.32	0.49	0.15	0.00	0.32
10	12	0.00	0.70	0.29	0.29	0.33	1.64	0.44	0.17	0.00	0.45	0.31	0.43	BDL	BDL	BDL
11	12	0.02	0.34	0.33	0.33	0.39	0.21	0.81	0.17	0.00	0.48	BDL	BDL	BDL	BDL	BDL
12	7	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
13	15	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
14	5	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.37	BDL	BDL	BDL
15	20	0.00	0.54	0.29	0.29	0.33	0.11	0.77	0.18	0.00	0.64	0.00	0.62	0.16	0.00	0.00
16	11	0.00	0.41	0.38	0.38	0.17	0.39	0.61	0.17	0.00	0.45	BDL	0.41	BDL	BDL	0.00
17	30	0.00	0.38	0.37	0.37	0.24	1.17	1.11	0.18	0.51	0.45	BDL	0.41	BDL	BDL	BDL
18	15	BDL	0.30	0.28	0.28	0.16	0.56	0.43	0.18	0.00	0.49	BDL	0.41	BDL	BDL	BDL
19	25	0.00	0.31	0.33	0.33	0.38	0.36	0.79	0.18	0.00	1.41	0.00	0.51	0.23	0.00	0.00
20	25	0.00	0.35	0.30	0.30	0.21	1.64	0.85	0.17	0.03	0.47	BDL	0.44	0.15	BDL	BDL

Note: BDL=Below the detection limit. 1=Gageri PHCN, 2=Gageri Behind Investment House, 3=Gageri Sale Hassan House, 4=Old campus Unijos, 5=Delimi Junction by CSC Church, 6=Hayeni Delimi, 7=Alasari8=Yakasuwa Rikkos, 9=NDLEA Rikkos, 10=Rikkos 2, 11=Yashanu Yareke, 12=AladeDelimi 13=Alade Delimi 2, 14=Sarki Street B, 15=Sarki Street A, 16=Suzuki Bauchi Rd17=Adebanyo Street, 18=Midwave Ajayi Street, 19=Zaria Bypass Jamil Motors and 20=Zaria Bypass Peace motor park. C₁₈=2,2,5-Trichlorobiphenyl C₂₀=2,3,3-Trichlorobiphenyl C₂₈=2,4,4-Trichlorobiphenyl, C₂₉=2,4,5-Trichlorobiphenyl, C₄₄=2,2,3,5-Tetrachlorobiphenyl, C₅₂=2,2,5,5-Tetrachlorobiphenyl C₁₀₁=2,2,4,5,5-Pentachlorobiphenyl, C₁₀₅=2,3,3,4,4-Pentachlorobiphenyl, C₁₁₈=2,3,4,4,5-Pentachlorobiphenyl, C₁₃₇=2,2,3,4,4,5-Hexachlorobiphenyl, C₁₄₂=2,2,3,4,5,6-Hexachlorobiphenyl, C₁₅₃=2,2,4,4,5,5-Hexachlorobiphenyl, C₁₇₀=2,2,3,3,4,4,5-Heptachlorobiphenyl, C₁₈₀=2,2,3,4,4,5,5-Heptachlorobiphenyl, C₁₉₄=2,2,3,3,4,4,5,5-Octachlorobiphenyl.

Table 1: Concentrations of various PCBs in soil (Mg/Kg).

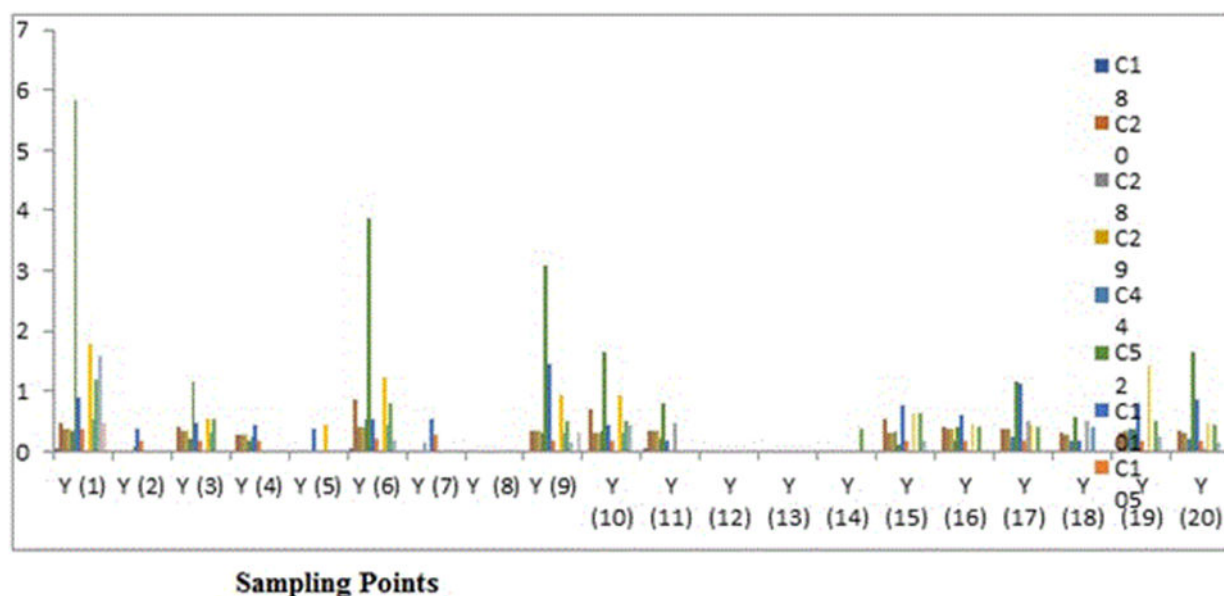


Figure 4: Comparison of Various PCBS Identified in Various Samples of Soil.

