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Research Article

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Ecological and Health Risk Assessment of Polychlorinated Biphenyls in Water and Sediments in Bodo Riverine Area, River State, Nigeria

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ABSTRACT

Concentrations of nine polychlorinated biphenyls (PCBs) were assessed in sediments and water in the Bodo River area, Gokana Local Government of River state Nigeria to assess the risk associated within the region due to the effect of oil spillage and marine pollution. The analytical procedure involved the application of Gas Chromatography coupled with mass spectrometric detection (GC/MS) for identification and quantification of and polychlorinated biphenyls respectively with high degree of accuracy and precision after triplicate analysis. All the selected PCB congeners analyzed were detected in the analyzed samples at different frequencies. The total concentrations of PCBs ranged from nd (not detected) to 4.15 mg/kg in sample A with an average concentration of 1.66 mg/kg, nd to 8.4 mg/kg in sample B with an average concentration of 3.25 mg/kg and nd to 7.30 mg/kg in sample C with an average concentration of 3.64 mg/kg in sediments. While the total concentrations of PCBs in the water sample ranged from nd (not detected) to 1.25 mg/kg in sample A with an average concentration of 0.56 mg/kg, nd to 4.50 mg/kg in sample B with an average concentration of 1.20 mg/kg and nd to 2.2 mg/kg in sample C with an average concentration of 0.88 mg/kg. Health risk assessment employed in this study includes the chronic daily intake and the carcinogenic risk via ingestion, inhalation and dermal contact using established guidelines. The total concentrations of PCBs were used to assess the cancer risk probabilities in humans via ingestion, dermal contact and inhalation of sediments particles. Very low cancer risk was found in all water samples compared to sediments samples caused by ΣPCBs. The results of the ecological risk assessment of PCBs in the Bodo River demonstrated the presence of PCBs in all sampling sites showing that the sites were highly contaminated with largely negative biological effects and a high potential risk to the environment.

Keywords: Polychlorinated Biphenyls, Risk Assessment

Introduction

PCBs also known as polychlorinated biphenyls is a class of pollutant grouped under persistent organic pollutants due to the long durability in the environment they are found and are capable of posing serious health challenges over a long period of time [1-3]. PCBs are a family of synthetic organic compounds with general chemical formula $C_{12}H_{10-n}Cl_n$ with n ranging between 1 and 10. They are hydrophobic and possess high rate of accumulation potential in organisms and magnification through the food chain. They are components of transformers, capacitors, hydraulic and heat exchange fluids, and the dismantling and burning activities promote its leakage and spread into the surrounding soils [1,4]. PCBs are believed to act as endocrine disruptors like other persistent organic pollutants such as polycyclic aromatic hydrocarbon (PAH) and dichlorodiphenyltrichloroethane (DDT) by antagonizing the actions of hormone regulation [5]. According to Jacobson et al., The most commonly observed health effects in people exposed to extremely high levels of PCBs are skin conditions, such as chloracne and rashes known to be symptoms of acute systemic poisoning dating back to 2002. Studies in workers exposed to PCBs have shown changes in blood and urine that may indicate liver damage [6]. PCBs that have dioxin-like activity are known to cause a variety of teratogenic effects in animals. Exposure to PCBs causes hearing loss and symptoms similar to hypothyroidism in rats [7]. There have been dozens of studies examining the possible association between breast cancer and PCB exposure [8,9]. Breast cancer and PCB body burdens have been examined in at least 24 study groups comprising over 5000 breast cancer cases, and the collective studies provide little support for the premise that body burdens of PCBs are associated with elevated risk for breast cancer. Laden et al., did a combined analysis of five US studies that assessed blood plasma or serum levels of DDE and PCBs and breast cancer risk [10]. The authors reported that the combined evidence does not support an association of breast cancer risk with plasma/serum concentrations of PCBs. Ecological risks assessment (ERA) is largely concerned with establishing the potential relationship between a contaminant source and an ecological effect triggered by exposure of organisms to the contaminant. Furthermore, human health risk assessment mainly aims to protect humans,

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whereas ERA is mainly concerned with protection of wildlife. This study evaluates the health and ecological implications on exposure to PCBs and possible recommendation in reducing the exposure to harmful persistent organic pollutants.

