POLYCHLORINATED BIPHENYLS IN RESIDENTIAL SOILS FROM THE POWER PLANT AREA OF INDIA: POSSIBLE RISK TO HUMANS

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Introduction

During past some decades, polychlorinated biphenyls (PCBs) have been synthesized and released into the environment for direct or indirect application over a long period of time. PCBs are thermally and chemically stable compounds were primarily used in electrical and industrial applications[1]. PCBs in the environment released from anthropogenic sources. PCBs have long been recognized for their health effects through ingestion, inhalation and skin contact to cause developing cancer, neurological and hormone disruption[2-3]. Soils are usually considered as the sink as well as a source for these pollutants. Higher concentrations of pollutants have been reported in urban and industrial soils when compared with soils of rural or remote area[4-6]. Accumulation of PCBs in soil may lead to contamination of vegetables and food chains and the close proximity of soils to humans may lead to human exposure[7]. In recent years, research emphasized more on the evaluation of environmental and human health risk from organic pollutants such PCBs in soils[8]. This study focused on quantification of 28 PCBs including 12 dioxin-like PCBs in soils, and their health risk for population in an industrial city (Korba) in India.

Material and methods

The study area is situated between geographical coordinates of 22° 01′ - 23° 01′ latitude and 82° 08′ - 83° 09′ longitude in Chhattisgarh, India. The area is enriched with coal and water resources, therefore, four thermal and one hydroelectric power plant with collectively more than 3650 MW of electricity generation are operative here. This region experiences the hot and dry climate zone. From April to June it is summer, from June to October it is raining season with an average rainfall of 1507 mm, while November to February is winter in this area. Soil sampling was collected during June 2012 from locations near human settlement areas.

Soil samples were extracted three times with acetone-hexane mixture in ultrasonic bath[9]. After extraction, the concentrated extracts subjected to silica gel column chromatography for cleanup. 10 g activated silica gel (100–200 mesh) was packed in glass column (25 cm × 10 mm) and 1 cm layer of anhydrous sodium sulphate. After loading the concentrated extracts, elution was made with 30 ml of hexane containing aliphatic hydrocarbons and discarded. Finally, elution was made with 35 ml of dichloromethane (@~2 ml min^{-1}) and fraction was retained for PCBs analysis by gas chromatograph.

Twenty eight individual PCB standards (PCB-18, -37, -44, -49, -52, -70, -74, -119, -128, -138, -151, -168, -170, -177, -187, -207 -77, -81, -105, -114, -118, -123, -126, -156, -157, -167, -169, and -189) from Dr. Ehrenstorfer (GmbH, Augsburg, Germany) were used during the study. Analysis was carried out with a gas chromatograph (Shimadzu SPD 2010, Tokyo, Japan) equipped with electron capture detector (ECD, ^{63}Ni). Separation and quantification of compound were carried out on HP-5MS column (60 m x 0.25 mm x 0.25 µm film).

Required quality control (QC) analysis was performed with procedural blanks, random duplicate samples, multi-level calibration curves (r^2, 0.999), calibration verification (<±10%) and matrix spiked recovery (±20%). Each sample was analyzed in duplicate and the average of two analyses was used in calculations. The detection limits for all PCBs 0.01 µg kg^{-1} was used during data interpretation.Potential equivalent of carcinogenic dioxin-like PCBs was calculated using toxic equivalent factors (TEFs) relative to 2,3,7,8-tetrachloro dibenzo-*p*-dioxin (TCDD)[3]. Incremental lifetime cancer risk (ILCR) and hazard quotient (HQ) was assessed by calculating the lifetime average daily dose (LADD) of PCBs[10-11] using the following equations:

$$\text{LADD (mg kg}^{-1}\text{ d}^{-1}\text{)} = (Cs \times IR \times F \times EF \times ED)/(BW \times AT)$$

