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Full Length Research Article

# POLYCHLORINATED BIPHENYLS CONTAMINATION IN LAGOS LAGOON AND IMPACTS ON THE BENTHIC MACROINVERTEBRATES COMMUNITY STRUCTURE

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**ABSTRACT**
Polychlorinated biphenyls (PCBs) are a group of persistent organic pollutants (POPs) that have generated global concerns for constituting hazards in the aquatic ecosystems. Their lipophilic nature makes them to accumulate in the sediment of water bodies resulting to some negative impacts on the benthic macroinvertebrates. This study was conducted to investigate the impact of the PCBs contamination on the benthic macroinvertebrate assemblage in the study area. Benthic samples were collected at six study stations for six months using Van-veen grab sampler. Sediments samples were removed from the benthic samples into a glass container and taken to the laboratory where extraction and clean up were conducted in preparation for Gas Chromatograph-Mass Spectrometer (GC-MS) analysis. This was performed using an Agilent 5977B GC/MSD system coupled with Agilent 8860 auto-sampler, a Gas (GC-MS) equipped with an Elite-5MS (5% diphenyl/95% dimethyl polysiloxane) fused with a capillary column (30 × 0.25μm ID × 0.25 μm df). The remaining part of each benthic sample was sieved *in situ* through a 0.5 mm sieve and preserved in 10% formalin inside a plastic container for further analysis in the benthic laboratory following standard procedures. Results obtained from this study indicate that there is a negative linear relationship between PCB concentrations and species abundance, diversity, equitability, evenness, and richness. This suggests that PCBs contamination in sediments may pose considerable ecotoxicological risk to the community structure of benthic macroinvertebrates of the lagoon. There is also a need to improve the waste management systems to prevent the entry of PCBs and other persistent organic pollutants into the Lagos lagoon and ultimately conserve the health of this very important marine ecosystem.

**Keywords:** Polychlorinated biphenyls; Benthic Macroinvertebrates; Sediment; Lagos lagoon; Anthropogenic; Pollution.

## 1.0 INTRODUCTION
Polychlorinated biphenyls (PCBs) are a class of non-polar toxic chemical compounds consisting of two connected benzene rings and chlorine atoms that can attach to any or all of 10 different positions (Figure 1). The PCBs have 209 different congeners and 10 different homologs (Jing *et al.,* 2018). The chemical formula of PCBs is $C_{12}H_{10-n}Cl_n$, where n (the number of chlorine atoms) ranges from 1 to 10 (Horwat *et al.,* 2015).

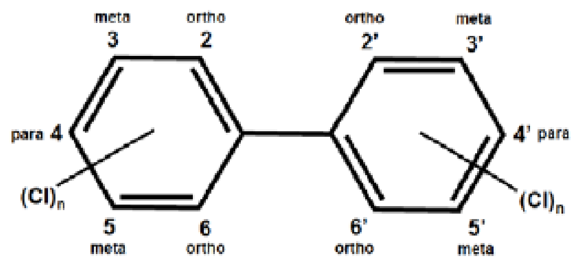


**Figure 1**: General chemical structure of polychlorinated biphenyls (Horwat *et al.,* 2015).
The number assigned to the carbon atoms represent the possible positions of chlorine atoms.

They are lipophilic in nature and hence, the tendency to accumulate along the food chains posing risks to the benthic communities (Almatari *et al.,* 2017). As PCBs concentrations settle in sediments, they bioaccumulate in organisms that inhabit the bottom of aquatic ecosystems (Bamidele *et al.,* 2020), known as benthic organisms (or benthos). This may be because benthic organisms are often deposit feeders, which feed by ingesting biota, organic and inorganic particles from the sediment surface or within the sediments (Simpson *et al.,* 2016).
Benthic macroinvertebrates are organisms without backbone and are big enough to be seen with an unaided eye, and live at least part of their lives at the bottom of a water body (Nwabueze *et al.,* 2020; Nkwoji *et al.,* 2020). The sedentary nature of this group of organisms renders them vulnerable to impacts from environmental stressors; hence, they represent site-specific ecological conditions and serve as useful bioindicators of pollution Nkwoji *et al.,* 2020). They also link organic matter and nutrient resources with higher trophic levels, thereby forming the key components of aquatic feeding relationship (Nkwoji *et al.,* 2020; Osuala *et al.,* 2020).
The species abundance, richness and diversity of aquatic communities can be used to determine the impacts of toxic substances and general health of the ecosystem (Nkwoji, 2022). Studies have reported that contamination of sediments by POPs including PCBs adversely affects the community structure of benthic macroinvertebrates (Moran *et al.,* 2017; Windsor *et al.,* 2019). According to Lohrer *et al.* (2023), contaminants can cause harmful effects to marine organisms and communities such as pathological and molecular disorders, impaired behaviour and survival and reduction in species diversity. Variations in community structure of benthic macroinvertebrates are therefore considered as veritable tools for monitoring alterations in aquatic ecosystems (Ibanga *et al.,* 2021).