Materials and Methods

Description of Sample Area

Bodo is located in Gokana Local Government Area of Ogoni Land in Rivers State, Nigeria. It is the largest population settlement in Ogoni and one of the largest in Rivers State. Its population is overwhelmingly comprised of subsistence farmers and fishermen. Much of the farming work is done by hand and by women [11]. It is bounded on the north and east by the Imo River, on the south by the coastal sand plains, and on the west by the Aba-Port Harcourt highway. The Delta region contains a range of environmental zones including coastal sand plains, deltaic and floodplains, mangrove forests, and barrier island habitats. The major source of palm wine comes from the raffia palm tree. Bodo an oil producing area, was hit by two massive oil spills in 2008-2009 which results in environmental devastation from the Trans-Niger pipeline. The average temperatures in the area range between 77.0°F in August to 81.0°F in March and April. This area receives 93 inches of rainfall during per year; heaviest rains arrive during the months of July and August. The Ogoni are renown for their carved masks and traditional dancers are an important part of many ceremonies in Bodo. The issue of frequent ailment and other pollution related diseases such as lung disease and food poison among other diseases have been found to be common among the habitants of this region.

Sample Collection

Sampling was carried out during September 2021 from three locations. From each sampling location, approximately 100 grams of soil and 100 ml of water was collected in duplicates, and mixed thoroughly to ensure the representative sample from each location. An aliquot of homogenized soil was transferred to clean and labelled wide mouth amber glass containers. After labelling the sample containers, they were transported ice-preserved to the laboratory and kept in refrigerator until further extraction.

Chemicals and material

HPLC grade solvents used in sample processing were procured from Merck, India. Silica gel (100-200 mesh) procured from Sigma-Aldrich (USA) and activated at 130°C for 16 h. Anhydrous sodium sulphate was cleaned with solvents and stored in the sealed desiccator. Reference standards of 28 PCB congeners. Standard solutions with suitable concentrations were used for instrument calibration and other quality control analysis.

The equipment used includes electric blender, grinder digital sensitive scale, 250ml and 500ml beaker, test tubes, sterilized sample bottles, injector, Absorption Spectrophotometer (Varian SpectrAA 600 model USA), injector, GC-Ms (gas chromatography/ mass spectrometer), 0-1000ml micro pipette, digital weighing balance, magnetic starrier and shaker,fume cupboard, heating mantle, gentrifuge tube, glass wool.

