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DETERMINATION OF POLYCHLORINATED BIPHENYLS (PCBS) LEVELS IN THE SOIL AND WATER FROM ELECTRONIC WASTE DUMPSITE AT ALABA, LAGOS STATE, NIGERIA

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ABSTRACT

Polychlorinated biphenyls (PCBs) may occur in the environment at high levels capable of threating human health. PCB levels in the water and soil of electronic waste dumpsite in Alaba, Lagos was evaluated to capture the public health status. Six (6) samples comprised of three (3) water and soil samples were randomly collected. The soil and water samples were extracted using USEPA methods and analyzed with Gas Chromatography Electron Capture Detector (GC-ECD) for detection of PCBs. Results show that nineteen (19) PCBs congeners were present in both water and soil samples including PCB – 1, 5, 18, 31, 44, 52, 66, 87, 101, 110, 138, 141, 151, 153, 170, 180, 183, 187 and 206. PCB-1 was highest (2.28 ± 1.85 µg/L) and PCB-206 (0.01 ± 0.02 µg/L) lowest in water samples. PCB level in water samples exceeded the tolerable levels for PCBs in portal water systems (0.5 µg/L). The concentration of PCB -44 in soil samples was highest (6.36 mg/kg) and PCB-180 was lowest (0.00 mg/kg). The differences between PCB levels in soil and water were not significant ($p>0.05$). Hazard index for the water sample for adults and children was greater than 1 showing no carcinogenic effects. Cumulative cancer risk due to PCBs in water was below 1.0×10^{-4} and shows no cancer risk. Therefore, electronic waste deposition and PCB levels in soil and the water in this location should be regularly checked in order to avoid the disruption of endocrine system in aquatic organisms and wildlife.

Keywords: Polychlorinated biphenyls, electronic waste dumpsite, cancer risk

INTRODUCTION

The habit of dumping wastes improperly, especially those of electronic origins, is the major cause of sustained release of Polychlorinated biphenyls (PCBs here in) in the environment including associating soils and water supply (Ngoubeyou *et al.*, 2022; Afolabi *et al.*, 2022). PCBs are persistent and hazardous compounds capable of lasting long and spreading in the environment (Subramanian *et al.*, 2017). Their bio-accumulating capacity, high toxic nature, and extensive range in the atmosphere with potentials of causing cancer confirms them as persistent organic pollutants (POPs) under the Stockholm Convention (Gouin *et al.*, 2004). The structure of PCBs is form from 2-10 atoms of chlorine bonding to biphenyl molecules and represented by $C_{12}H_{10-n}Cl_n$. They have long term history of existence with productions estimated at 1.5 million tons annually (Andersson *et al.*, 2015). PCBs were banned in 1980 and since then production has declined but traces of their occurrence is linked to poorly disposed electrical devices and management, and leakages in electronic devices, such as transformer and capacitor oil (Wang *et al.*, 2016). PCBs have broad uses including their application as cooling and lubricating agents for transformers, capacitors, and other electrical devices (Fouial-Djebbar *et al.*, 2010). Distinctively, there are 209 congeners (Wang & Chen, 2013). They are quite present in soil and water, with abilities of thriving long if left unattended and ability of being partially destroyed (Sharma *et al.*, 2018). However, Subramanian *et al.* (2017) reported their bioaccumulation in plant which could be an avenue for sustained pollution in the environment. Apart from this, they can be transferred through vapour migration to considerable distances or adsorption of pollution-contaminated solid particles (Anyasi and Atagana, 2011).

PCBs can occur in soil, water, air, sediment, plants, and animal tissue. Bioaccumulation in animal tissues being common in fish and macrobenthic invertebrates. They can persist in soil and sediment with variations from months to years, due to their low solubility in water and poor volatility, and that sediments serve as viable reservoir (Bonmatin *et al.*, 2015). For instance, electric transformers containing PCBs can stay for 30 years and more (Wang and Zhong, 2011). The physical and chemical character of the soil defines the behavior of PCB therein. More so, the presence of PCBs in soil significantly affects the soil's absorption strength to organic matter as well as triggering leaching in soils with low humus concentration (Xu *et al.*, 2010; Jang and Townsend, 2011). PCBs are confirmed by the presence of the 7 ICES (International Council for the Exploration of the Sea) such as CB-28, -52, -101, -118, -138, -153 and -180 (Boalt *et al.*, 2014; Igbaro *et al.*, 2018). Health wise, exposure to PCBs can cause fatalities such as weight losses, thymicatrophy, skin allergies, liver damage, teratogenicity, reproductive incapability, immunotoxicity, and strong induction potency of 3-methyl cholanthrene type hepatic microsomal enzymes (Wang and Zhong, 2011). These public health issues mandate the need for genotoxicity studies of PCBs in order to fully understand their impacts in the environment (Igbo *et al.*, 2018). Waste scavengers are common in large dump sites in Nigeria especially at Alaba where they carry out their activities and live there. In Nigeria, some children have been seen wandering about dumpsites where they and other scavengers have direct contact with PCB contaminated soil and water. Contact with contaminants may result to dermal complications and digestion could cause endocrine disruption (Moyo *et al.*, 2022). Growing evidence based report linked endocrine disruption to negative health effects, but the cause

and effect relationship is still unknown. A study on the physicochemical parameters of the soil and water from this location has been reported by Oluwagbemi *et al.* (2023). There is need to complete the study by determining the level of PCBs in soil and water from electronic dumpsite in Alaba Lagos.