The Lagos lagoon serves as a major hub of fishing, transportation and recreation for the Lagos population. Unfortunately, the lagoon is heavily impacted with pollutants due to the high human population and industries around the lagoon. Although, previous studies reported the presence of PCBs in sediment samples from Lagos Lagoon (Adewuyi & Adeleye, 2013; Benson *et al*., 2020; Benson *et al*., 2023; Unyimadu and Benson, 2023), there are still dearth of information on the impacts on the PVBs on the community structure of benthic macroinvertebrates in the lagoon.

## 2.0 MATERIALS AND METHODS

### 2.1 Description of Study Area and Stations

The Lagos lagoon (Figure 2) is the largest of the Nigeria lagoon system and drains into the Atlantic Ocean through the Lagos Harbour (Fajemila *et al.,* 2020). The lagoon has a depth that ranges between 2 and 5m in most part of it, and depending on tide and season. (Nkwoji *et al.,* 2020; Fajemila *et al.,* 2020). Salinity of the Lagos lagoon is highly influenced by the season (Fajemila *et al.,* 2020).

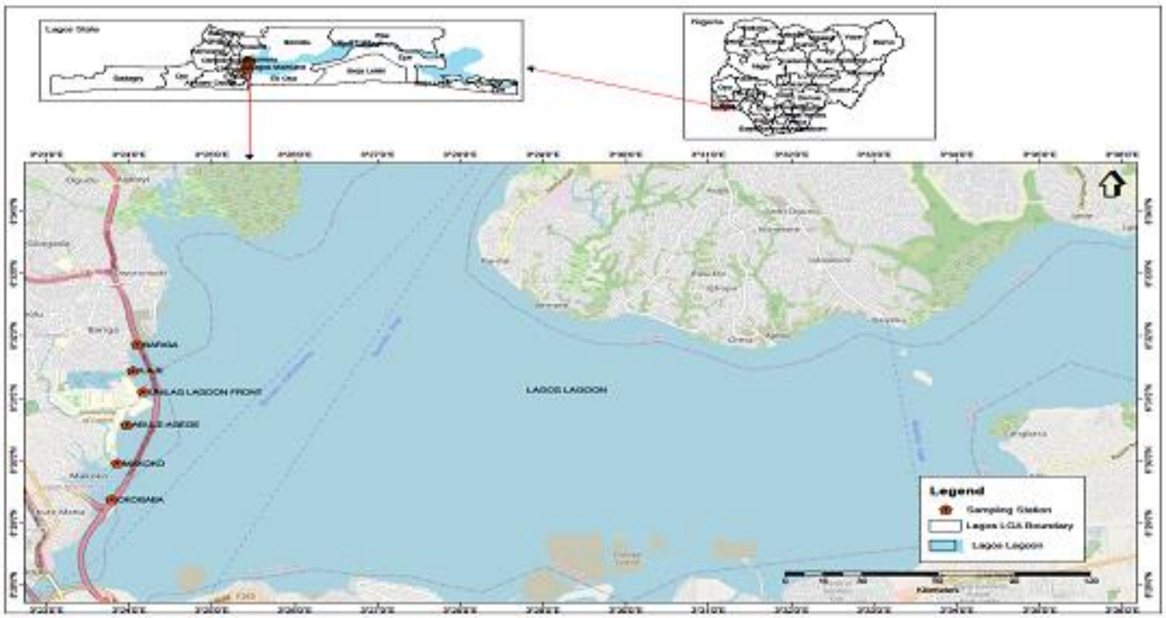


**Figure 2**: Lagos lagoon showing the sampling stations

### 2.2 Sampling Stations

Six sampling stations were selected for the study based on accessibility and proximity to expected pollution sources. The exact locations of the stations were determined with the aid of the global positioning system (GPS).