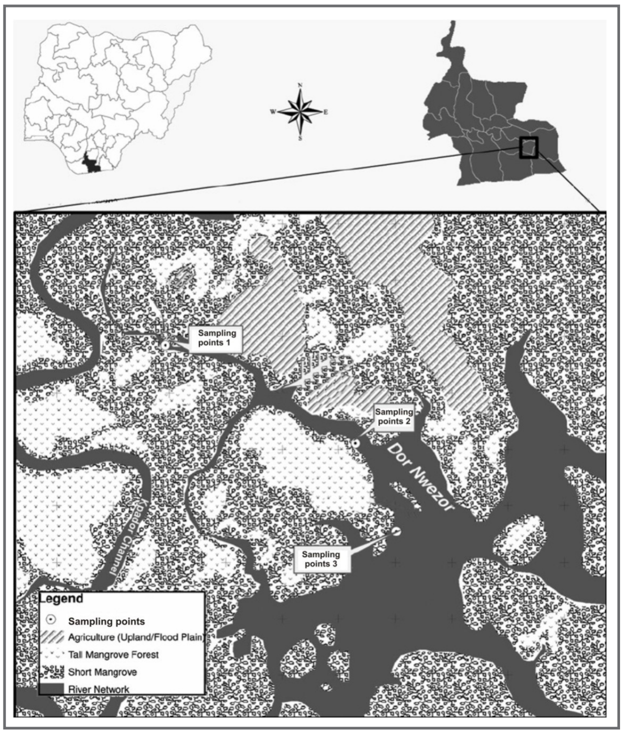


Figure 1: Map showing the study area and sampling point

Sample Extraction and Clean-Up

Sediment samples were extracted using pressurized liquid extraction procedure as per USEPA's SW-846 Method 3545 adopted from Bhupander et al., 2 g sample was homogenized and dried. The extraction was carried out with accelerated solvent extractor using acetone: hexane (v/v, 1:1) in two cycles with 5 min. static time. The multilayered glass column chromatography with modified silica was performed for extract clean up. Multilayered silica column (300×30 mm) was packed from bottom to up with 2.5 g silica gel, 4.0 g silver nitrate silica gel, 2.5 silica gel, 4.0 basic silica gel, 2.5 g silica gel, 12.0 g acid silica and 5.0 g anhydrous sodium sulphate. The column was prerinsed with 100 mL n-hexane before sample was loaded. 10 ml of water samples was measured. To each portion of the samples, 2ml methanol,4ml 0.5 of sodium hydroxide and 2ml distil water was added. The mixture was rinsed with 4ml 0.5M sodium hydroxide solution. 25ml of the solution was measured using measuring cylinder and 2ml hydrogen per oxide solution was added and stir on a magnetic stirrer for 10mins to homogenize. 4ml of 0.5M HCL and acetonitrile was added and heated to evaporate in a water bath for 40-50min then reconstituted with 20ml of distil water ready to be injected in GC-MS (Gas Chromatography/ Mass Spectrometer). The elution of PCBs was subsequently carried out using 170 mL hexane and concentrated to 2.0 mL. The eluted extract was concentrated under gentle stream of pure nitrogen using Rotatory Vacuum evaporator and Turbo Vap (Caliper, USA) to 1.0 mL and transferred to auto sampler vial for PCBs analysis by gas chromatograph to quantify eight PCB congeners (PCB 28, PCB 44, PCB 52, PCB 70, PCB 101, PCB 105, PCB 118 and PCB 138).

Health Risk Assessment

The health risk assessment employed in this study includes the following:

Chronic daily intake (CDI) (mg/kg/day) of PCBs in sediments

$$\text{CDI-ingestion} = \left(\frac{CS \times IRs \times EF \times ED \times TR}{BW \times AT}\right) \quad (1)$$

$$\text{CDI-dermal} = \left(\frac{CS \times SA \times EF \times ED \times TR}{BW \times AT \times GIABS}\right) \quad (2)$$

$$\text{CDI-inhalation} = \left(\frac{CS \times \frac{1}{VF} \times \frac{1}{PEF} \times EF \times ET_{ih} \times 1day/24hr \times ED}{AT}\right) \quad (3)$$

Where CS is PCBs concentration in sediment and water (mg/kg), IRs is soil ingestion rate (mg/day) (100mg/day for adults and 200mg/day for children), EF is exposure frequency (350-day year^{-1}), ED is exposure duration (26 years for adults and 6 years for children), TR* is target risk ($1x10^{-6}$ mg/mg) for carcinogen calculation only, BW is body weight (80kg for adults and 15kg for children), AT is average time (carcinogen =70×365), SA is skin surface area (6032cm^2/day for adults and 2373 cm^2/day for children), AF is water adherence factor: (0.2mgcm^{-2} for adults and 0.07mgcm^{-2} for children), ABSsk is fraction of chemical absorbed through the skin (unit-less) (0.001 for adults and children), GIABS is fraction of contaminant absorbed in gastrointestinal tracts (unit-less) (1.0 for adults and children), ETih is Exposure time (9hrs/days for adults and 6 hrs/day for children), VF is Volatilization factor (0.006 m^3/kg for adults and children), PEF is Particulate emission factor (1.36x106 m^3/kg for adults and children), [11,12].

Chronic Daily Intake (CDI) (mg/kg/day) of PCBs in Water

$$\text{CDI-ingestion} = \left(\frac{CS \times IR_W \times EF \times ED \times TR}{BW \times AT}\right) \quad (4)$$

$$\text{CDI-dermal} = \left(\frac{CS \times SA \times EF \times ED \times TR}{BW \times AT \times GIABS}\right) \quad (5)$$

Where CS is PCBs concentration in water (mg/L), IRw is daily water ingestion rate (L/day) (2.5L/day for adults and 0.78L/day for children), EF is exposure frequency (350-day year^{-1}), ED is exposure duration (26 years for adults and 6 years for children), TR is target risk ($1x10^{-6}$ mg/mg) for carcinogen, BW is body weight (80kg for adults and 15 kg for children), AT is (carcinogen =70×365), SA is skin surface area (19652cm^2 for adults and 6365cm^2 for children), ABSsk is fraction of chemical absorbed through the skin (unit-less) (0.001 for adults and children), GIA_{BS} is fraction of contaminant absorbed in gastrointestinal tracts (unit-less) (1.0 for adults and children) and ET_w is exposure time during work event (1h/event for adults and children).