MATERIALS AND METHODS

Study Area

This study was carried out at electronic waste dumpsite in Alaba, Lagos. The dumping site under study is an area where electronic wastes such as television, radio, electronic plastics amongst other waste are disposed and burnt. The dumpsite is closer to Alaba market and wells can be found closer to the site (Oluwagbemi *et al.*, 2023). The dumpsite is located on Longitude 3.11°E and latitude 6.28°N. Plants such as vegetables grow along the dumpsite region. Children and adults are found around the study area carrying out their daily activities such as disposing electronic wastes, burning of wastes and picking up some recyclable materials (Amponsah *et al.*, 2022). Daily, an estimated one million people transact business at Alaba market (Ochia, 2022). The market occupies a land area of approximately two kilometers by one kilometer on Ojo Igbede road (Balogun *et al.*, 2022). The market can be accessed from Badagry on Badagry-Oshodi express way through Iyana Iba, and can also be reached from any part of Lagos via Mile 2/Festac Town. The market is also very popular because it is on the international boarder road leading to Seme and Ghana road (Adeola *et al.*, 2022).

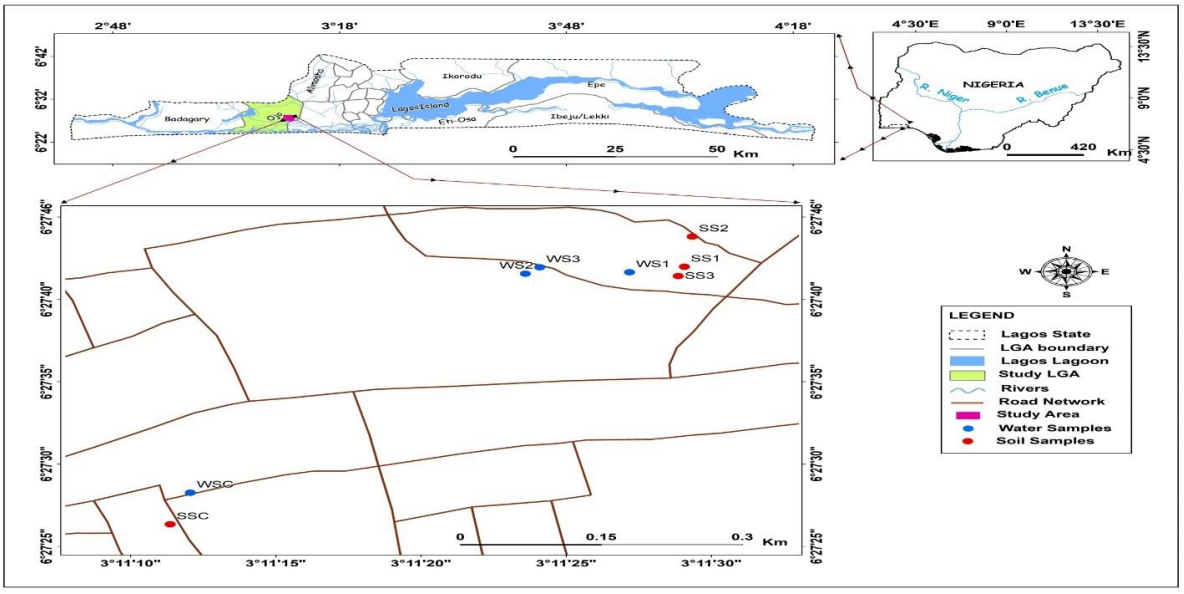

Figure 1: Map of the study area showing sampling sites. **Legend:** points with WS signify water samples and SS, soil samples (Oluwagbemi *et al.*, 2023).

Sample Collection

Six (6) soil samples were collected, three (3) of which were top soil samples and three (3) sub soil samples from same sampling points during the dried season. Two (2) soil samples collected 5km from the waste dump site served as control for the study. Similarly, three (3) water samples were taken from selected points and one (1) water sample taken 5km away from the sampled point served as control.

Soil Sample Collection

The soil in the dumpsite was excavated and collected using an auger (Agbeshie and Adjei, 2019). Prior to the collection of soil, root of plants, leaves, gravels and other irrelevant materials were manually removed. The top soils were collected from 0 to 0.15m and the sub soil from 0.16 to 3.0m in four different locations of the site. Eight (8) samples of soil in total were extracted and cleaned up for analysis.

Water Sample Collection

Water samples were collected from 3 selected wells. Prewashed amber bottles bathed with water were used to collect samples. Thereafter, samples were kept cool in ice packed coolers before extraction of compounds.

Extraction and Cleanup

Soil Sample Extraction

Soxhlet extraction method described by USEPA method 3540C was used in soil extraction. Soil were sieved to allow for thorough mixing, thereafter they were air dried and analyzed. The soils were pre-extracted with dichloromethane and 10 g each of the pre-extracted samples were measured into Whatman extraction thimbles. Extraction was done using the soxhlet extractor with 250 mL DCM for 16 h. The extracts were reduced to 10 mL using a rotary evaporator, and transferred to 4 mL amber vials, where they are stored in the refrigerator for cleaning and examination (Bilikis *et al.*, 2018).

Soil Sample Cleanup

The USEPA Method 3630C was used to clean up extracted soil components. Cleaning up and fractionation were done on a multilayered silica gel column made up of 3g of silica gel and 3g of anhydrous sodium sulphate (Na_2SO_4) set from bottom to top. The extracted soil components were introduced into the multilayer column and subsequently eluted with 20ml of *n*-hexane/acetone (1:1, v/v) as a standard method to isolate PCBs from samples of soil. The purified extract was concentrated and then reconstituted in 2ml hexane (USEPA, 2007).

Extraction of water samples

Water samples were extracted following protocols by Adeyemi *et al.* (2009). Air dried soil measuring 3g and equal gram of anhydrous sodium sulphate were measured into a porclain mortar and homogenized to completely mix with a pestle.

The mixture was carefully poured into a PTFE extraction tube with a PTFE screw cap that had already been cleaned. A 100ml PTFE extraction tube received 40ml of DCM.

After being properly corked, the extraction tube was let to stand for at least 20 minutes. This enables the solvent to completely permeate the matrix. The slurry was made to flow freely after a vigorous shake of the tube.The samples were centrifuged for approximately 30 minutes to allow for sample extraction.

