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Determination of Polychlorinated Biphenyls (PCBS) using Gas Chromatography Electron Capture Detector in Dust from Schools in Okitipupa, Ondo State, Nigeria

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Abstract
The presence of polychlorinated biphenyls (PCBs) in dust, and subsequent exposure to humans via unintentional ingestion, inhalation, or skin contact, has serious health repercussions due to their toxicity profiles. There is a lack of knowledge concerning the concentration of PCBs in the dust/atmosphere. The quantities of seven (7) polychlorinated biphenyls (PCBs) in outdoor dust were measured at five different locations across southern Ondo State, Nigeria. The study's purpose was to provide data on the distribution of polychlorinated biphenyls (PCBs) in air dusts and to assess the influence of metrological parameters on PCB dust concentration. The PCB content was evaluated with a gas chromatography-electron capture detector (GC-ECD). PCB values varied from 1.51–32.52 µg/kg. Six (6) PCBs were below the detection limit in five separate sites. The total content of polychlorinated biphenyls (PCBs) in air dust displayed a negative (-0.614) and strong connection with wind speed, a positive (0.023) and bad correlation with temperature, and a positive (0.485) but poor association with relative humidity. In conclusion, the level of atmospheric PCBS has no significant effect on meteorological parameters. The EPA's health-based screening standard for total PCBs is 0.22 µg g¹, which aim to prevent deleterious effects from long-term exposure.

Keywords; Dust particle, polychlorinated biphenyls, outdoor, meteorological parameters.

INTRODUCTION
Pollutants, such as PCBs, represent significant health concerns in indoor environments (Pironti *et al.,* 2022; Motta, *et.al,* 2022; Ricciardi *et al.,* 2022). People often spend more than 90% of their time indoors, between their homes and jobs. For many years, PCBs have been widely used in the manufacture of materials and/or objects commonly found in indoor environments, such as building materials, sealing and caulking materials, fluorescent lighting fixtures, electrical equipment, plasticizers, surface coatings, paints and ink (ATSDR 2000; Kohler *et al.* 2005; Anh *et.al.* 2021). As a result, they could still be released into the indoor

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environment, absorbed as indoor dust, and bioaccumulated by humans through non-dietary intake and inhalation pathways. Indoor PCB inhalation is a cause for concern in schools and other buildings (e.g., offices) built and renovated between the 1950s and the late 1970s, as demonstrated by several studies in the United States and Europe (Herrick *et. Al.*, 2004; Herrick, 2010; Audy *et al.*, 2018; Marek *et al.*, 2017). Dust is a diverse collection of particulate matter that serves as a sink for both inorganic and organic contaminants (Chakraborty *et al.*, 2016; Ediagbonya *et al.*, 2014). The presence of polychlorinated biphenyls (PCBs) in indoor dusts, and their subsequent exposure to humans via unintentional ingestion, inhalation, or skin contact, has major health consequences given their toxicity profiles and the amount of time individuals spend each day indoors. PCBs are a class of non-polar hazardous chemical compounds made up to 209 congeners (Adeyemi *et al.*, 2009), with only around 130 (di- to deca-PCBs) present in commercial combinations. They are water-soluble organic compounds with 1-10 chlorine atoms bonded to biphenyl, a molecule composed of two benzene rings with a chemical formula of $C_{12}H_{10}$-xClx, (where x = 1-10). The Stockholm Convention has classed PCBs as persistent organic pollutants (Li *et al.*, 2011; Iwegbue, 2016) due to documented evidence of their ubiquitous nature resulting from photostability (Barreca *et al.*, 2014) and long-range transportation and deposition capabilities. Furthermore, these chemicals in general tend to bioaccumulate, resulting in reproductive and developmental dysfunctions, as well as other health issues (Nouira *et al.*, 2013; Iwegbue 2016; Ediagbonya *et al.*,2022). Human exposure to PCBs is linked to an increased risk of childhood leukaemia, low birth weight, and cognitive impairments (Turyk *et al.*, 2009; Knobeloch *et al.*, 2012) and has resulted in international prohibitions, or restrictions on the use of certain substances. However, PBDEs and PCBs continue to be present in the environment due to their widespread use and legacy sources, such as leftovers from past use (Batang *et al.*, 2016) and outdated electrical and electronic equipment. Developing countries, such as Nigeria, are considered particularly vulnerable to hazards associated with electrical and electronic equipment components because the maintenance, repair, and upgrade of these items is primarily handled by the informal sector, which rarely follows any safety procedures when handling hazardous wastes (Iwegbue *et al.*, 2018). Approximately 55,000 (46%) public and private schools in the United States were built during the time when PCBs were supplied for open system use (Moglia *et al.*, 2006). According to Schwenk *et al.* (2002), the volatilization of PCBs from construction materials can result in levels of up to 20 μg/m³ in outdoor air, which is four orders of magnitude higher than ambient values. Outdoor air PCB concentrations at some schools have been found to surpass the US Environmental Protection Agency's (EPA) health-protective guidelines. The purpose of this study was to measure the concentration of polychlorinated biphenyls in the atmospheric dust in five distinct places, as well as the metrological characteristics in Okitipupa, Ondo State.