Cancer Risk Assessment of PCBs

Carcinogenic risk assessment was determined using CDI of dermal, ingestion and inhalation as shown in equation (6) [11,12].

$$Risk_{total} = Risk_{der} + Risk_{ing} + Risk_{inh} \quad (6)$$

Where Risk is a unit-less probability of an individual developing cancer over a lifetime, CSF is Cancer slope factor of PCBs (mg/kg/day), Risk total is the total excess lifetime cancer calculated from risk pathway. While in water samples, the total risk is given as:

$$Risk_{total} = Risk_{der} + Risk_{ing} \quad (7)$$

Table 1: Reference Value for PCBs

TPHs	Dermal		Ingestion		Inhalation	
	CSF	RfD	OSF	RfD	IUR	RfC
PCB 28 (TriCB)	NA	NA	NA	0.3	NA	0.003
PCB 31 (TriCB)	0.01*	0.16**	0.01*	0.2	6E-06*	0.16**
PCB 44	0.001*	0.16**	0.001*	0.6	6E-07*	0.16**
PCB 52 (TetraCB)	NA	NA	NA	0.4	NA	NA
PCB 70	NA	NA	NA	0.4	NA	NA
PCB 101 (PentaCB)	NA	NA	NA	3.0	NA	NA
PCB 105	0.01*	0.16**	0.01*	0.1	6E-06*	0.16**
PCB 118	0.1*	0.16**	0.1*	0.3	6E-05*	0.16**
PCB 138 (HexaCB)	0.1*	0.16**	0.1*	0.16**	6E-05*	0.16**

Where: *, **[11,12]. IRIS: CSF: cancer slope factor (mg/kg/day), OSF: oral slope factor (mg/kg/day), IUR: inhalation unit risk (mg/m^3), RfD: reference dose, RfC: reference concentration.

Ecological Risk Assessment of Sediment PCBs

This study was conducted by using quantitative methods to classify the level of potential ecological risk.

$$RI = \Sigma E^i_r \quad (8)$$

$$E^i_r = T^i \times C^i_f \quad (9)$$

$$C^i_f = C_i / C^i_n \quad (10)$$

C^i_f is the pollution index of a pollutant; C^i is the measured concentrations of contaminants in the sediment; C^i_n is the global contaminant levels in pre-industrial sediments (0.01 mg/kg); E^i_r is the potential risk parameters for individual pollutants; and T^i is the toxic response parameters for individual pollutants ($T^i = 40$) and RI is the risk index.

The risk levels corresponding to the indices of individual risk factors are as follows:

- $E^i_r < 40$ is a minor ecological hazard;
- $40 \leq E^i_r < 80$ is a medium ecological hazard;
- $80 \leq E^i_r < 160$ is a strong ecological hazard;
- $160 \leq E^i_r < 320$ is a very strong ecological hazard;
- $E^i_r \geq 320$ is a pole-strength ecological hazard.

Statistical Analysis

The data collected were subjected to one way ANOVA at significant level of 0.05% to determine the if the analysis is under statistical control and to check for significance. Standard deviation was also calculated to determine the extent of precision of instrument.

Results and Discussion

Results

The results of PCBs analysis are shown in the table below:

Table 2: Concentration of PCBs in sediments in mg/kg

PCBs	Retention Time(secs)	Soil Samples Concentration (mg/kg) Sample code		
PCBs		S_A	S_B	S_C
PCB 28 (TriCB)	6.18	3.11 ± 0.002	5.9 ± 0.002	2.3 ± 0.011
PCB 31 (TriCB)	6.23	ND	0.6 ± 0.003	7.3 ± 0.045
PCB 44	6.45	1.40 ± 0.001	4.6 ± 0.002	6.9 ± 0.001
PCB 52 (TetraCB)	6.47	6.1 ± 0.002	ND	1.8 ± 0.001
PCB 70	6.47	ND	0.3 ± 0.004	ND
PCB 101 (PentaCB)	7.21	0.15 ± 0.33	8.4 ± 0.015	5.2 ± 0.001
PCB 105	7.26	ND	5.9 ± 0.021	2.6 ± 0.001
PCB 118	7.39	4.15 ± 0.024	0.45 ± 0.025	6.67 ± 0.003
PCB 138 (HexaCB) MEAN	7.82	ND 1.66	3.1± 0.032 3.25	ND 3.64

Results presented as mean ± standard deviation of three replicates. No significant difference at $p<0.05$.