$$\text{Cancer Risk} = \text{LADD} \times \text{Cancer Oral Slope Factor (CSF)}$$

$$\text{Hazard Quotient (HQ)} = \text{LADD/RfD}$$

Where, Cs is the pollutant concentration in soil (mg kg^{-1}), IR is the soil ingestion rate (100 mg d^{-1} for adult and 200 mg d^{-1} for children), F is the unit conversion factor, EF is exposure frequency (365 d y^{-1}), ED is the lifetime exposure duration (adult, 70 y; Children, 12 y), BW is the body weight (adult, 70 kg; children, 27 kg), and AT is the averaging time for carcinogens (EFxED d). CSF is an oral cancer slope factor (per mg/kg/day). RfD is the reference dose of individual dioxin like PCBs[12].

Table 1: Estimated PCB's TEQ, and LADD, ILCR and HQ for adults and children due to PCBs exposure

Parameters*		**Unit**	**Range**		**Mean**
			Minimum	Maximum	
Σ28PCBs		µg kg^{-1}	3.25	25.22	9.21
Σ12DL-PCBs†		µg kg^{-1}	0.12	2.25	0.65
Total Toxic equivalent		ng-TEQ kg^{-1}	1.52	64.32	12.47
$LADD_{Non\ DL\text{-}PCBs}$	Adults	mg kg^{-1} d^{-1}	$4.6x10^{-9}$	$3.6x10^{-8}$	$1.3x10^{-8}$
	Children	mg kg^{-1} d^{-1}	$2.4x10^{-8}$	$1.9x10^{-7}$	$6.8x10^{-8}$
$LADD_{DL\text{-}PCBs\text{-}TEQ}$	Adults	mg kg^{-1} d^{-1}	$2.2x10^{-12}$	$9.2x10^{-11}$	$1.8x10^{-11}$
	Children	mg kg^{-1} d^{-1}	$1.1x10^{-11}$	$4.8x10^{-10}$	$9.2x10^{-11}$
$ILCR_{Non\ DL\text{-}PCBs}$	Adults	-	$9.3x10^{-9}$	$7.2x10^{-8}$	$2.6x10^{-8}$
	Children	-	$4.8x10^{-8}$	$3.7x10^{-7}$	$1.4x10^{-7}$
$ILCR_{DL\text{-}PCBs\text{-}TEQ}$	Adults	-	$3.3x10^{-7}$	$1.4x10^{-5}$	$2.7x10^{-6}$
	Children	-	$1.7x10^{-6}$	$7.1x10^{-5}$	$1.4x10^{-5}$
HQ	Adults	-	$6.6x10^{-5}$	$2.8x10^{-3}$	$5.4x10^{-4}$
	Children	-	$3.4x10^{-4}$	$1.4x10^{-2}$	$2.8x10^{-3}$

*LADD-life time average daily dose, ILCR-Incremental life time cancer risk, HQ-Hazardous quotient;
†DL-PCBs=Sum of CB-77, -81, -105, -114, -118, -123, -126, -156, -157, -167, -169 and CB-189

Results and discussions

The concentration of total 28 PCBs and 12 DL-PCBs were ranged between 3.25-25.22 µg kg^{-1} and 0.12-2.25 µg kg^{-1} with the mean value of 9.21±1.17 µg kg^{-1} and 0.65±0.13 µg kg^{-1}, respectively (Table 1). Environmental guidelines for PCBs in soil have not been established in India. Therefore, PCBs concentration was compared with guideline from National Oceanography and Atmospheric Administration (NOAA), USA and Canadian government. The observed levels of PCBs obtained in this study were much lower than stipulated guideline values and concluded with no environmental health risk.