MATERIALS AND METHODS

Study Area

The samples for this investigation were gathered from schools in Okitipupa (longitude 4°43′E and latitude 6°33′N), Southwest Nigeria. Okitipupa is a Local Government Area in Nigeria's Ondo State, where the Ikale language is spoken. According to a 2016 estimate, the population of Okitipupa local government is 316,100. The residents of the town are primarily farmers. The main crops are oil palm, rubber, and cassava. There is also extensive cultivation of yams, beans, okra, pepper, melon, and vegetables. The town contains a few enterprises, including Okitipupa Oil Palm Plc and Oluwa Glass Factory. Okitipupa serves as the commercial and social hub for Ondo's southern region. The town has been experiencing power outages for almost ten years. Many businesses and residences today rely heavily on diesel and premium

motor spirit for their energy requirements. Exhaust emissions from automobiles and generators have become the primary source of PCBs. Figure 1 depicts a map of the study region with sampling locations indicated, and Table 1 lists the sampling coordinates.

Table 1: **Coordinates of the various Sampling Points**

Locations	Latitudes	Longitudes.
Sample A: PCBs in Oaustech main campus (dust sample).	6.45951262 N	4.76192726E
Sample B: PCBs in Igodan lisa high school (dust sample).	6.44054947 N	4.77310896E
Sample C: PCBs in Igodanlisa primary school (dust sample).	6.45533621 N	4.77300838 E
Sample D: PCBs at number 18, Lafijo street Ayeka (dust sample).	6.48865333N	4.79053197 E
Sample E: PCBs in Oaustech Mega campus (dust sample).	6.49027667N	4.78940500E

Sample Collection

In total, fifteen (15) dust samples were collected. These included three samples from Oaustech's main campus, three from Igodan Secondary School, three from Igodan Primary School, three from 18, Lafijo Street, Ayeka, and three from the Oaustech Mega Campus in Ayeka. Dust samples were taken in February to April 2022 from these schools in Okitipupa, Southwest Nigeria. The dust samples were gathered using a brush and dustpan, which included gently sweeping dust deposits off the floor into the dustpan using the brush. To avoid contamination, the brush and dustpan were thoroughly cleaned with acetone after each sample collection. Dust samples were wrapped in foil paper, placed in polyethylene bags, and sent to the laboratory in an ice chest. The samples were filtered through a 65 µm mesh screen and kept in a refrigerator at 4°C before extraction and chromatographic analysis (Iwegbue *et al.*, 2017; Iwegbue *et al.*, 2018).