ND- Not Detected

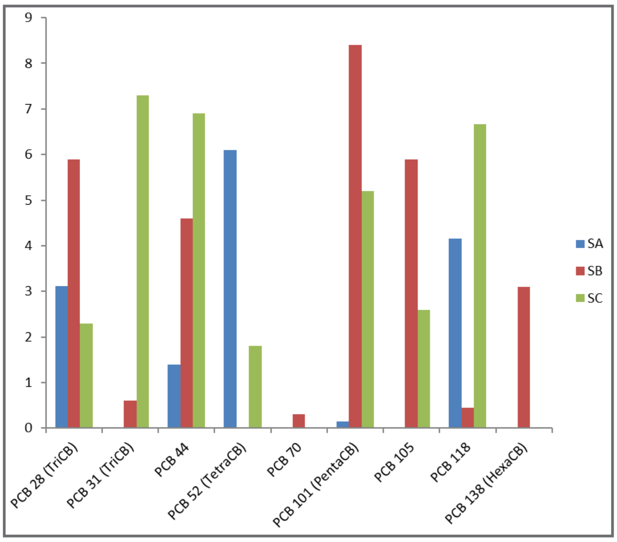


Figure 2: Chart of PCBs Concentration in soil in mg/kg

Table 3: Concentration of PCBs in water in mg/l

PCBs	Retention Time(secs)	Water Samples Concentration (mg/l)		
PCBs		S_A	S_B	S_C
PCB 28 (TriCB)	6.18	3.11 ± 0.002	5.9 ± 0.002	2.3 ± 0.011
PCB 31 (TriCB)	6.23	ND	0.6 ± 0.003	7.3 ± 0.045
PCB 44	6.45	1.40 ± 0.001	4.6 ± 0.002	6.9 ± 0.001
PCB 52 (TetraCB)	6.47	6.1 ± 0.002	ND	1.8 ± 0.001
PCB 70	6.47	ND	0.3 ± 0.004	ND
PCB 101 (PentaCB)	7.21	0.15 ± 0.33	8.4 ± 0.015	5.2 ± 0.001
PCB 105	7.26	ND	5.9 ± 0.021	2.6 ± 0.001
PCB 118	7.39	4.15 ± 0.024	0.45 ± 0.025	6.67 ± 0.003
PCB 138 (HexaCB) MEAN	7.82	ND 1.66	3.1± 0.032 3.25	ND 3.64

Results presented as mean ± standard deviation of three replicates. No significant difference at $p<0.05$.

ND- Not Detected

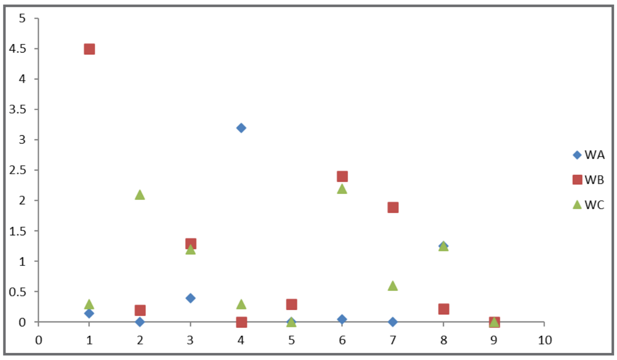


Figure 3: Chart of PCBs Concentration in water in mg/l

Table 4: Chronic daily intake of PCBs in sediment (Adults)