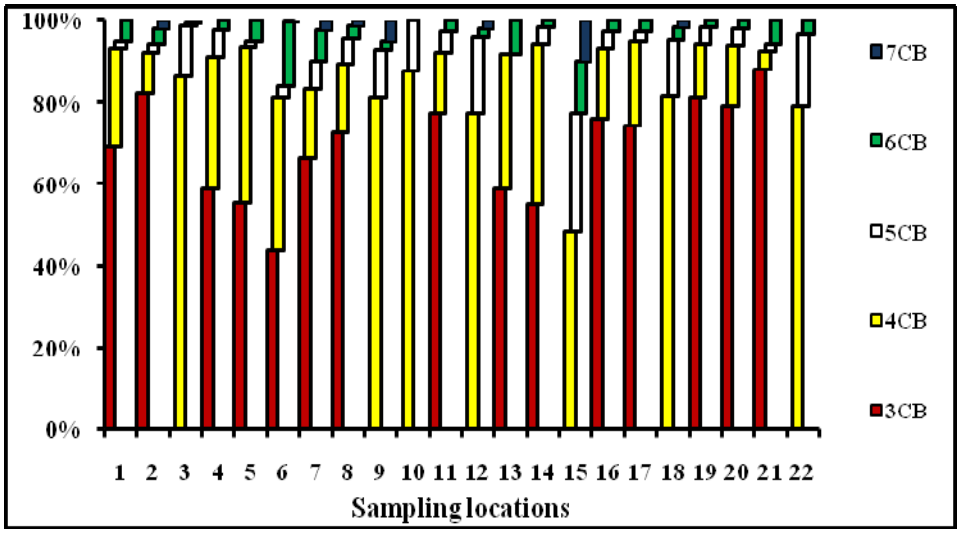

Fig. 1: PCB Homolog pattern in soils at different sampling locations.

PCB-18 was the sole dominant and accounted for more than 50% of total 28-PCBs, the contribution of other individual congeners was less than 10%. WHO's DL-PCBs accounted for 6.5% of total PCBs. Non-ortho PCBs were contributing comparatively more than mono-ortho PCBs to total DL-PCBs. PCB congener 169 was the dominant contributor and accounted for 60% of total DL-PCBs. The WHO toxicity equivalent quotient (TEQ) for all DL-PCBs ranged from 1.52 to 64.32 ng-TEQ kg^{-1} with the mean values of 12.47 ng-TEQ kg^{-1} (±3.38 ng-TEQ kg^{-1}). Non ortho-PCB congener CB-169 was the main contributor and accounted for >99% to total TEQ. Congener CB-169 represent the higher TEQ and sole contributor with >99%.

Three-chlorinated PCBs (57%) was the most dominant homolog with concentration ranges and mean value of 1.9-22.2 µg kg^{-1} and 7.7±1.1 µg kg^{-1}, respectively, followed by tetra-chlorinated (31%) with range and mean of 1.0-9.1 µg kg^{-1} and 2.8±0.4 µg kg^{-1}, respectively (Figure 1). Tri-chlorinated biphenyls along with tetra-chlorinated homolog accounted for 88% of total PCBs. Researchers have reported the combustion process, automobile exhaust and the industrial activities as potential sources of PCBs to industrial areas[13].

PCB congeners in the ambient environment partition into the gas and particle phases[8]. Observed homolog pattern in this study may have originated from the atmospheric transport[14]. Other sources of PCBs in these soils may be from anthropogenic activities, especially burning of mixtures of waste, containing garden wastes, paper, plastics, PVC (polyvinyl chloride) and painted wood may produce a relatively large amount of dioxin like-PCBs[15].