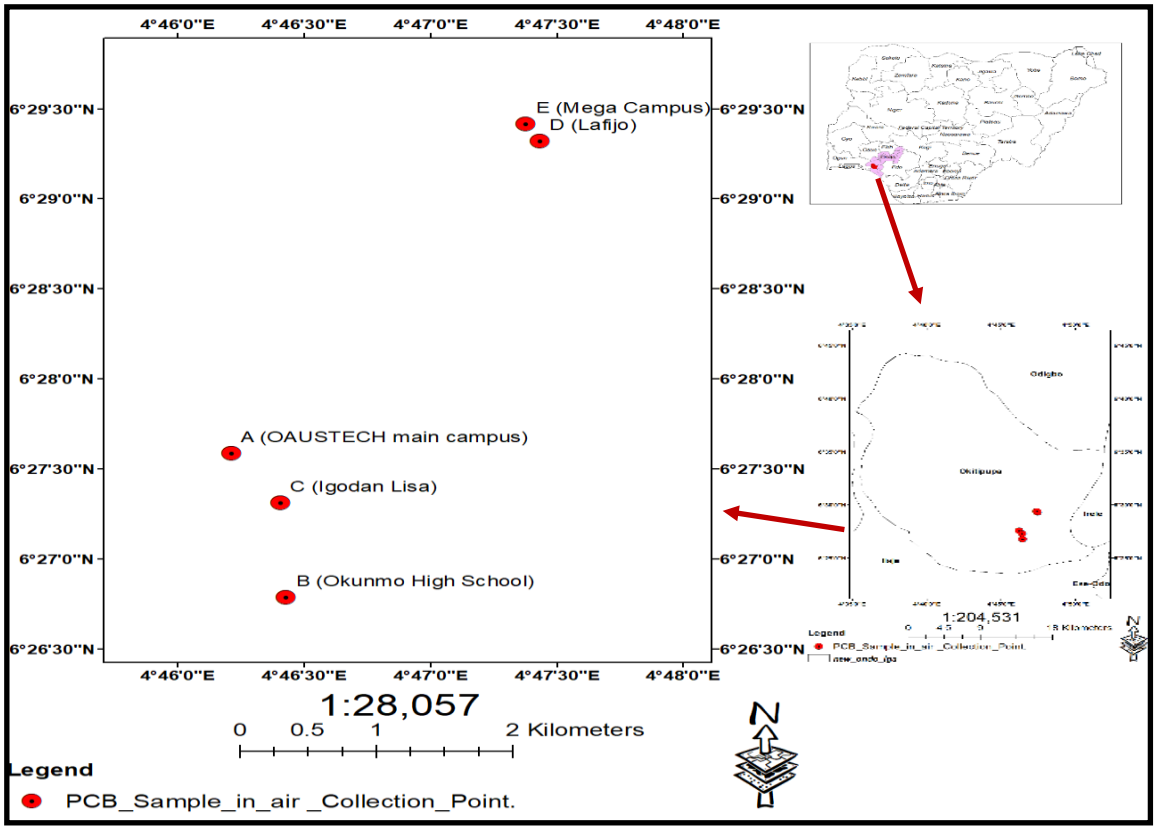

Figure 1: Map of the study area

Clean Up

PCBs were analysed using a previously developed method by Chu *et al.* (1996). Aliquots of 50mL per 5 g of material (dust) were crushed into a dry homogenate using 5 g of anhydrous sodium sulphate. Biota samples were saponified using an ethanoic potassium hydroxide solution (Baumard *et al.,* 1998). An internal standard was applied, and PCBs were extracted from the samples using ultrasonic extraction in 50 mL hexane/acetone (1:1 v/v). The extract was concentrated to roughly 3 mL using a rotary evaporator. To clean up, agitate the sample solution with concentrated H_2SO_4 in a test tube. After centrifugation, the acid layer was removed. This procedure was done numerous times until the hexane layer was dried with anhydrous sodium sulphate and concentrated to about 1 mL for column chromatography clean-up. The concentrations of seven PCB congeners were tested using an Agilent 7820A GC-ECD. The recovery rate of PCB congeners ranged from 87% to 100%.