PCBs	Concentration (mg/kg)	Mean concentration (mg/kg)	CDI (Sediments) in Adults			
			Ingestion	Dermal	Inhalation	Total risk
ΣPCB 28	11.31	3.77	1.67E-06	1.02E-04	6.17E-05	1.65E-04
ΣPCB 31	7.9	2.63	1.17E-06	7.06E-05	4.30E-05	1.15E-04
ΣPCB 44	12.9	4.30	1.91E-06	1.15E-04	7.03E-05	1.87E-04
ΣPCB 52	7.9	2.63	1.17E-06	7.06E-05	4.30E-05	1.15E-04
ΣPCB 70	0.3	0.10	4.45E-08	2.67E-06	1.63E-06	4.34E-06
ΣPCB 101	13.75	4.58	2.03E-06	1.23E-04	7.50E-05	2.0E-04
ΣPCB 105	8.5	2.83	1.26E-06	7.60E-05	4.63E-05	1.24E-04
ΣPCB 118	11.27	3.76	1.67E-06	1.01E-04	6.15E-05	1.64E-04
ΣPCB 138	3.1	1.03	4.59E-07	2.77E-05	1.69E-05	4.51E-05
Total PCBs	76.93	25.63	1.14E-05	6.89E-04	4.20E-04	1.12E-03

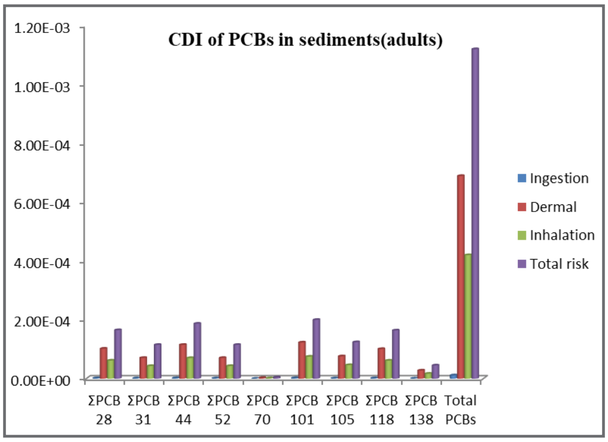


Figure 4: Chronic daily intake of PCBs in sediment (Adults)

Table 5: Chronic daily intake of PCBs in sediment (children)

PCBs	**Concentration (mg/kg)**	**Mean concentration (mg/kg)**	**CDI (Sediments) in children**			
			Ingestion	Dermal	Inhalation	Total risk
ΣPCB 28	11.31	3.77	2.06E-06	4.90E-05	9.49E-06	6.06E-05
ΣPCB 31	7.9	2.63	1.44E-06	3.42E-05	6.62E-06	4.23E-05
ΣPCB 44	12.9	4.30	2.36E-06	5.59E-05	1.08E-05	6.91E-05
ΣPCB 52	7.9	2.63	1.44E-06	3.42E-05	6.62E-06	4.23E-05
ΣPCB 70	0.3	0.10	5.48E-08	1.30E-06	2.51E-07	1.61E-06
ΣPCB 101	13.75	4.58	2.51E-06	5.96E-05	1.15E-05	7.36E-05
ΣPCB 105	8.5	2.83	1.55E-06	3.68E-05	7.13E-06	4.55E-05
ΣPCB 118	11.27	3.76	2.06E-06	4.89E-05	9.47E-06	6.04E-05
ΣPCB 138	3.1	1.03	5.64E-07	1.33E-05	2.59E-06	1.65E-05
Total PCBs	76.93	25.63	1.40E-05	3.33E-04	6.45E-05	4.12E-04

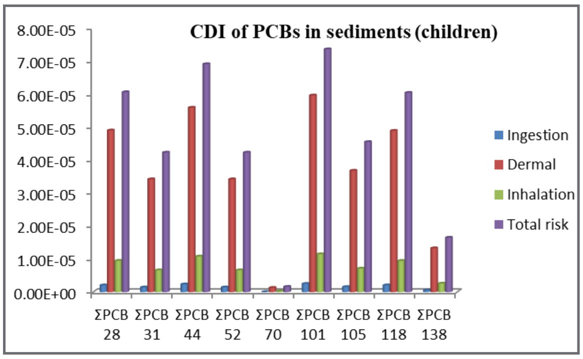


Figure 5: Chronic daily intake of PCBs in sediment (children)

Table 6: Chronic daily intake of PCBs in water (Adults)