**Table 1**: Sampling Stations and their Coordinates

| Station No. | Station Name | Latitude | Longitude |
|---|---|---|---|
| 1 | Bariga | 6° 31' 51.2"N | 3° 24' 5.7"E |
| 2 | Ilaje | 6° 31' 26.4"N | 3° 24' 2.6"E |
| 3 | Unilag lagoon front | 6° 31' 5.9"N | 3° 24' 10"E |
| 4 | Abule-Agege | 6° 30' 34.2"N | 3° 23' 58.1"E |
| 5 | Makoko | 6° 29' 57.2"N | 3° 23' 51.2"E |
| 6 | Okobaba | 6° 29' 22.6"N | 3° 23' 47.2"E |

### 2.3 Sample Collection

Monthly collections of benthic samples were conducted using a Van-Veen grab monthly at the study stations for a period of six months. Sediment samples were removed from the benthic samples and stored in a glass container according to standard procedure for further sediment PCBs analysis in the laboratory.

### 2.4 Analysis of PCBs in Sediment Samples

#### *2.4.1 Extraction and Clean up for polychlorinated Biphenyls*

Five grams (5g) of the dried and sieved sediment was weighed into 100 ml conical flask and 25 mL of the mixture of Acetone / N-hexane / Dichlomethane (1:2:1) was added, sonicated for about 30 minutes at room temperature. The clear portion was decanted into a separate 100 mL beaker. Another 25mL of the above solvent was added to the residue in the conical flask and the extraction was repeated. The clear portion was decanted into the 100mL beaker. The extract was centrifuged at 1000RPM for 5 minutes. The clear supernatant was decanted into another clean 100mL beaker. The extract was allowed to concentrate to about 5mL under cool air in the absence of light. Then, the extract was cleaned up in a column containing anhydrous sodium sulphate and silica gel (Kampire *et al.*, 2017; Iniaghe and Kpomah, 2022)).

A column was packed with cotton wool containing 1g each of anhydrous sodium sulphate and silica gel. 2mL of N-hexane was used to condition the column. The extract was allowed to run through the column and was later eluted with a 2mL mixture of n-hexane & Dichloromethane (1:1). Then, the eluted sample was ready for gas chromatography-mass spectrometry analysis.

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#### *2.4.2 Gas Chromatography-Mass Spectrometry (GC-MS)*
GC-MS analysis of the extract was performed using an Agilent 5977B GC/MSD system coupled with Agilent 8860 auto-sampler, a Gas Chromatograph interfaced to a Mass Spectrometer (GC-MS) equipped with an Elite-5MS (5% diphenyl/95% dimethyl polysiloxane) fused with a capillary column (30 × 0.25μm ID × 0.25 μm df). For GC-MS detection, an electron ionization system was operated in electron impact mode with ionization energy of 70 eV. Helium gas (99.999%) was used as a carrier gas at a constant flow rate of 1 mL/min, and an injection volume of 1μl was employed (a split ratio of 10:1).
The injector temperature was maintained at 300°C, and the ion-source temperature was 250°C, and the oven temperature was programmed from 100°C (isothermal for 0.5 min), with an increase of 20°C/min to 280°C (2.5 min), Mass spectra were taken at 70 eV; a scanning interval of 0.5s and fragments from 45 to 450 Da. The solvent delay was 0 to 3 mins, and the total GC/MS running time was 21.33mins.

#### *2.4.3 Identification of photo components*
Interpretation of mass spectrum GC-MS was conducted using the database of the National Institute Standard and Technology (NIST) having more than 62,000 patterns and the National Centre for Biotechnology Information. the unknown components were compared with the spectrum of known components stored in the NIST library. The names of the compounds were identified.