Solid was left to sediment as the solvent was poured out gently into a receiving conical flask through a small glass funnel containing a layer of anhydrous sodium sulphate over a plug of glass wool. Sodium sulphate was rinsed with 2ml of DCM as soon as the surface is exposed. The top of the sodium sulphate layer was not allowed to go dry. The extraction was repeated by adding 40ml of DCM to the sediment sample by securely sealing the extraction tube and violently shaking by hand for two minutes.

The rotary evaporator's flask was filled with a mixture of all the extracts. The concentrator flask of the rotary evaporator was partially, but not fully, submerged in a constant temperature hot water bath. In order to ensure that the solvent heated uniformly, the bath temperature and equipment placement were both change. The sample was diluted to around 1.0ml.

Clean-Up Procedure for Water Samples

Using the US EPA method 3630C, the product from the water analysis were cleaned (Method 3630: silica gel cleanup, 1996). Anhydrous sodium sulphate was added to the column, 3g of activated silica gel (60 mesh), glass wool was used to close the hole, and the column was then topped with it. The column was then cleaned by eluting with 20ml n-hexane and discarded. The constructed column was loaded with the concentrated extract, and it was eluted with 50ml of n-hexane. A rotary evaporator and a gentle stream of pure nitrogen were then used to concentrate the elutes to 1ml. The extract was put into a well-labelled container and kept at 40 degrees Celsius until it could be examined with a gas chromatography electron capture detector (GC-ECD).

Quality Assurance and Quality Control (QA/QC)

This was done using the procedural blanks for QA/QC and multi-level calibration curves (r^2) which was between 0.997 and 0.999. PCBs are detected between 1.0 x 10^{-6} and 1.4 x 10^{-6} mg/kg (0.001 and 0.0014ng/g). It is expected that the concentrations of the desired compounds in the procedural blanks should be less than the quantification limit of the instruments. Data analysis in this study was expressed in terms of dry weight (mg/kg).

Health Risk Assessment (HRA) for Water Samples

The health risk of PCBs in samples were assessed in terms of average daily dose (ADD), hazard quotient (HQ), hazard index (HI), and cancer risk (CR) using the following formulae (USEPA (2001; 2002; 2005): $ADD = \frac{(C \times IR \times EF \times ED)}{(BW \times AT)} \; x\, 10^{-3} \quad (mgL^{-1}day^{-1})$ (1)

Where, ADD exposure in water (mg L^{-1} day^{-1})

C = PCBs Concentration in water samples (µg L^{-1}),

IR = Ingestion rate of PCBs in water (2 L/day for adults, 0.3 L/day for children)

ED = Duration of exposure (in years) = 30 years for adults and 6 years for children.

EF = Frequency of exposure (day/year) = 365 days/year,

AT = Averaging time or life expectancy = ED x 365 days i.e. 30 x 365 days for adults and 6 x 365 days for children.

BW = Body weight (kg); 70 kg for an adult and 15 kg for a child.

$HI = \sum_{i=1}^{n} HQ$ i=1…n (2)

$HQ = \frac{ADD}{RfD}$ (3)

Where, ADD exposure in water (mg kg^{-1} day^{-1}),

RfD = Reference dose (2 x 10^{-5} $mgkg^{-1}day^{-1}$),

N = numbers of elements observed.

HQ>1 denotes non-carcinogenic adverse health effects, HQ<1 denotes no adverse effects,

Cancer Risk = ADD x SF (4)

SF = Slope factor is 0.07 $mgkg^{-1}day^{-1}$

Conversion factor = 10^{-3} x µgL^{-1} to mgL^{-1}

Statistical Analysis

Data presentation was done by simple descriptive statistics specifically mean and standard deviation. Analysis of Variance (ANOVA) was used to show significant difference at p=0.05 using SPSS version 23 (IBM Corp, 2015).

RESULTS AND DISCUSSION

Level of PCBs in Water Samples

Variable levels of PCBs in water samples was recorded in this present study. Nineteen (19) PCB congeners were detected in the water samples. The PCB Congener -1 had the highest concentration (2.28 µg/L) in water sample from Alaba, Lagos (SW1). The lowest concentration of PCB (0.01 µg/L) was recorded for PCB congener-206 in water sample from SW3. The differences of water samples in the locations were significant ($p<0.05$). The goal of Environmental Protection Agency for drinking water is zero tolerance to PCB contaminants, and the possible enforceable maximum for PCB contaminant levels in public water systems is 0.0005ppm (0.5 µg/L) (EPA 2001). The water samples from Alaba Lagos were found to exceed the maximum tolerable levels for PCBs in drinkable water (EPA, 2001). Although, the finding of this study is not in agreement with the study of Igbaro *et al.* (2018), that reported indicator CB-28 at highest level of 0.57 µg/L and the lowest occurring in CB-180 (0.11 µg/L) in water samples at Alaba. However, the finding of this study corresponded to the study of Ajagbe *et al.* (2018) which reported concentrations of PCBs in water samples between 0.06 and 6 µg/L. Cui *et al.* (2020) reported a total PCBs concentration range of 0.00004 – 0.011 µg/L. A slight increase in the levels of PCBs in this study was observed compared to the study of Cui *et al.* (2020) which could be as a result of factors of the environment influencing the level of PCBs.

The correlation of PCBs in water was strong (Table 2). PCB-52 was strongly correlated with PCB-18 (r=0.941; p>0.01) which implied they were likely to be from the same source. PCB-44 and PCB-18 were strongly correlated with r value = 0.877 at p>0.01. PCB-153 was also correlated with PCB-138 (r=0.697; p>0.01) which is similar to Naert *et al.* (2006) that found a high correlation coefficient between PCB-153 and PCB-138. In all, no statistical differences were (p>0.05) were observed in the samples.