PCBs	**Concentration (mg/kg)**	**Mean concentration (mg/kg)**	**CDI (water)**		
			Ingestion	Dermal	Total Risk
ΣPCB 28	11.31	3.77	4.15E-08	3.30E-04	3.30E-04
ΣPCB 31	7.9	2.63	2.92E-08	2.30E-04	2.30E-04
ΣPCB 44	12.9	4.30	4.77E-08	3.76E-04	3.76E-04
ΣPCB 52	7.9	2.63	2.92E-08	2.30E-04	2.30E-04
ΣPCB 70	0.3	0.1	1.11E-09	8.75E-06	8.75E-06
ΣPCB 101	13.75	4.58	5.08E-08	4.00E-04	4.00E-04
ΣPCB 105	8.5	2.83	3.14E-08	2.45E-04	2.45E-04
ΣPCB 118	11.27	3.76	4.17E-08	3.29E-04	3.29E-04
ΣPCB 138	3.1	1.03	1.14E-08	9.01E-05	9.01E-05
Total	76.93	25.63	2.84E-07	2.24E-03	2.24E-03

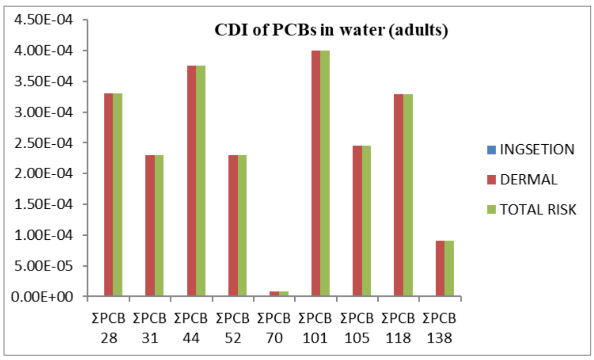


Figure 6: Chronic daily intake of PCBs in water (Adults)

Table 7: Chronic daily intake of PCBs in water (children)

PCBs	Concentration (mg/kg)	Mean concentration (mg/kg)	CDI (water)		
			Ingestion	Dermal	Total Risk
ΣPCB 28	11.31	3.77	1.62E-08	1.31E-04	1.31E-04
ΣPCB 31	7.9	2.63	1.13E-08	9.17E-05	9.17E-05
ΣPCB 44	12.9	4.30	1.85E-08	1.50E-04	1.50E-04
ΣPCB 52	7.9	2.63	1.13E-08	9.17E-05	9.17E-05
ΣPCB 70	0.3	0.1	4.3E-10	3.48E-06	3.48E-06
ΣPCB 101	13.75	4.58	1.96E-08	1.60E-04	1.60E-04
ΣPCB 105	8.5	2.83	1.21E-08	9.87E-05	9.87E-05
ΣPCB 118	11.27	3.76	1.62E-08	1.31E-04	1.31E-04
ΣPCB 138	3.1	1.03	4.43E-09	3.59E-05	3.59E-05
Total	76.93	25.63	1.10E-07	8.94E-04	8.94E-04

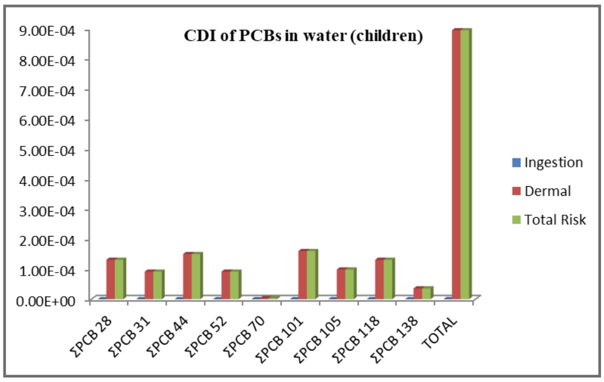
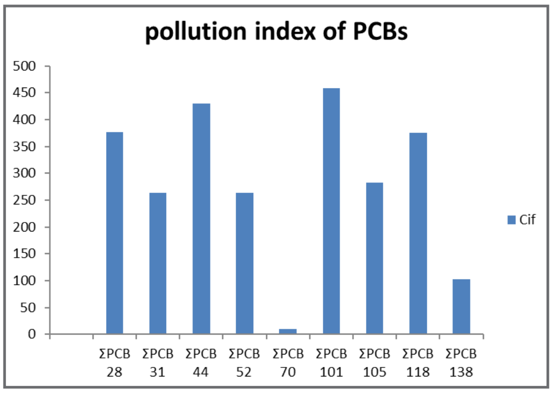
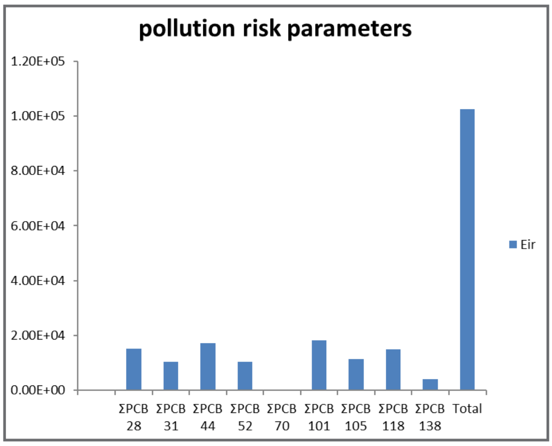