INSTRUMENTAL ANALYSIS

PCB detection and quantification were carried out using an Agilent 6890 series gas chromatograph with a 63Ni ECD and a split/splitless injector. The PCB congeners were separated using a 30 m Agilent Technologies fused silica capillary column (0.25 mm I.D.; film thickness 0.25µm) containing 5% diphenylpolysiloxane and 95% dimethylpolysiloxane. The oven temperature was initially set at 60°C, kept for 1 minute, then increased to 180°C at a pace of 30°C/min, then to 200°C at a rate of 2.5°C/min, and finally to 270°C at a rate of 7°C/min. The injector and detector had temperatures of 280°C and 300°C, respectively. Splitless mode injection was implemented. PCB established the elution order of congeners as 18, 44, 28, 170,156,185, and 195 (internal injection standard).

Quality Control

Analytical quality control involved strictly adhering to written processes, laboratory standard operating procedures, and calibrating analytical instruments. The GC-ECD was calibrated with high-quality analytical standards from the United States Environmental Protection Agency (USEPA). Standards were conducted to determine concentrations, physicochemical characteristics, pH, resolution, and detection limit.

RESULTS AND DISCUSSION

Table 2: Mean Concentration of Polychlorinated biphenyls (PCBs) (µg/g) in Outdoor dust in different locations.

	OAUSTECH outdoor sample	Mega Campus Ayeka outdoor Sample	Igodan secondary School outdoor sample	18, Lafijo street Ayeka (outdoor)	Igodan primary school outdoor	P
PCB 44	0.41±0.00	22.40±0.02	0.35±0.00	BDL	0.33±0.00	<0.001
PCB 18	BDL	1.90±0.00	0.12±0.00	BDL	0.24±0.00	<0.001
PCB28	0.42±0.00	2.66±0.01	0.63±0.00	1.12±0.02	0.70±0.02	<0.001
PCB170	0.69±0.00	BDL	1.87±0.00	BDL	0.43±0.00	<0.001
PCB156	BDL	5.57±0.00	1.40±0.00	5.57±0.01	0.75±0.02	<0.001
PCB185	BDL	BDL	0.30±0.03	BDL	BDL	NC
PCB195	BDL	BDL	0.44±0.00	1.23±0.00	BDL	<0.001
Total PCBs	1.51±0.00	32.52±0.04	5.11±0.04	7.92±0.02	2.44±0.03	<0.001

P is the level of significance; BDL is below detection limit

Table 2 compares the mean of PCBs from OAUSTECH, mega campus (Ayeka, Igodan Secondary and Primary School, and 18, Lafijo Street outdoor samples). PCBs are usually broken down in the atmosphere by sunshine or microorganisms. PCBs are dangerous

compounds due to their persistence, hydrophobicity, and toxic characteristics (ATSDR 2000). PCBs enter the air by evaporation from soil and water. PCBs in the air can deposit on land when it rains or snows, or when they adhere to particle matter like dust or soot that settles on the ground. PCBs contained in the atmosphere react with ozone and water when exposed to sunlight. The reactions, among other things, result in the removal of chlorine atoms. The more chlorine atoms there are, the longer the process takes. For compounds with 1 to 5 chlorine atoms, it takes between 3.5 and 83 days to break down half of the initial amount of PCBs. A decrease in the ambient concentration of PCBs should result in a drop in PCB content in both solid and household waste (Iwegbue *et al*. 2018; 2016).