The average LADD of PCBs-TEQ intake for adults ($1.8x10^{-11}$ mg TEQ kg^{-1} d^{-1}) and children ($9.2x10^{-11}$ mg TEQ kg^{-1} d^{-1}) corresponds to 0.018 pg TEQ kg^{-1} d^{-1} or 0.126 pg TEQ kg^{-1} $week^{-1}$ and 0.092 pg TEQ kg^{-1} d^{-1} or 0.644 pg TEQ kg^{-1} $week^{-1}$ for adults and children, respectively (Table 1). These estimated TEQ intakes were lower than recommended tolerable intake of TEQ set by the international agencies. ATSDR recommended the TDI dioxins as 1.0 pg TEQ $kg^{-1}d^{-1}$ proposed by ATSDR[1]. The European Commission recommended and fixed a tolerable weekly intake (TWI) of 14 pg WHO-TEQ kg^{-1} for dioxins and 12 dioxin-like PCBs. In Asian countries like Japan established the comparatively higher TDI of dioxins as 4 pg-TEQ $kg^{-1}d^{-1}$.

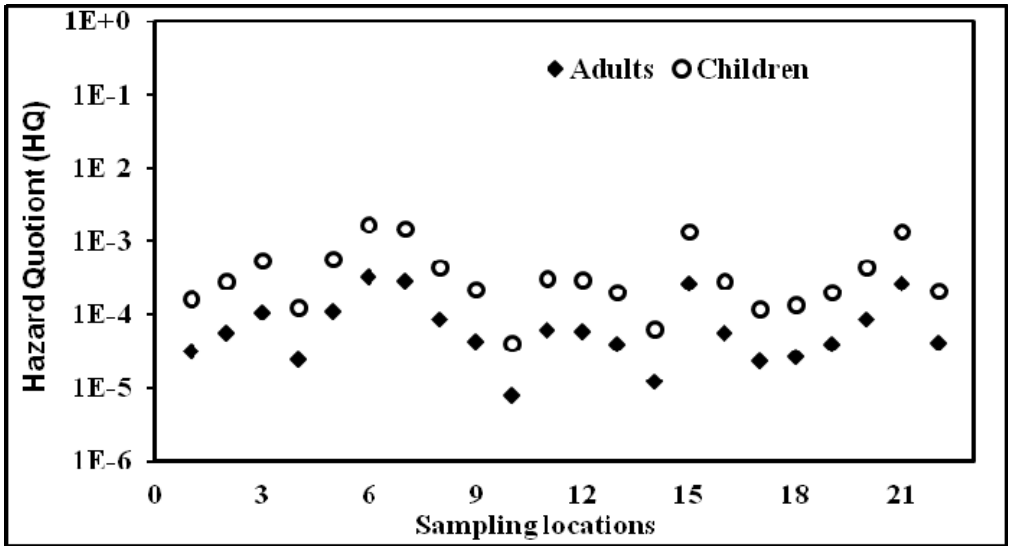

Fig. 2: Hazard Quotient (HQ) due to total PCBs exposure to adults and children

The estimated ILCR from non dioxin like PCBs to adults and children was between $9.3x10^{-9}$-7.2x10-8 and $4.8x10^{-8}$-3.7x10-7, respectively, with the average value of $2.6x10^{-8}$ and $1.4x10^{-7}$, respectively for adults and children. However, the ILCR from dioxin like PCBs (DL-PCB-TEQ) to adults and children was in the range of $3.3x10^{-7}$-$1.4x10^{-5}$ and $1.7x10^{-6}$-$7.1x10^{-5}$, respectively with an average of $2.7x10^{-6}$ and $1.4x10^{-5}$, respectively for adults and children. These estimated ILCR for residents of Korba, India were within acceptable risk distribution of 10^{-6}-10^{-4} by USEPA[12].

The non-carcinogenic hazard quotients (HQs) for human adults and children from PCBs exposure through soil ingestion pathway were quantified. The average HQs was $5.4x10^{-4}$ and $2.8x10^{-3}$ for adults and children

respectively, and ranged between $6.6x10^{-5}$ to $2.8x10^{-3}$ and $3.4x10^{-4}$ to $1.4x10^{-2}$ for adults and children respectively (Figure 2). The observed HQs for adults and children living in Korba, India, is much below the acceptable risk level (HQ=1) indicating a low risk.

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