### 2.5 Analysis of Benthic Macroinvertebrate Samples
The remaining part of each benthic sample was sieved *in situ* through a 0.5 mm sieve, and the materials retained on the sieve were preserved in 10% formalin inside a plastic container (Nkwoji *et al.,* 2020). Then, the benthic samples were transported to the laboratory and sorted with the aid of a hand-held magnifying lens to obtain the clean samples of the macrobenthos. All the cleaned benthic samples were identified to at least Genus level and analysed to assess their distribution, abundance and diversity.

### 2.6 Statistical Analysis
The data were presented as descriptive statistics (mean ± SD) using Microsoft Excel (2019) and to one-way Analysis of Variance (ANOVA) and correlation analysis to compare means, and also determine relationships and levels of significance using Microsoft Excel (2019) and the Statistical Package for Social Sciences (SPSS version 23). The biological indices such as the Margalef's index for species richness, Shannon–Wiener and Simpson's diversity indices, Dominance, as well as the Equitability index for evenness of the community were computed using the PAST statistical program. Values were considered statistically significant at $P \leq 0.05$.

## 3.0 RESULTS AND DISCUSSION

### 3.1 PCB concentration in sediment of the study area
The mean concentration of PCBs in the six sampled stations of the study area are presented in Figure 3. Okobaba sampling station recorded the highest concentration (2.62mg/L) of PCBs in the study, while the lowest (0.092500) was recorded in Unilag lagoon front. However, there was no significant difference (P>0.05) in the mean PCB concentrations across the six sampled stations.
It was also observed in this study that the number of low-chlorinated PCB homologues (mono- to penta-chlorinated PCBs) were more than that of the high-chlorinated ones (hexa-chlorinated PCBs). This is in agreement with Unyimadu and Benson (2023) who also reported similar findings in sediments from the Lagos lagoon. Out of the six stations sampled in this study, only two stations (Makoko and Okobaba) had mean sediment PCB concentrations that are above the effect range median (ERM) limit for total PCBs. The ERM estimates the likely adverse effects on organisms with respect to individual PCBs and also the cumulative toxic effects with respect to the sum of all the PCBs; thus, a concentration above ERM limit, which is 0.18 infers that adverse biological effects will frequently occur (Benson *et al.,* 2020). The mean sediment PCBs concentrations in Makoko and Okobaba were 1.24 and 2.63 respectively, while that of the remaining four stations sampled in this study were below the ERM limit. This could be as a result of the high level of anthropogenic activities in these areas. These include activities like boat construction, fishing, and trading in Makoko, as well as sawmilling activities and log transportation in Okobaba. Benson *et al.* (2020) also reported significant levels of PCBs in sediment samples from the Lagos lagoon which were above the ERM limit. Similarly, Benson *et al.* (2023) reported the presence of considerable amounts of PCBs in Makoko and Okobaba.