Table 2 shows the findings of determining 7 PCBs in dust samples collected from schools. The PCB values in all samples ranged from 1.51±0.00 to 32.52±0.04 ng/kg. Table **2** shows that PCB 44 was highest in Mega Campus Ayeka dust (22.40±0.02) and lowest in Igodan Primary School dust (0.33±0.00). There was no record of PCB 44 in 18, Lafijo Street Ayeka dust. PCB 18 was not found in the dust at Oaustech's main campus or on Lafijo Street in Ayeka. PCB28 levels were highest in the Mega campus Ayeka dust (2.66±0.01) and lowest in the Oaustech main campus dust (0.42±0.00). PCB170 was not detected in Mega Campus Ayeka Dust or 18 Lafijo Street Ayeka Dust. PCB 156 was found in all dust samples except for Oaustech's main campus dust. PCB 185 was only found in Igodan Secondary School dust. PCB 195 was only found in Igodan Secondary School dust and 18 Lafijo Street Ayeka dust, but PCBs overall had the highest value in Mega Campus Ayeka dust and the lowest in Oaustech Main Campus dust. Statistically significant variances were observed for PCB44, PCB18, PCB28, PCB170, PCB156, PCB195, and total PCBs, showing significant spatial variation.

Table 3: Mean concentration of (PCBs) (µg/g)) in this and other studies

Location	Sample Site	Mean Concentration (µg/g)	References
Igodan	Oaustech main campus.	1.51±0.00	This Study
Ayeka	Mega campus Ayeka.	32.52±0.04	This Study
Igodan	Igodan secondary school.	5.11±0.04	This Study
Ayeka	28, Lafijo street.	7.92±0.02	This Study
Igodan	Igodan primary school.	2.44±0.03	This Study
Guangzhou	Outdoor dust	0.004–0.22	Wang *et al.* (2013)
Hong Kong	Outdoor dust	0.007–0.11	Wang *et al.* (2013)
Singapore	Home	5.6	Tan, *et al.* (2007)
Vietnam	Home	11–1900	Anh, *et al.* (2020)
Raipur	Road dust	241 - 246	Yogita, *et al.* (2008)
Czech Republic	Home dust	0.01–0.35	Audy, *et al.* (2018)
Abraka and Warri	Office dust	96.6–3949	Iwegbue *et al.*,2018
Texas	Home dust	47–620	Harrad, *et al.*,2009

Table 3 shows a comparison of PCB contamination at various areas around the world. With regard to the total concentrations of PCBs in the dust reported in other locations: Guangzhou and Hong Kong, Singapore, Raipur, Czech republic, Abraka/Warri and Texas (Wang *et al*., 2013; Tan *et al*., 2007; Anh *et al*., 2019 and 2020; Yogita *et al*., 2008; Audy *et al*., 2018; Iwegbue *et al*., 2018 and Harrad *et al*., 2009) ranged from 0.004 to 0.22, from 0.007 to 0.11, from 5.6, from 11 to 1900, from 241 to 246, from 0.01 to 0.35, from 96.6 to 3949. A recent study (Iwegbue *et al*., 2018) on the distribution and content of PCBs in electronic repair industry dust in Nigeria reported PCB concentrations from 96.6 to 3949 µg/g, with a mean of 1234 µg/g. Hexa-PCBs were found to be the most frequent, with a high estimated hazard index and cancer risk linked with human exposure. Efforts to regulate e-waste include source control, limiting illicit imports, collecting and transporting e-waste, and controlling processes. Environmental

remediation methods for polluted places should be performed to reduce the health risks to workers and the local community.

Table 4. Pearson correlation coefficients for the relationship between the PCB homologs.

	triPCB	tetraPCB	HexaPCB	HeptaPCB	OctaPCB
TriPCB	1	.993**	.625*	0.857	.999**
TetraPCB	.993**	1	.992**	0.954	0.771
HexaPCB	.625*	.992**	1	-0.327	1.000**
HeptaPCB	0.857	0.954	-0.327	1	0.545
OctaPCB	.999**	0.771	1.000**	0.545	1

∗ *Correlation is significant at the 0.05 level (2-tailed).* ∗∗ *Correlation is significant at the 0.01 level (2-tailed).*