Table 2 and Figure 5 shows the results of PCBs quantification in water (dug) well located within the transformer site, but most of the sampling site show that the concentration of these congeners studies were really below instrument detection limit, only congeners C₂₀ at sampling site 4 which is 0.27 ppm, C₂₈/C₂₉ is 0.28 ppm, C₄₄ (0.16 ppm) C₁₀₁ (0.3 ppm) which is higher than Alberta standard for PCBs in

ground water (0.0094 ppm) AENV [4,15]. Table 2 also shows transformer at site 4 has more of these congeners and also older in age compare with others which may suggest as older in years of installation there is tendency of ground water pollution as a result of leakages of the oils from transformers.

Site/Congeners	Age (YRS)	C ₁₈	C ₂₀	C ₂₈	C ₂₉	C ₄₄	C ₅₂	C ₁₀₁	C ₁₀₅	C ₁₁₈	C ₁₃₇	C ₁₄₂	C ₁₅₃	C ₁₇₀	C ₁₈₀	C ₁₉₄
1	20	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
3	9	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
4	40	0.00	0.27	0.28	0.28	0.16	BDL	0.37	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
6	25	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.48	0.00	BDL	BDL	0.57	BDL	BDL	BDL
7	7	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
11	12	BDL	BDL	BDL	BDL	BDL	BDL	0.17	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
12	7	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
13	7	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
14	5	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
15	20	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL

Note: BDL=Below the detection limit. 1=Gageri PHCN, 3=Gageri Sale Hassan House, 4=Old campus Unijos, 6=Hayeni Delimi, 7=Alasari, 11=Yashanu Yareke, 12=AladeDelimi 13=Alade Delimi 2, 14=Sarki Street B, 15=Sarki Street A.

Table 2: Concentration of PCBs in water samples (ppm).

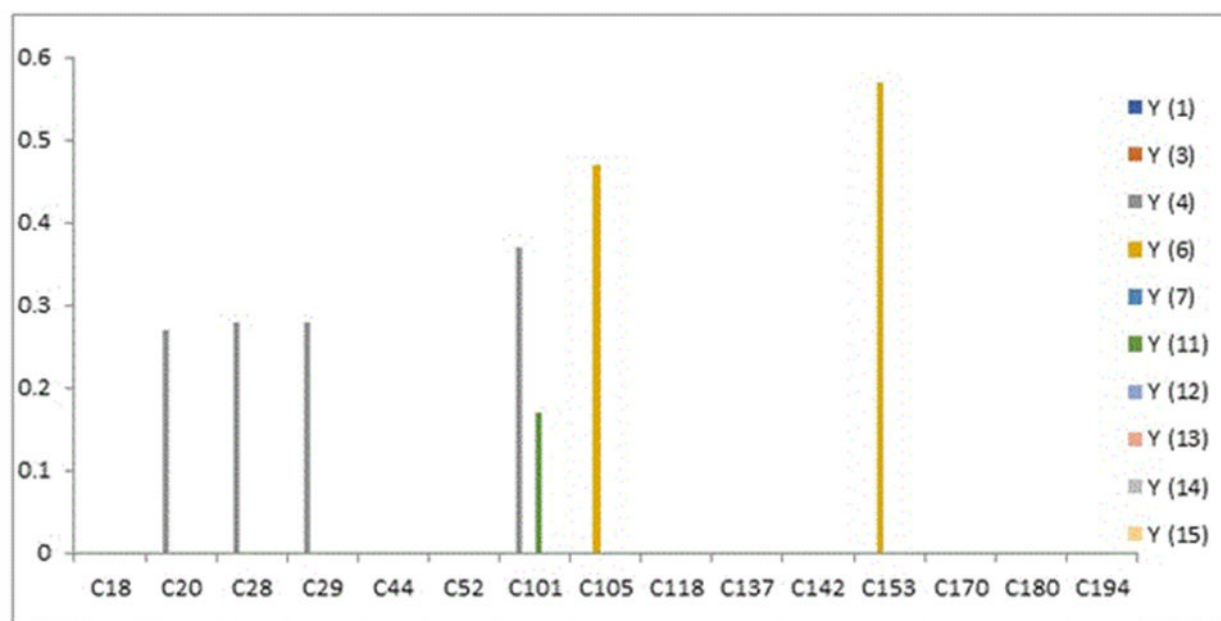


Figure 5: Comparison of Concentration of PCBs in various water samples.

From Figure 2. C₄₄, C₅₂, C₁₁₈, C₁₃₇, C₁₄₂, C₁₇₀, C₁₈₀ and C₁₉₄ were not detected in the water sample at any of the site. This study agreed with finding of Adeyi et al. [2] who found the concentration of PCBs in old transformer site in Lagos to be higher than the Alberta standard for ground water but for that of soil they also discovered the PCBs in soil is lower than the Alberta standard for industrial soil [2].

From Table 1 the concentration in the PCBs congeners ranges from 0.00-5.87 mg/kg which is similar with the result gotten by Klanora et al. [17] in Ross Island with concentration of PCBs, ranges from 0.32-0.83 mg/kg, in their work they also identified and quantified congeners PCB₂₈, PCB₅₈, PCB₁₀₁, PCB₁₁₈, PCB₁₅₃, PCB₁₃₈, and PCB₁₈₀, which agreed with this study except for the additional PCB₂₀, PCB₂₉, PCB₄₄, PCB₁₀₅, PCB₁₃₇, PCB₁₄₂, PCB₁₇₀, and PCB₁₉₄, that were identified and quantified in the soil sample.

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