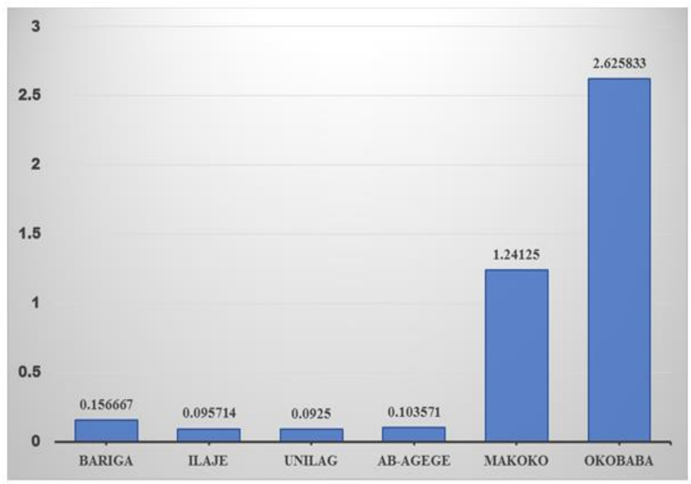


**Figure 3**: Mean spatial variation in PCB concentration during the period of study

### 3.2 Community Structure of Benthic Macroinvertebrates in the Study Area
The overall percentage contribution of species to the benthic macroinvertebrates sampled during the study period is represented in Figure 4. The gastropod *Tympanotonus fuscatus* dominated the macrobenthic assemblage, contributing 56% and followed by the Bivalve, *Aloides trigona* (12%). The least sampled benthic macroinvertebrates during the period of study were the Crustacea, *Penaeus notialis* and the Gastropod, *Thais* sp. Percentage contribution of the benthic macroinvertebrates by Class is represented in Figure 40. The Class Gastropoda contributed 74% while the Class Bivalvia, Crustacea, and Polychaeta accounted for 20%, 4%, and 2% respectively. Figure 5 represents the mean spatial and monthly variations in numerical abundance of benthic macroinvertebrates during the period of study. There is an observed general low abundance of the benthic macroinvertebrates in Makoko sampling station for all the months sampled. This low abundance is also corroborated in Table 2.

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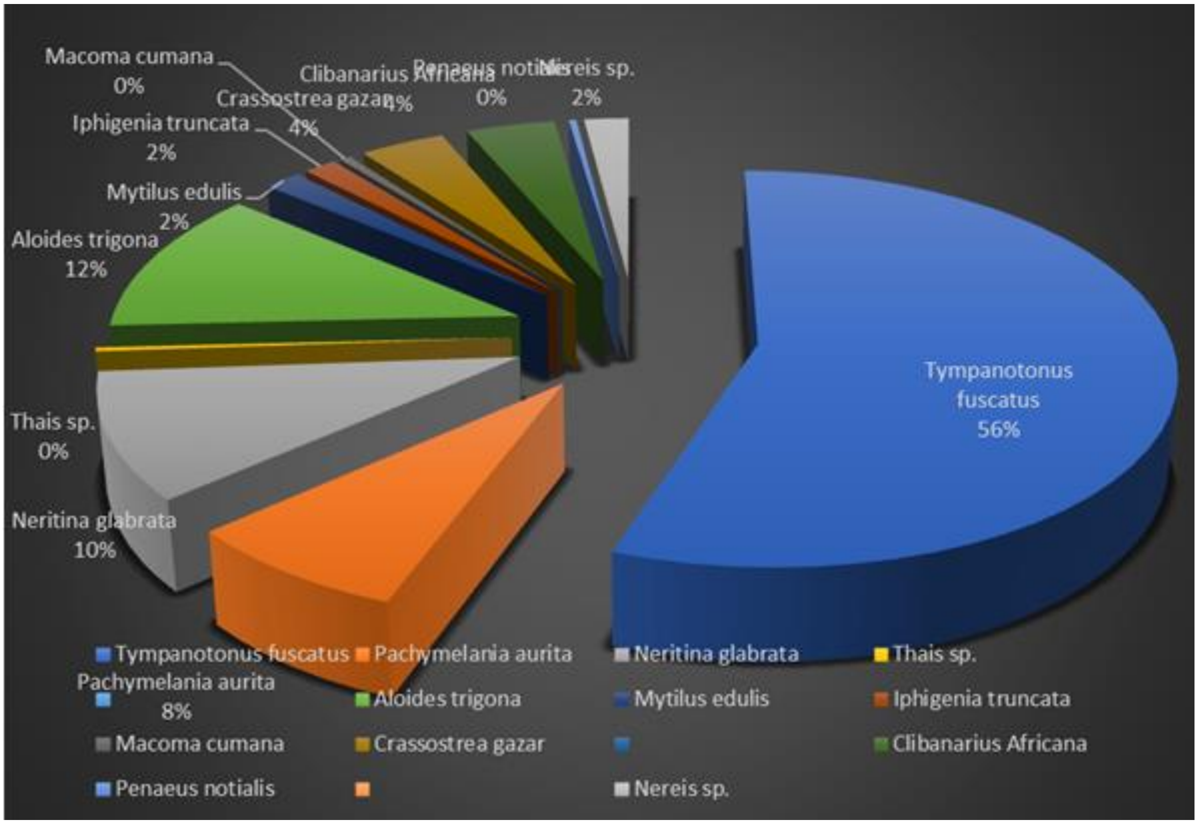