PCB Levels in Soil Samples

The level of PCBs in soil samples ranged from 9.45 mg/kg to 27.45 mg/kg. SS1 had highest PCB-1 concentration of 3.35 mg/kg while SS2 had lowest concentration of PCB-1 concentration (0.47 mg/kg). TS1 had highest PCB-44 congeners of 6.36 mg/kg while SS3 had lowest PCB-44 contamination of 1.70 mg/kg. This study also deduced that the level of PCB-66 congeners ranged from 0.81 mg/kg to 4.92 mg/kg. This study found PCB – 1, 5, 18, 31, 44, 52, 66, 87, 101, 110, 138, 141, 151, 153, 170, 180, 183, 187 and 206. The daily PCB intake that is safe is 20 ng/kg of body weight (USEPA, 2005). The total of PCB levels in soil samples in this study were higher than those reported in Dutch action value, Australian and New Zealand ecological investigation level of 1000μg/kg (1mg/kg), as well as the Canadian soil guideline for residential areas of 1300 μg/kg (1.3mg/kg) (Canadian Environmental Quality Guidelines, 2003). There is a link between the level of PCBs in the study of Alawi & Azeez (2017) and Canadian environmental quality guidelines 270 μg/kg (0.27mg/kg) with this present study. However, soil samples in some locations in this study exceeded the recommended standards. These soils were found to be highly contaminated with PCBs and capable of causing adverse effects to humans.

PCB-5 and PCB-1were positively correlated (r=0.644; p>0.01), indicating that they were most likely to be from same source. PCB-66 and PCB-31 were equally strongly correlated (r = 0.838; p>0.01) (Table 4). PCB congeners 87 and 31 were equally strongly correlated (r=0.822; p>0.01), as were PCB-66 and PCB-44 (r=0.756; p>0.01) indicating that they may be from the same source. PCB-87 and PCB-66 were likewise strongly correlated (r=0.976; p>0.01), as were PCB-187 and PCB-170 (r=0.802; p>0.01). PCB-206 and PCB-170 had a strong correlation (r = 0.740; p>0.01) which also indicate they were most likely from the same source.

Average daily dose (ADD) values of PCBs for water consumption in adults and children (mg/kg/day)

ADD of PCBs due to water consumption in adults and children was highest (6.51E-05 mg/kg/day) for PCB-1 through water consumption in adults and lowest with PCB-206 (2.86E-07 mg/kg/day) (Table 5). According to the observation by Ghosh *et al.*, (2018) in line with USEPA PCBs are classified as potential carcinogens in humans. This present study however observed that ADD of PCBs in the water samples were highly significant (p< 0.0001) and classified to cause non-carcinogenic effects to adults. The ADDs of PCBs consumed in water by children ranged from 2.00E-07 mg/kg/day to 4.56E-05 mg/kg/day. The ADD of PCBs in water samples in this present study is substantially below 0.0001. This portends that these waters do not have the potentials of causing carcinogenic effects in children when consumed.

Hazard quotient and hazard index values of PCBs in water for adults and children.

The hazard index value of PCBs recorded in this study was higher than the USEPA maximum limit of 1, indicating possible non-carcinogenic health impacts in adults. The Hazard Index (HI) values of PCBs and the HQ values in adults recorded in this study were greater than 1.0 (>1) indicating non-carcinogenic effect (Table 6). The result of this study compared favourably to the study of Olayinka *et al.* (2017) which reported HQ values ranges of 493 to 1046 in dry season. Hazard prediction in studies rely on the up-to-date risk assessment reports by USEPA (2015) because they are trusted in predicting hazards posed on human consumers than the associated levels in the substance. Considering the water intake in children, SW1 had hazard index of 5.39, SW2 had 3.04 and SW3; 3.26. These hazard indices show a non-carcinogenic effects. Wang and Chen, (2013) have noted that liver disorders, and other body malfunctioning with consumption of carcinogenic waters.

Cancer risk values of PCBs in water for adults and children

The risk of cancer was considered common in water within the limit of $1\times10^{-6} – 1\times10^{-4}$ (EPA, 2001). In this present study, the cancer risk value was between 2.00E-08 and 4.56E-06 for adults and, 1.40E-0.8 and 3.19E-0.6 for children (Table 7). This portends that calculated risk of cancer was below the acceptable limit value of 1.0×10^{-4}. The finding of this study suggests that hazard quotient and ADD of water samples have link to a non-carcinogenic effects. Cancer risk assessment estimates the chances of cancer occurrence without considering the severity or significance. Furthermore, it is the probability of the incidence of any type of cancer and not the probability of death due to cancer. It is expressed in terms of number associated with a consistent chronic exposure dose and this relates to the exposure concentration as 1 in 1 million (USEPA 2009a).

CONCLUSION

This study detected nineteen PCB congeners in water and soil samples. Of which hazard quotient indicated chances of non-carcinogenic effects occurring from intake of the water samples and lower risk of cancer due to value significantly lower than the acceptable USEPA tolerable risk. Water samples in all point of collection exceeded the tolerable limit for PCBs in public water and were found to be significantly contaminated with PCBs. Soils of the electronic dumpsite were equally contaminated with PCBs portending harmful impacts on humans and animals.

RECOMMENDATIONS

i. The resident or passerby should take precaution when getting in contact with the soil in electronic waste dumpsite at Alaba. Precautions such as making use of some personal protective equipment.
ii. The people should be educated on the harmful effects of PCBs exposure as a result of improper disposal of electronic waste and also burning of e-waste which can results into exposure to harmful endocrine disruptors like PCBs.
iii. The government body in charge of waste disposal should ensure they run a better means of waste disposal and follow through its maintenance.
iv. Any food that get in contact with the soil should not be put into the mouth to avoid accumulating PCBs in the body system.
v. Any dumpsite that is not properly managed by responsible agencies should be closed down with immediate effect to prevent further human and children exposure to persistent organic pollutants (POPs) or endocrine disruptors.