Values from Table 4 show that, greater tri-PCB levels will result in increased tetra-PCBs, and vice versa. However, HexaPCB had no statistically significant connection with triPCB or tetraPCBs. Trii-PCBs, tetra-PCBs, hexa-PCBs, as well as hepta-PCB and octa-PCB, were the most common PCBs found in dust from all five locations. The PCB homologues had the following composition: hexa-PCBs, tri-PCBs, tetra-PCBs, hepta-PCBs, and octa-PCBs. Wang et al. (2013) found a similar distribution trend in indoor dust from China. Hexa-PCBs (23.8-945 μg/g) are the most common PCB homologues in electronic repair workshop dust, accounting for 7.9–61.8% of Σ28 PCB concentrations.

Table 5. Correlation coefficient of wind speed (m/s), temperature (°C), relative humidity with total PCBs.

	Wind Speed(m/s)	Temperature(°C)	Relative Humidity	Total PCBs
Wind Speed(m/s)	1	.589*	-.662**	-.614*
Temperature(°C)	.589*	1	-.721**	0.023
Relative Humidity	-.662**	-.721**	1	0.485
Total PCBs	-.614*	0.023	0.485	1

∗ *Correlation is significant at the 0.05 level (2-tailed).*∗∗ *Correlation is significant at the 0.01 level (2-tailed).*

Wind speed, temperature, and relative humidity all have an impact on PCBs in the air/dust. These serve as the foundation for the distribution and movement of PCBs in the air surrounding the affected area. Table 5 shows the results of a correlation analysis conducted to evaluate the link between total PCB concentrations and relative humidity. The total concentration of polychlorinated biphenyls (PCBs) in air dusts was negatively correlated (-0.614) with wind speed, positively correlated (0.023) with temperature, and positively correlated (0.485) with relative humidity. There are some controversial observations regarding the impact of wind speed on ∑PCB air concentrations. A theoretical model suggests that increasing wind speed will produce PCB volatilization by increasing mass transfer at the air/water interface (Ediagbonya *et al.*,2014). In contrast, it has been proposed that increasing wind speed promotes greater atmospheric mixing (Arya, 1988), resulting in dilution of atmospheric concentrations (Haugen *et al.,* 1999). Field tests at the coastal station of Lista (Norway) revealed that PCB concentrations declined significantly as wind speed increased (Haugen *et al.*, 1999), indicating that PCBs are diluted at greater wind speeds. During periods of intense atmospheric turbulence induced by high wind speeds, the link between atmospheric concentration and temperature may fail.

PCBs have been shown to induce a wide range of negative health impacts. They have been found to induce cancer in animals, as well as a variety of harmful non-cancer health impacts,

such as effects on the immune system, reproductive system, neurological system, endocrine system, and others. Human studies provide evidence for the potential carcinogenic and non-carcinogenic effects of PCBs. The various health consequences of PCBs may be connected. Changes in one system might have far-reaching consequences for the rest of the body. The presence of polychlorinated biphenyls (PCBs) in dust, and subsequent exposure to humans via unintentional ingestion, inhalation, or skin contact, has serious health repercussions due to their toxicity profiles. There is a lack of knowledge regarding the level of PCBs in the atmosphere.

