Characterization of polychlorinated biphenyls (PCBs) in indoor dusts from electricity power stations in Lagos, Nigeria

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Introduction

The term polychlorinated biphenyls (PCBs) refers to a class of synthetic organic chemicals that have been widely used as additives to oils in electrical equipment and other applications where chemical stability is required for safety, operation or durability [13]. PCBs possess advantages such as non-flammability, inertness, high dielectric strength and high heat resistance. Their primary applications are found in insulating materials for fire resistance including facilities which use, store, and service electrical equipment and which use huge amounts of electricity such as electrical transmission and distribution facilities; electrical equipment maintenance - transformers and capacitors in electricity power generation and transmission stations. Past use of PCBs with their advantage of chemical stability in transformer oil has created severe environmental and health problems which have translated into extreme persistence when they are released into the environment. Environmental and health concerns have been associated with the persistence and bioaccumulation of PCBs and their metabolites due to their serious adverse health impacts, such as disruption of the endocrine system and carcinogenicity [4].

In Nigeria, PCBs remain in use even after the introduction of bans on the production and use of these chemicals worldwide. However, even though production of new PCBs has ceased, these chemicals are still contained in many industrial applications particularly old power generation stations which used transformer oil containing PCBs prior to the ban and also through past practices involving poor handling and testing procedures [10]. There is also likelihood that some of this oil which might have become contaminated before PCB hazards were recognized might still be used in some facilities. In countries where there has been strict compliance on the current regulation of PCBs, it has been found that some locations in certain cases exceeded regulatory assessment criteria [5, 13]. Sources of PCB contamination could originate from abandoned or illegal landfills and electronic waste yards and leaks or explosions of electrical equipment and other equipment (such as locomotive transformers) that may still contain PCBs. PCBs are emitted to the environment via volatilization from contaminated materials as well as secondary reservoirs such as water and soil etc. [9].

This study conducts a baseline survey of the occurrence of PCBs in indoor dust within offices of electricity power generating and transmission stations in Lagos, Nigeria, to provide information on the concentrations of PCBs in such power stations and to compare the effect of seasonal variations on these parameters.

Materials and methods

A total of 48 indoor dust samples were collected from 2 offices in each of 12 power stations (6 power distribution, 5 power transmission, and 1 former power generation station within Lagos, Nigeria) in the months of June and December 2015. These months represent the two major seasons of the Nigerian climate i.e., the wet and dry seasons respectively. Indoor dust from surfaces was collected using a paintbrush, sieved with a 500 µm sieve and stored at – 20 °C. Samples were later transported to the University of Birmingham laboratory and were stored at 4 °C prior to analysis.

Analysis of dust samples for PCBs was conducted in accordance with previously published methodology [8]. In summary, 200 mg of dust was weighed into extraction tubes treated with internal standards prior to addition of extraction solvent. The mixture was vortexed for about 1 minute and then extracted in an ultrasonic bath for 15 minutes. The resulting clear extract was separated by centrifugation for 5 minutes at 3500 rpm. Extracts from 3 successive extractions of the same sample were combined and blown down to dryness under a gentle stream of nitrogen. During extract clean-up, dried extracts were reconstituted in 2 mL hexane and acidified with 2 mL conc. H_2SO_4, to eliminate lipids. Further clean up using florisil was conducted to remove interfering compounds. The cleaned extract was blown down to dryness and reconstituted with 150 µL recovery determination standard (PCBs 29 and 129).

Target PCBs were quantified using an Agilent 5975-C GC-MSD, fitted with a Restek RXi-PAH capillary column (40 m × 180 µm × 0.01 µm) using oven program, MS parameters, and ion selection method employed reported previously [8]. In our study, the target PCBs analysed were: PCBs 28, 52, 101, 118, 138, 153 and 180 that covered 5 homologous series (tri, tetra, penta, hexa, hepta). The individual congeners selected are the ICES-7 defined during the International Conference of the Environment of the Sea based on their prominence and persistence [15].

Standard reference material (SRM 2585, NIST organics in indoor dust) was used for method validation. As a measure of precision, 6 replicate analyses of target PCBs in SRM 2585, extracted and cleaned-up as described above, gave a RSD ranging from 4% for PCB 101 to 13% for PCB 52. Concentrations of target PCBs in the SRM aliquots analysed (Table 1) were comparable to the certified values. Recoveries of internal standards in SRM ranged from 72-109%. A method blank was analysed for every 12 samples. Results obtained were not corrected for blank concentrations since almost all the target PCBs were absent in the blank, and even where present, levels in the blanks were less than 5 % of the concentration found in the corresponding samples.