Table 1: Concentrations of PCBs in water samples (µg/L)

PCBs Congeners	SW 1	SW 2	SW 3	WC
PCB 1	$2.28^{a} \pm 1.85$	$0.93^{c} \pm 1.00$	$2.00^{b} \pm 0.19$	$2.39^{a} \pm 2.07$
PCB 5	$0.35^{a} \pm 0.24$	$0.22^{c} \pm 0.05$	$0.25^{b} \pm 0.09$	$0.41^{a} \pm 0.14$
PCB 18	$0.14^{a} \pm 0.07$	$0.12^{a} \pm 0.07$	0.08 ± 0.00	$0.18^{a} \pm 0.12$
PCB 31	$0.10^{b} \pm 0.08$	$0.10^{b} \pm 0.09$	$0.14^{a} \pm 0.11$	$0.16^{a} \pm 0.15$
PCB 44	$0.31^{b} \pm 0.12$	$0.25^{c} \pm 0.11$	$0.24^{c} \pm 0.03$	$0.42^{a} \pm 0.16$
PCB 52	$0.07^{a} \pm 0.04$	$0.05^{a} \pm 0.03$	$0.03^{a} \pm 0.00$	$0.08^{a} \pm 0.04$
PCB 66	$0.64^{a} \pm 0.45$	$0.36^{b} \pm 0.19$	$0.03^{c} \pm 0.02$	$0.12^{c} \pm 0.09$
PCB 87	$0.17^{a} \pm 0.13$	$0.08^{b} \pm 0.04$	$0.05^{b} \pm 0.01$	$0.19^{a} \pm 0.13$
PCB 101	$0.09^{b} \pm 0.05$	$0.08^{b} \pm 0.06$	$0.05^{c} \pm 0.05$	$0.28^{a} \pm 0.40$
PCB 110	$0.08^{a} \pm 0.04$	$0.06^{a} \pm 0.04$	$0.07^{a} \pm 0.04$	$0.13^{a} \pm 0.10$
PCB 138	$0.08^{a} \pm 0.04$	$0.07^{a} \pm 0.05$	$0.02^{a} \pm 0.01$	$0.12^{a} \pm 0.09$
PCB 141	$0.21^{a} \pm 0.15$	$0.10^{b} \pm 0.04$	$0.04^{c} \pm 0.03$	$0.15^{a} \pm 0.13$
PCB 151	$0.05^{a} \pm 0.02$	$0.04^{a} \pm 0.02$	$0.02^{a} \pm 0.01$	$0.06^{a} \pm 0.06$
PCB 153	$0.10^{a} \pm 0.11$	$0.05^{b} \pm 0.04$	$0.04^{b} \pm 0.03$	$0.08^{a} \pm 0.06$
PCB 170	$0.03^{a} \pm 0.03$	$0.05^{a} \pm 0.08$	$0.02^{a} \pm 0.01$	$0.06^{a} \pm 0.05$
PCB 180	$0.03^{a} \pm 0.06$	$0.07^{a} \pm 0.01$	$0.04^{a} \pm 0.03$	$0.14^{a} \pm 0.13$
PCB 183	$0.28^{a} \pm 0.29$	$0.10^{b} \pm 0.05$	$0.06^{b} \pm 0.01$	$0.21^{a} \pm 0.14$
PCB 187	$0.06^{a} \pm 0.04$	$0.07^{a} \pm 0.06$	$0.07^{a} \pm 0.06$	$0.09^{a} \pm 0.11$
PCB 206	$0.32^{b} \pm 0.30$	$0.24^{b} \pm 0.20$	$0.01^{c} \pm 0.02$	$0.61^{a} \pm 0.92$
Total PCBs	$\mathbf{5.39^{a} \pm 4.11}$	$\mathbf{3.04^{b} \pm 2.23}$	$\mathbf{3.24^{b} \pm 0.84}$	$\mathbf{5.82^{a} \pm 5.09}$

Similar alphabets along the row are not significantly different at p>0.05 SW1, SW2, SW3

Table 2: Pearson's correlation coefficients of PCBs in water samples

	PCB 1	**PCB 5**	**PCB 18**	**PCB 31**	**PCB 44**	**PCB 52**	**PCB 66**	**PCB 87**	**PCB 101**	**PCB 110**	**PCB 138**	**PCB 141**	**PCB 151**	**PCB 153**	**PCB 170**	**PCB 180**	**PCB 183**	**PCB 187**	**PCB 206**
PCB 1	1																		
PCB 5	.496	1																	
PCB 18	.682*	.541	1																
PCB 31	.562	.254	.652*	1															
PCB 44	.665*	.767**	.877**	.503	1														
PCB 52	.669*	.697*	.941**	.526	.946**	1													
PCB 66	.302	.423	.479	.209	.311	.563	1												
PCB 87	.723**	.374	.836**	.576*	.771**	.837**	.435	1											
PCB 101	.342	-.044	.501	.684*	.248	.295	.063	.523	1										
PCB 110	.716**	.390	.886**	.812**	.811**	.812**	.192	.842**	.587*	1									
PCB 138	.567	.320	.910**	.720**	.734**	.802**	.377	.882**	.752**	.874**	1								
PCB 141	.767**	.466	.808**	.554	.694*	.836**	.709**	.913**	.428	.720**	.792**	1							
PCB 151	.510	.194	.774**	.705*	.505	.634*	.466	.775**	.877**	.720**	.928**	.769**	1						
PCB 153	.542	.091	.597*	.521	.521	.640*	.422	.888**	.395	.699*	.697*	.815**	.623*	1					
PCB 170	.097	.210	.686*	.564	.564	.572	.104	.387	.457	.630*	.668*	.274	.543	.227	1				
PCB 180	.517	.305	.715**	.695*	.538	.506	.050	.527	.810**	.714**	.799**	.458	.786**	.213	.570	1			
PCB 183	.572	.288	.573	.286	.608*	.692*	.474	.882**	.148	.584*	.589*	.821**	.460	.921**	.073	.084	1		
PCB 187	.355	-.001	.554	.932**	.310	.382	.188	.540	.818**	.717**	.738**	.482	.785**	.549	.543	.679*	.251	1	
PCB 206	.322	-.086	.536	.633*	.275	.360	.186	.642*	.958**	.579*	.813**	.542	.921**	.558	.448	.720**	.341	.798**	1