**Figure 4**: Species contribution to the total macrobenthic fauna abundance during the period of study

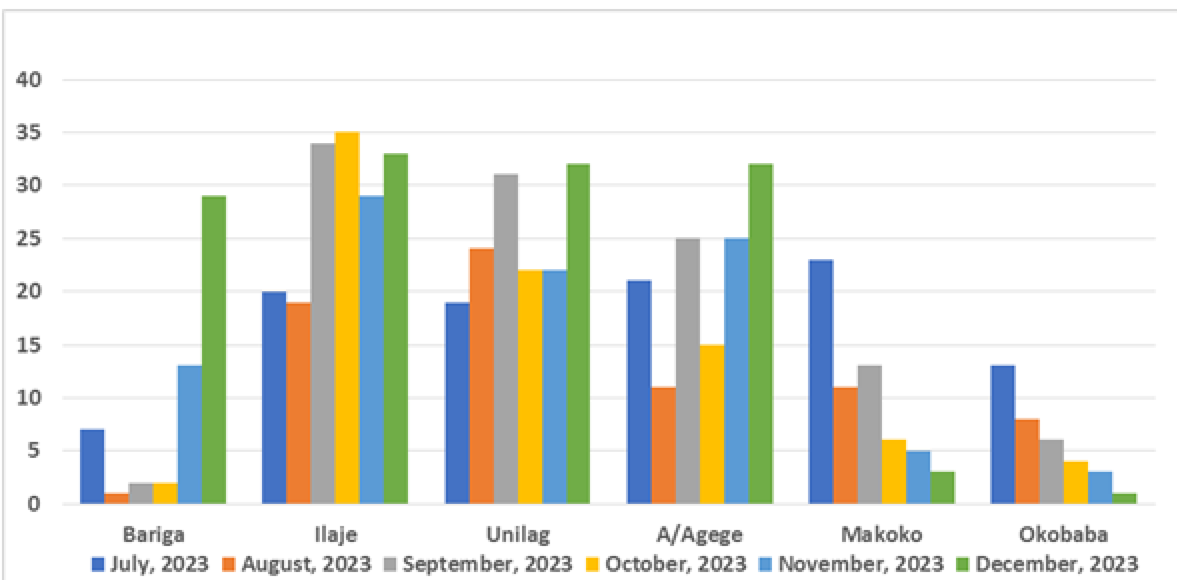


**Figure 5**: Mean spatial and monthly variations in numerical abundance of benthic macroinvertebrates during the period of study

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**Table 2**: Community Structure of the Benthic Fauna in the Study Area during the Period of Study

| | Bariga | Ilaje | Unilag | A/Agege | Makoko | Okobaba |
|---|---|---|---|---|---|---|
| No. of Species | 6 | 6 | 9 | 7 | 9 | 5 |
| No. of Indiv. | 54 | 170 | 150 | 129 | 61 | 105 |
| Dominance_D | 0.27 | 0.41 | 0.24 | 0.51 | 0.29 | 0.34 |
| Simpson_1-D | 0.73 | 0.59 | 0.76 | 0.49 | 0.71 | 0.66 |
| Shannon_H | 1.48 | 1.22 | 1.69 | 1.1 | 1.69 | 1.17 |
| Evenness_e^H/S | 0.73 | 0.56 | 0.6 | 0.43 | 0.6 | 0.65 |
| Brillouin | 1.33 | 1.16 | 1.59 | 1.02 | 1.49 | 1.11 |
| Menhinick | 0.82 | 0.46 | 0.73 | 0.62 | 1.15 | 0.49 |
| Margalef | 1.25 | 0.97 | 1.6 | 1.23 | 1.95 | 0.86 |
| Equitability_J | 0.83 | 0.68 | 0.77 | 0.56 | 0.77 | 0.73 |
| Fisher_alpha | 1.73 | 1.21 | 2.1 | 1.59 | 2.92 | 1.09 |
| Berger-Parker | 0.37 | 0.61 | 0.39 | 0.7 | 0.51 | 0.45 |
| Chao-1 | 6 | 6 | 9 | 7 | 9 | 5 |

### 3.3 Relationships Between PCB Concentration and the Community Structure of Benthic Macroinvertebrates in the Study Area

The relationships between PCB concentrations and the community structure of benthic macroinvertebrates in the six sampled stations were deduced using Pearson product moment correlation coefficient. A negative linear relationship was observed between PCB concentrations and both the Simpson's (-0.752mg/L) and Shannon-Wiener (-0.684mg/L) diversity indices (Figures 6 and 7 respectively). Similarly, PCB concentrations had a negative linear relationship with the number of individuals (-0.709), equitability (-0.728), evenness (-0.344), and Margalef's species richness (-0.398) as shown in Figures 8, 9, 10, and 11 respectively. On the other hand, a positive linear relationship was observed between PCB concentrations and dominance (0.752) as presented in Figure 12.