Table 1: Concentrations (ng/g) of Target PCBs in SRM 2585

Congener	SRM1	SRM2	SRM3	SRM4	SRM5	SRM6	Mean ± SD	Certified Concentration
PCB 28	18.1	16.1	16.2	18.2	19.5	18.1	17.7 ± 1.3	13.4 ± 0.5
PCB 52	19.2	17.4	15.6	16.4	15.5	13.1	16.2 ± 2.1	21.8 ± 1.9
PCB 101	33.8	35.1	35.8	33.0	34.0	32.3	34.0 ± 1.3	29.8 ± 2.3
PCB 118	31.9	31.8	34.1	27.3	28.0	29.0	30.4 ± 2.7	26.3 ± 1.7
PCB 153	40.1	36.0	38.2	35.6	37.1	40.7	37.9 ± 2.1	40.2 ± 1.8
PCB 138	25.0	27.1	32.0	29.9	29.3	30.1	28.9 ± 2.5	27.6 ± 2.1
PCB 180	18.6	21.4	21.8	23.6	21.9	21.7	21.5 ± 1.6	18.4 ± 3.2

Results and discussion

Table 2 shows the mean, median, maximum and minimum concentrations of the 7 indicator PCBs monitored in 48 office dust samples collected in the months of June and December 2015.

Table 2: Mean, median, minimum, and maximum concentrations (ng/g) of PCB congeners in office dusts

PCB Congener	December				June			
	Mean	**Median**	**Min**	**Max**	**Mean**	**Median**	**Min**	**Max**
28	24.63	12.36	<0.09	112.56	20.23	9.31	<0.09	109.67
52	28.55	13.15	<0.08	144.80	18.32	11.81	<0.08	68.50
101	40.67	4.33	<0.11	612.41	35.96	3.33	<0.11	294.70
118	34.63	5.01	0.61	342.94	41.44	4.13	0.42	390.30
153	67.28	10.59	1.84	739.65	79.31	7.25	<0.11	640.78
138	101.51	36.11	2.00	902.65	81.15	13.76	2.02	972.52
180	86.26	57.73	3.96	384.73	98.60	45.68	<0.08	500.95

A paired T-test comparing the concentrations of each of the 7 PCB congeners in all dust samples for the month of June and December revealed that concentrations of the 7 indicator PCBs studied were statistically indistinguishable between both months i.e., season does not exert a significant influence on concentrations of PCBs in dust samples in this study.

Table 3: Average ΣPCB_7 concentrations (ng/g) in dust samples in individual offices

Power station	office 1	office 2	Mean ΣPCB_7
A*	141.06	153.86	147.46
B**	155.31	81.72	118.52
C*	29.87	21.09	25.48
D*	107.29	127.74	117.52
E**	356.17	151.23	253.70
F*	172.47	128.79	150.63
G*	109.78	248.08	178.93
H**	1049.16	45.66	547.41
I***	2328.65	2155.01	2241.83
J**	450.08	775.77	612.92
K*	114.35	118.96	116.66
L**	21.26	59.06	40.16

* Power distribution Station. **Power Transmission Station ***Power Generation Station

It was hypothesized that levels of PCBs in the power stations should follow this trend; generation > transmission > distribution, since the voltage of transformers, numbers of transformers, and general power activities decrease in that order. From the results obtained, it was observed that the average concentrations of ΣPCB_7 in the 4 dust samples taken from the 2 offices in power station **I** (a former power generation station) exceeded substantially at 2241.8 ng/g those in the other facilities monitored. Such elevated concentrations were not unexpected, as these indoor dust samples were from the former turbine room of the old power generation station, which is currently used as a workshop for the repair of transformers. The power transmission stations followed, with a mean ΣPCB_7 concentration of 314.5 ng/g and finally the power distribution stations with an average ΣPCB_7 concentration of 122.8 ng/g. A power distribution station (**C**) displayed the lowest mean concentration of 25.5 ng/g, with the other power distribution stations **A**, **D**, **F** and **K** also displaying much lower concentrations (117-148 ng/g) than measured at facility I. For power transmission stations, concentrations at facilities **J**, **H** and **E** (254-613 ng/g) were substantially lower than at facility I, but exceeded those in the power distribution stations. It is noteworthy however, that the mean concentration at power transmission facility **B** was 119 ng/g and a much newer power transmission station **L** were the second lowest of the 12 facilities studied at 40 ng/g.