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

Table 3: Level of PCBs in soil samples (mg/kg)

	TS1	**SS1**	**TS2**	**SS2**	**TS3**	**SS3**	**TSC**	**SSC**
PCB 1	2.81 ± 1.17^{b}	3.35 ± 1.83^{a}	1.96 ± 1.38^{c}	0.47 ± 0.42	1.46 ± 1.01^{c}	3.32 ± 0.25^{a}	1.35 ± 1.66^{c}	1.93 ± 1.42^{c}
PCB 5	0.48 ± 0.08^{a}	0.42 ± 0.28^{a}	0.55 ± 0.30^{a}	0.17 ± 0.08^{c}	0.26 ± 0.04^{c}	0.47 ± 0.11^{a}	0.50 ± 0.45^{a}	0.35 ± 0.11^{b}
PCB 18	0.56 ± 0.24^{a}	0.58 ± 0.22^{a}	0.39 ± 0.21^{c}	0.14 ± 0.18	0.33 ± 0.15^{c}	0.48 ± 0.36^{b}	0.35 ± 0.18^{c}	0.32 ± 0.05^{c}
PCB 31	0.42 ± 0.20^{b}	0.44 ± 0.13^{b}	1.06 ± 0.95^{a}	0.22 ± 0.27^{c}	0.59 ± 0.27^{b}	0.63 ± 0.69^{a}	0.29 ± 0.10^{c}	0.43 ± 0.10^{b}
PCB 44	6.36 ± 4.21^{a}	4.64 ± 1.80^{b}	5.35 ± 5.51^{a}	2.30 ± 0.50^{c}	3.10 ± 0.99^{b}	1.70 ± 2.02^{c}	3.68 ± 2.04^{b}	3.82 ± 0.76^{b}
PCB 52	0.61 ± 0.44^{a}	0.44 ± 0.38^{b}	0.11 ± 0.09^{c}	0.30 ± 0.17^{b}	0.22 ± 0.11^{c}	0.79 ± 1.19^{a}	0.70 ± 0.61^{a}	0.69 ± 0.10^{a}
PCB 66	2.31 ± 1.06^{b}	1.76 ± 0.15^{c}	4.92 ± 6.55^{a}	0.81 ± 0.40^{c}	1.24 ± 0.61^{c}	0.87 ± 1.26^{c}	1.74 ± 0.90^{c}	1.31 ± 0.28^{c}
PCB 87	0.45 ± 0.13^{b}	0.44 ± 0.10^{b}	1.67 ± 2.47^{a}	0.29 ± 0.11^{c}	0.38 ± 0.03^{c}	0.40 ± 0.32^{b}	0.51 ± 0.22^{b}	0.39 ± 0.08^{c}
PCB 101	0.33 ± 0.09^{c}	0.79 ± 0.74^{a}	0.36 ± 0.27^{c}	0.26 ± 0.00^{c}	0.32 ± 0.10^{c}	0.31 ± 0.28^{c}	0.48 ± 0.35^{b}	0.83 ± 0.40^{a}
PCB 110	1.50 ± 0.76^{a}	0.95 ± 0.09^{b}	0.88 ± 0.63^{b}	0.59 ± 0.56^{c}	1.17 ± 0.86^{a}	0.48 ± 0.56^{c}	1.09 ± 0.95^{a}	0.76 ± 0.19^{b}
PCB 138	0.43 ± 0.26^{c}	0.62 ± 0.39^{b}	0.40 ± 0.32^{c}	0.29 ± 0.16^{c}	0.33 ± 0.14^{c}	0.26 ± 0.25^{c}	1.47 ± 0.76^{a}	0.75 ± 0.26^{b}
PCB 141	0.56 ± 0.36^{b}	1.22 ± 0.72^{a}	0.28 ± 0.34^{c}	0.27 ± 0.24^{c}	0.42 ± 0.39^{b}	0.17 ± 0.09^{c}	0.93 ± 1.62^{a}	1.03 ± 0.66^{a}
PCB 151	1.27 ± 0.45^{a}	0.81 ± 0.10^{a}	0.87 ± 0.31^{a}	0.48 ± 0.28^{b}	1.23 ± 0.84^{a}	0.38 ± 0.55^{c}	1.15 ± 1.15^{a}	0.74 ± 0.36^{b}
PCB 153	1.43 ± 0.45^{b}	1.13 ± 0.41^{b}	0.88 ± 0.93^{c}	0.86 ± 0.46^{c}	0.71 ± 0.41^{c}	0.73 ± 1.01^{c}	2.33 ± 1.21^{a}	1.20 ± 0.67^{b}
PCB 170	0.73 ± 0.58^{a}	0.51 ± 0.37^{b}	0.27 ± 0.13^{c}	0.15 ± 0.13^{c}	0.14 ± 0.18^{c}	0.22 ± 0.13^{c}	0.60 ± 0.33^{a}	0.41 ± 0.37^{b}
PCB 180	0.09 ± 0.16^{a}	0.64 ± 0.65^{b}	0.07 ± 0.11^{a}	0.04 ± 0.07^{c}	0.00 ± 0.00	0.15 ± 0.13^{c}	0.00 ± 0.00	0.11 ± 0.20^{c}
PCB 183	1.67 ± 1.02^{b}	2.33 ± 2.21^{a}	0.85 ± 0.37^{c}	0.62 ± 0.11^{c}	0.85 ± 0.33^{b}	0.58 ± 0.33^{c}	1.77 ± 0.09^{b}	0.93 ± 0.06^{b}
PCB 187	3.27 ± 3.89^{a}	2.65 ± 2.83^{b}	0.53 ± 0.30^{c}	0.56 ± 0.48^{c}	2.39 ± 1.01^{a}	0.20 ± 0.05	4.74 ± 2.29^{a}	3.09a ± 0.39^{a}
PCB 206	1.86 ± 0.99^{b}	1.53 ± 0.63^{b}	0.47 ± 0.50^{c}	0.63 ± 0.20^{c}	1.01 ± 0.36^{b}	0.56 ± 0.43^{c}	2.04 ± 2.24^{a}	1.25 ± 0.21^{b}
Total PCBs	**27.14 ± 16.54^{a}**	**27.45 ± 14.03^{a}**	**21.87 ± 21.67^{a}**	**9.45 ± 4.82^{c}**	**16.15 ± 7.83^{b}**	**12.7 ± 10.01^{b}**	**25.72 ± 17.15^{a}**	**20.34 ± 6.67^{a}**