Figure 7: Chronic daily intake of PCBs in water (children)

Table 8: Ecological Risk Assessment of PCBs in Sediments

PCBs	Mean concentration (mg/kg)	C^i_f	E^i_r	RI
ΣPCB 28	3.77	377	15.1E+03	
ΣPCB 31	2.63	263	10.5E+03	
ΣPCB 44	4.30	430	17.2E+03	
ΣPCB 52	2.63	263	10.5E+03	
ΣPCB 70	0.1	10	4.0E+02	
ΣPCB 101	4.58	458	18.3E+03	
ΣPCB 105	2.83	283	11.3E+03	10.25E+04
ΣPCB 118	3.76	376	15.0E+03	
ΣPCB 138	1.03	103	4.12E+03	
Total	25.63	2563	10.25E+04	





Discussion

PCBs in the aquatic region are mainly derived from land runoffs and food chain transfer, they are volatile, displaceable and can be deposited back into water bodies. Coupled with the effects of oil spillage in the sampling locations, sediments are found to be a reservoir of pollutants and have continuous environmental effects. Health risk assessment was used to provide an indication of whether the level of PCBs detected in sediments and water samples can cause adverse health effects to human or not. Health risk assessment was evaluated via inhalation of sediment particles, dermal contact and ingestion according to the equations described in 1-7. Taking into the level of PCB concentrations in this study, the results were only used to assess the potential impact of these measured PCBs on humans. As shown in Table 4, the detected PCBs in sediments sample are above the acceptable limit of 1.0×10^{-6} via all exposure pathways and are capable of causing serious health effect in adults when exposed to them with the exception of PCB 70. The cumulative or total risk shows that adults within the vicinity are prone to serious health effects. The same conclusion is also applicable to children who are prone to serious health effect via ingestion and dermal contact of the sediment. Exposure via inhalation has minimal effect on children based on the calculated risk value as shown in Table 5. Also, adults are exposed to serious health effect on contact with water around the vicinity as the calculated risk values shows that dermal contact is the major pathway of contamination as compared to ingestion in Table 6. Before ingestion of the water, it is assumed to be subjected to treatment i.e boiling before usage or consumption. Similar risk is also seen in children as shown in Table 7. For different exposure pathways, the increasing trend in risks of cancer for PCBs was as follows: inhalation < ingestion < dermal contact. Table 8 shows the cumulative ecological risk associated with the sediments in the sampling area and it reveals that the calculated potential risk parameter falls within the range of $E^i_r \geq 320$ and therefore pose a pole-strength ecological hazard in respect to Eq (9) which is be traceable to the effect of oil spillage overtime.

Conclusion

The study concluded that concentrations of PCBs including dioxin like-PCBs were higher than recommended guidelines for sediments and water samples which remain a source of diverse health problems in the Bodo community. The possible sources of PCBs contamination can be attributed to oil spillage, enhanced iol recovery and local industrial emissions from long range. It is therefore advisable that effective water treatment process be employed to minimize the effect of pollutant and health hazard. Furthermore, risk assessments via ingestion, dermal and inhalation were evaluated based on the data obtained. The cancer risk of PCBs in the soils fell into very high range. The results of the ecological risk assessment of PCBs in the Bodo River demonstrated that PCBs in all sampling sites were highly contaminated and largely caused negative biological effects, with a high potential risk to the environment. It is noteworthy that Bodo community is contaminated with a number of pollutants in addition to PCBs such as PAHs and heavy metals and it is recommended that comprehensive risk assessment is required for all significant pollutants for the area.

Conflict of Interest: No conflict of interest

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