The PCB congener and homologue profile in dust samples from the 12 power stations were further investigated. The congener profile varied slightly moving from one power station to another but notably, PCB 180 gave the highest percentage concentration for 8 of the 12 stations, while at the other 4 stations (**F**, **H**, **I** and **L**), PCB 52, PCB 118, PCB 138 and PCB 28 respectively were the major congener. This profile indicated the presence of Arochlor 1260 and 1254 in the majority of the dust samples, with obviously more of 1260 [3].

Table 4: Congener and homologue pattern expressed as percentage (%) contribution of ΣPCB_7 in dust samples from each power station.

	A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**
Tri 28	5.8	16.7	27.9	7.9	20.8	14.5	2.9	1.0	3.0	9.5	4.9	21.5
Tetra 52	30.1	5.3	14.9	13.3	7.0	30.4	11.0	4.1	3.8	1.5	4.4	12.0
Penta 101	1.2	2.9	3.0	4.3	4.8	2.4	2.3	10.6	15.3	3.7	1.6	8.9
Penta 118	2.3	2.4	5.1	3.2	6.4	2.2	2.9	26.2	10.0	6.3	7.0	12.1
Σ Penta CB	3.5	5.3	8.1	7.5	11.3	4.6	5.2	36.8	25.3	10.0	8.6	21.0
Hexa 153	5.2	4.6	7.4	6.9	8.6	5.1	13.3	25.8	24.6	14.7	13.2	12.2
Hexa 138	16.4	10.4	13.6	24.7	19.2	18.3	33.1	18.4	28.0	20.1	29.2	16.8
Σ Hexa CB	21.6	15.1	21.1	31.6	27.8	23.3	46.4	44.2	52.6	34.7	42.4	29.0
Hepta 180	39.0	57.7	28.0	39.7	33.1	27.1	34.4	13.8	15.3	44.2	39.6	16.4
PCB Congener with highest concentration	**180**	**180**	**180**	**180**	**180**	**52**	**180**	**118**	**138**	**180**	**180**	**28**
PCB homologue with highest concentration	Hepta	Hepta	Hepta	Hepta	Hepta	Tetra	Hexa	Hexa	Hexa	Hepta	Hexa	Hexa

The homologue concentration profile in our dust samples further highlighted this, with the contribution to ΣPCB_7 being hepta > hexa > penta or hexa > hepta > penta in most samples especially those from those power stations (**E, G, H, I, J**) displaying the highest ΣPCB_7 concentrations (Table 3).

Table 5: Comparison of median concentrations (ng/g) of indicator PCBs in dust from this study with selected reports

Country [Ref.]	Micro environment	Sample (N)	PCB 28	PCB 52	PCB 101	PCB 138	PCB 153	PCB 180
Nigeria (This study)	Offices	48	16.3	12.5	3.8	8.9	24.9	51.7
Nigeria [8]	Offices	18	5.2	4.4	6.2	5.1	6.5	14
Nigeria [8]	Homes	12	3.8	4.1	2.7	6.0	5.8	10
Nigeria [8]	Cars	16	1.9	2.1	0.72	1.4	1.6	1.9
South Africa [1]	Offices	11	28.3	NA	NA	NA	136	812
South Africa [1]	E waste workshop	5	9	NA	NA	NA	NA	47
UK [2]	Homes	5	8.2	7.4	6.9	0.8	0.9	0.3
Kuwait [3]	Homes	15	NA	NA	<0.2	<0.2	<0.1	<0.2
Pakistan [3]	Homes	15	NA	NA	<0.2	<0.2	<0.1	0.4
Vietnam [12]	Homes near e waste	10	1.3	0.65	0.91	2.0	1.0	0.59
China [16]	Homes near e waste	13	NA	NA	634	462	415	120
US [7]	HOME	20	5.1	6.7	8.7	6.5	7.1	2.6
Canada [7]	HOME	10	7.3	7.2	8.8	9.5	9.9	6.8

NA- not applicable (Congeners were not analysed)

The concentrations of PCBs in Nigerian power station offices reported here exceed those reported in our previous study [8] of PCBs in dust from Nigerian cars, homes and offices. Worthy of note is that the congener profile in this study closely resembles that observed in previous studies of PCBs in dust from other African countries [1, 8]. This may imply that the PCB formulations in products used in African countries (Nigeria and South Africa) were those dominated by higher chlorinated congeners such as Aroclors 1254 and 1260 [6].

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