Table 4: Pearson's correlation coefficients of PCBs in soil samples

	PCB 1	PCB 5	PCB 18	PCB 31	PCB 44	PCB 52	PCB 66	PCB 87	PCB 101	PCB 110	PCB 138	PCB 141	PCB 151	PCB 153	PCB 170	PCB 180	PCB 183	PCB 187	PCB 206
PCB 1	1																		
PCB 5	.644**	1																	
PCB 18	.556**	.551**	1																
PCB 31	.134	.375	.615**	1															
PCB 44	-.092	.122	.555**	.604**	1														
PCB 52	.298	.215	.483*	.184	.075	1													
PCB 66	.017	.418*	.466*	.838**	.756**	-.009	1												
PCB 87	-.031	.362	.332	.822**	.657**	-.052	.976**	1											
PCB 101	.125	.135	.265	.212	.315	.430*	.201	.213	1										
PCB 110	.113	.281	.560**	.401	.572**	.314	.421*	.288	.152	1									
PCB 138	-.101	.258	.252	.093	.276	.409*	.244	.194	.506*	.243	1								
PCB 141	.165	.378	.263	.039	.151	.394	.148	.115	.777**	.368	.616**	1							
PCB 151	.064	.080	.471*	.244	.410*	.248	.255	.107	-.041	.417*	.464*	.019	1						
PCB 153	.010	.140	.285	.214	.431*	.467*	.335	.294	.233	.610**	.440*	.217	.167	1					
PCB 170	.048	.325	.493*	.130	.559**	.387	.244	.130	.582**	.548**	.600**	.716**	.233	.329	1				
PCB 180	.076	-.132	-.057	-.164	-.067	-.103	-.121	-.113	.204	-.150	.004	.268	-.192	-.164	.096	1			
PCB 183	.127	.063	.380	.072	.560**	.313	.177	.099	.666**	.409*	.499*	.535**	.268	.422*	.718**	.249	1		
PCB 187	.005	.224	.303	-.060	.423*	.344	.083	-.024	.529**	.541**	.692**	.672**	.407*	.398	.802**	-.039	.736**	1	
PCB 206	.232	.467*	.406*	.039	.300	.509*	.179	.085	.475*	.724**	.538**	.781**	.201	.570**	.740**	.029	.576**	.801**	1

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

Table 5: ADD values for PCBs through consumption of water by adults and children (mg/kg/day)

	Adults				Children			
PCBs Congeners	**SW 1**	**SW 2**	**SW 3**	**WC**	**SW 1**	**SW 2**	**SW 3**	**WC**
PCB 1	6.51E-05	2.66E-05	5.71E-05	6.83E-05	4.56E-05	1.86E-05	4.00E-05	4.78E-05
PCB 5	1.00E-05	6.29E-06	7.14E-06	1.17E-05	7.00E-06	4.40E-06	5.00E-06	8.20E-06
PCB 18	4.00E-06	3.43E-06	2.29E-06	5.14E-06	2.80E-06	2.40E-06	1.60E-06	3.60E-06
PCB 31	2.86E-06	2.86E-06	4.00E-06	4.57E-06	2.00E-06	2.00E-06	2.80E-06	3.20E-06
PCB 44	8.86E-06	7.14E-06	6.86E-06	1.20E-05	6.20E-06	5.00E-06	4.80E-06	8.40E-06
PCB 52	2.00E-06	1.43E-06	8.57E-07	2.29E-06	1.40E-06	1.00E-06	6.00E-07	1.60E-06
PCB 66	1.83E-05	1.03E-05	8.57E-07	3.43E-06	1.28E-05	7.20E-06	6.00E-07	2.40E-06
PCB 87	4.86E-06	2.29E-06	1.43E-06	5.43E-06	3.40E-06	1.60E-06	1.00E-06	3.80E-06
PCB 101	2.57E-06	2.29E-06	1.43E-06	8.00E-06	1.80E-06	1.60E-06	1.00E-06	5.60E-06
PCB 110	2.29E-06	1.71E-06	2.00E-06	3.71E-06	1.60E-06	1.20E-06	1.40E-06	2.60E-06
PCB 138	2.29E-06	2.00E-06	5.71E-07	3.43E-06	1.60E-06	1.40E-06	4.00E-07	2.40E-06
PCB 141	6.00E-06	2.86E-06	1.14E-06	4.29E-06	4.20E-06	2.00E-06	8.00E-07	3.00E-06
PCB 151	1.43E-06	1.14E-06	5.71E-07	1.71E-06	1.00E-06	8.00E-07	4.00E-07	1.20E-06
PCB 153	2.86E-06	1.43E-06	1.14E-06	2.29E-06	2.00E-06	1.00E-06	8.00E-07	1.60E-06
PCB 170	8.57E-07	1.43E-06	5.71E-07	1.71E-06	6.00E-07	1.00E-06	4.00E-07	1.20E-06
PCB 180	8.57E-07	2.00E-06	1.14E-06	4.00E-06	6.00E-07	1.40E-06	8.00E-07	2.80E-06
PCB 183	8.00E-06	2.86E-06	1.71E-06	6.00E-06	5.60E-06	2.00E-06	1.20E-06	4.20E-06
PCB 187	1.71E-06	2.00E-06	2.00E-06	2.57E-06	1.20E-06	1.40E-06	1.40E-06	1.80E-06
PCB 206	9.14E-06	6.86E-06	2.86E-07	1.74E-05	6.40E-06	4.80E-06	2.00E-07	1.22E-05