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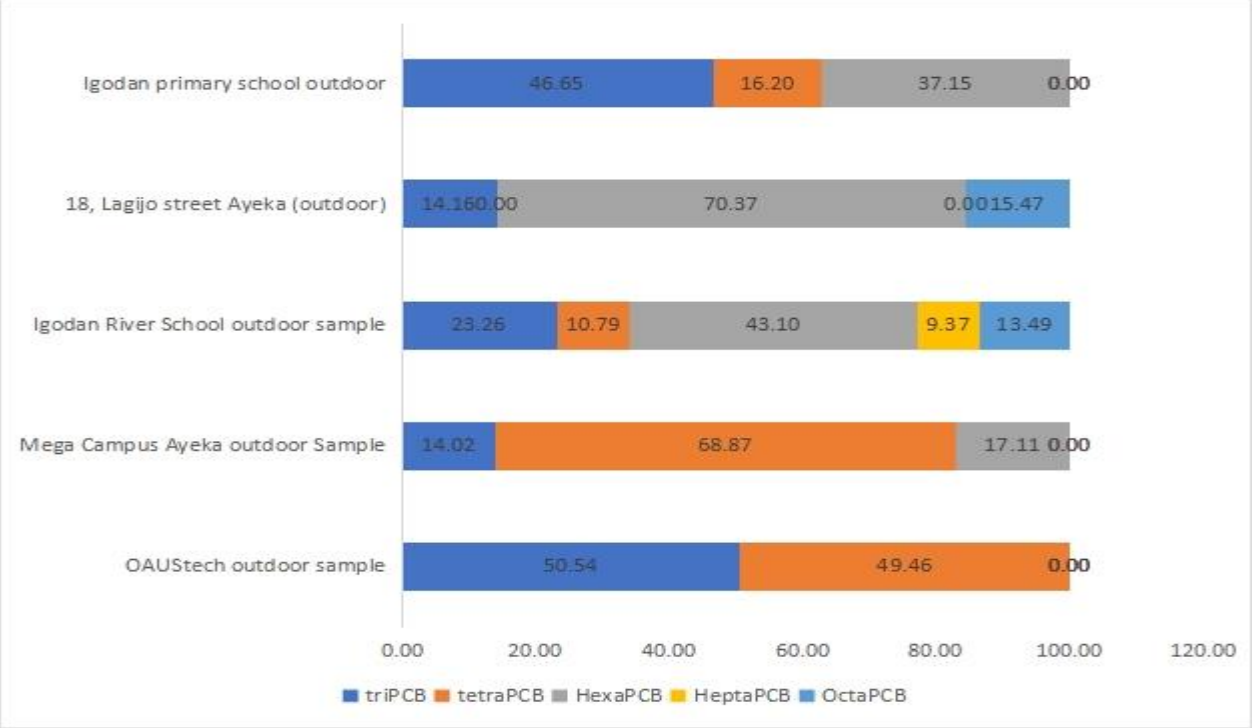

Figure 2: Distribution of the PCB homologs in Outdoor Samples.

Other publications have employed PCB distribution patterns to characterise the homologous profile of PCB congeners (Iwegbue *et al*., 2020; Iwegbue 2016; Li *et al*., 2007). PCB homologue dispersion pattern in dust. Figure 2 shows that the highest concentration of ∑-Tri-PCBs (50.54%) was found in Oaustech outdoor samples, followed by Tetra-PCBs (68.87%) in Mega campus Ayeka, hexa-PCBs (70.37%) in 18, Lafijo street sample, and octa-PCBs (0.0015.47%) and hepta-PCBs (9.37%) in Igodan secondary school. This is due to the extensive usage of tri-PCBs in electrical appliances (Zhang *et al.,* 2014). Decades of industrial production of polychlorinated biphenyls (PCBs) and inappropriate disposal have resulted in contamination in many places. Because of their widespread and uncontrolled usage in industry, PCBs have become ubiquitous pollutants around the world (Brázová *et al*., 2012).

CONCLUSION

PCB concentrations in dust samples collected from five (5) separate school locations in Ondo South, Nigeria. In all the sampling sites chosen for this study, Mega campus dust had the highest PCB concentration levels due to waste dumped in the environment, exhaust from generators, and the burning of charcoal and wood for domestic use, while Oaustech main campus dust had the lowest PCB concentration levels due to less activity. In comparison to prior studies, PCBs in dust were found to be significantly higher in Raipur (China) than in the other study locations, owing to increased industrial activity, exhaust from cars, and generators. The level of atmospheric PCBS has no significant impact on meteorological

parameters. Negative correlation values were found between wind speed, temperature, and relative humidity, indicating that the dust is different.

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