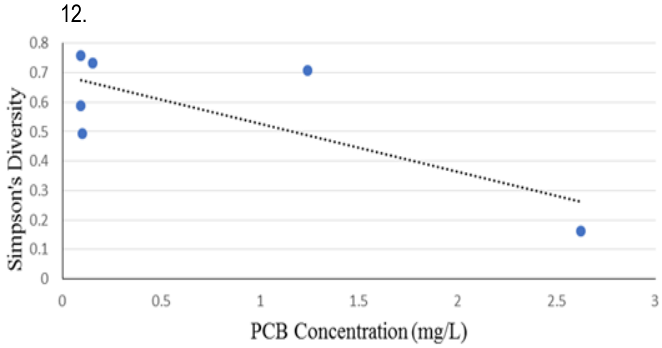


**Figure 6**: Relationship between PCBs concentrations and the Simpson's diversity index

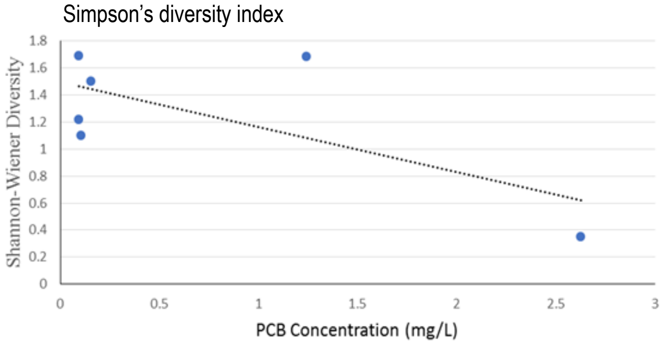


**Figure 7**: Relationship between PCBs concentrations and the Shannon-Wiener's diversity index

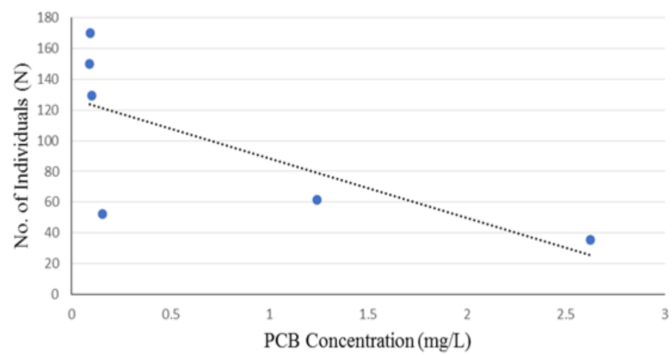


**Figure 8**: Relationship between PCBs concentrations and the total number of individuals

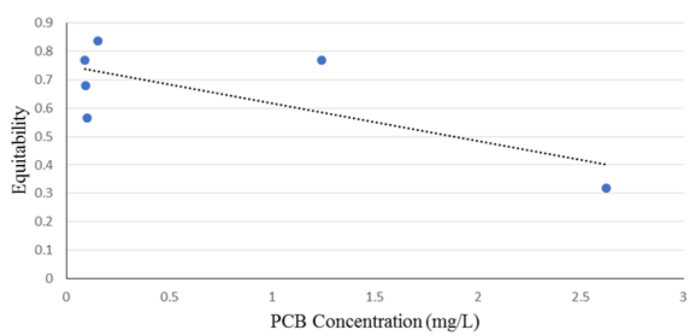


**Figure 9**: Relationship between PCBs concentrations and equitability

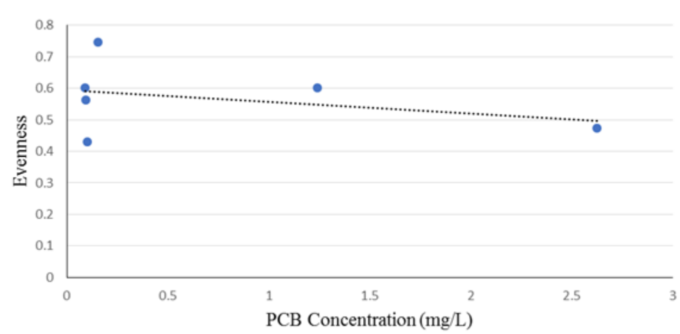


**Figure 10**: Relationship between PCBs concentrations and evenness

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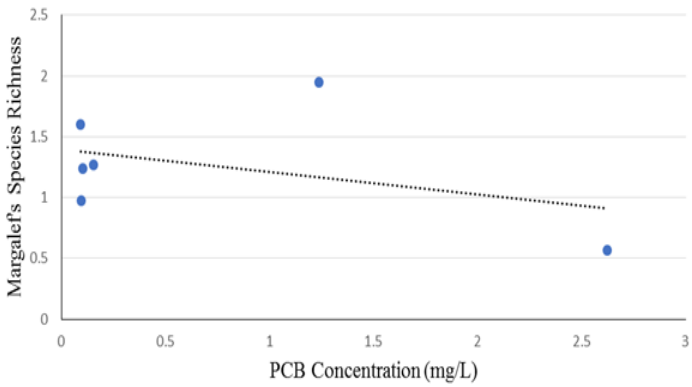


**Figure 11**: Relationship between PCBs concentrations and Margalef's species richness

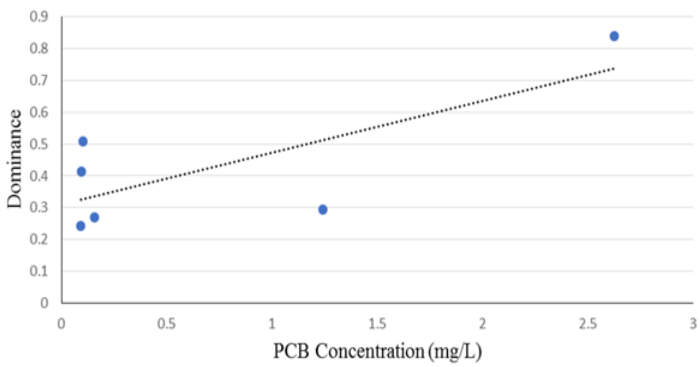


**Figure 12**: Relationship between PCBs concentrations and dominance

Results obtained from this study indicate that there is a negative linear relationship between PCB concentrations and species abundance, diversity, equitability, evenness, and richness. This implies that a higher concentration of PCBs could lead to a reduction in the total number of benthic macroinvertebrates, the number of different species and the extent to which each species is represented in an environment. Also, the reverse case may occur at low PCB concentrations. Fasuyi *et al.* (2021) also reported that different pollution sources in the Lagos lagoon have reduced the diversity and abundance of its benthic macroinvertebrates, and this was attributed to the sedentary nature of these benthic fauna (Fasuyi *et al.,* 2021). Likewise, Nkwoji *et al.* (2020) reported that a high influx of pollutants from land into the Lagos lagoon may lead to low diversity and abundance of the benthic macroinvertebrates in that water body. It was also observed in this study that PCB concentrations correlated positively with species dominance. This indicate that species dominance may be high in areas containing high concentrations of PCBs and low in regions having low PCB concentrations. Benson *et al.* (2020) reported that the concentrations of PCBs detected in sediment cores of the Lagos lagoon may pose significant ecotoxicological risk to marine organisms.

## Conclusion

This study observed a potentially toxic levels of PCBs in some of the study stations emanating from anthropogenic inputs of pollutants into the Lagos lagoon. This study also evaluated the relationship between PCB concentrations in sediment samples and benthic macroinvertebrate community structure in the Lagos lagoon and found that PCB concentrations correlated negatively with species abundance, diversity, equitability, evenness, and richness. This suggests that PCBs contamination in sediments may pose considerable ecotoxicological risk to the community structure of benthic macroinvertebrates of the lagoon. There is also a need to improve our waste management systems to prevent the entry of PCBs and other persistent organic pollutants into the Lagos lagoon and ultimately conserve the health of this very important marine ecosystem.

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