Table 6: Hazard quotient and hazard index values of PCBs in water for adults and children

	Adults				Children			
PCBs Congeners	**SW 1**	**SW 2**	**SW 3**	**WC**	**SW 1**	**SW 2**	**SW 3**	**WC**
PCB 1	3.26	1.33	2.86	3.41	2.28	0.93	2.00	2.39
PCB 5	0.50	0.31	0.36	0.59	0.35	0.22	0.25	0.41
PCB 18	0.20	0.17	0.11	0.26	0.14	0.12	0.08	0.18
PCB 31	0.14	0.14	0.20	0.23	0.10	0.10	0.14	0.16
PCB 44	0.44	0.36	0.34	0.60	0.31	0.25	0.24	0.42
PCB 52	0.10	0.07	0.04	0.11	0.07	0.05	0.03	0.08
PCB 66	0.91	0.51	0.04	0.17	0.64	0.36	0.03	0.12
PCB 87	0.24	0.11	0.07	0.27	0.17	0.08	0.05	0.19
PCB 101	0.13	0.11	0.07	0.40	0.09	0.08	0.05	0.28
PCB 110	0.11	0.09	0.10	0.19	0.08	0.06	0.07	0.13
PCB 138	0.11	0.10	0.03	0.17	0.08	0.07	0.02	0.12
PCB 141	0.30	0.14	0.06	0.21	0.21	0.10	0.04	0.15
PCB 151	0.07	0.06	0.03	0.09	0.05	0.04	0.02	0.06
PCB 153	0.14	0.07	0.06	0.11	0.10	0.05	0.04	0.08
PCB 170	0.04	0.07	0.03	0.09	0.03	0.05	0.02	0.06
PCB 180	0.04	0.10	0.06	0.20	0.03	0.07	0.04	0.14
PCB 183	0.40	0.14	0.09	0.30	0.28	0.10	0.06	0.21
PCB 187	0.09	0.10	0.10	0.13	0.06	0.07	0.07	0.09
PCB 206	0.46	0.34	0.01	0.87	0.32	0.24	0.01	0.61
HI	**7.70**	**4.34**	**4.66**	**8.40**	**5.39**	**3.04**	**3.26**	**5.88**

Table 7: Cancer risk values of PCBs in water for adults and children

	Adults				Children			
PCBs Congeners	**SW1**	**SW2**	**SW3**	**WC**	**SW1**	**SW2**	**SW3**	**WC**
PCB 1	4.56E-06	1.86E-06	4.00E-06	4.78E-06	3.19E-06	1.30E-06	2.80E-06	3.35E-06
PCB 5	7.00E-07	4.40E-07	5.00E-07	8.20E-07	4.90E-07	3.08E-07	3.50E-07	5.74E-07
PCB 18	2.80E-07	2.40E-07	1.60E-07	3.60E-07	1.96E-07	1.68E-07	1.12E-07	2.52E-07
PCB 31	2.00E-07	2.00E-07	2.80E-07	3.20E-07	1.40E-07	1.40E-07	1.96E-07	2.24E-07
PCB 44	6.20E-07	5.00E-07	4.80E-07	8.40E-07	4.34E-07	3.50E-07	3.36E-07	5.88E-07
PCB 52	1.40E-07	1.00E-07	6.00E-08	1.60E-07	9.80E-08	7.00E-08	4.20E-08	1.12E-07
PCB 66	1.28E-06	7.20E-07	6.00E-08	2.40E-07	8.96E-07	5.04E-07	4.20E-08	1.68E-07
PCB 87	3.40E-07	1.60E-07	1.00E-07	3.80E-07	2.38E-07	1.12E-07	7.00E-08	2.66E-07
PCB 101	1.80E-07	1.60E-07	1.00E-07	5.60E-07	1.26E-07	1.12E-07	7.00E-08	3.92E-07
PCB 110	1.60E-07	1.20E-07	1.40E-07	2.60E-07	1.12E-07	8.40E-08	9.80E-08	1.82E-07
PCB 138	1.60E-07	1.40E-07	4.00E-08	2.40E-07	1.12E-07	9.80E-08	2.80E-08	1.68E-07
PCB 141	4.20E-07	2.00E-07	8.00E-08	3.00E-07	2.94E-07	1.40E-07	5.60E-08	2.10E-07
PCB 151	1.00E-07	8.00E-08	4.00E-08	1.20E-07	7.00E-08	5.60E-08	2.80E-08	8.40E-08
PCB 153	2.00E-07	1.00E-07	8.00E-08	1.60E-07	1.40E-07	7.00E-08	5.60E-08	1.12E-07
PCB 170	6.00E-08	1.00E-07	4.00E-08	1.20E-07	4.20E-08	7.00E-08	2.80E-08	8.40E-08
PCB 180	6.00E-08	1.40E-07	8.00E-08	2.80E-07	4.20E-08	9.80E-08	5.60E-08	1.96E-07
PCB 183	5.60E-07	2.00E-07	1.20E-07	4.20E-07	3.92E-07	1.40E-07	8.40E-08	2.94E-07
PCB 187	1.20E-07	1.40E-07	1.40E-07	1.80E-07	8.40E-08	9.80E-08	9.80E-08	1.26E-07
PCB 206	6.40E-07	4.80E-07	2.00E-08	1.22E-06	4.48E-07	3.36E-07	1.40E-08	8.54E-07

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