Research Article

Distribution of Polychlorinated Biphenyls (PCBs) in Sediments from Fish Farming Cages in Different Areas of Shatt Al-Arab Basrah /Iraq

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Abstract | Polychlorinated Biphenyls (PCBs) are found in large quantities in the environment and are poisonous, persistent, and bioaccumulative due to their high stability and propensity to build up in living things' bodies, which can have detrimental consequences on health. **Aim of study:Aim of study:** study the distribution of polychlorinated biphenyls (PCBs) in sediments from fish farming cages in different areas of Shatt al-Arab Basra/Iraq. Composite sediment samples were collected from fish farming cages in different areas of Shatt al-Arab .Five stations were chosen along Shatt Al-Arab during (2020-2021). Sediment samples are wrapped with aluminums foil, kept in refrigerator until determination. Current investigation, showed that high significant differences between the seasons (P<0.05) among all studied group of the PCBs, in different areas of Shatt al-Arab, but this study was found that the concentrations were higher in Al-Hartha compared to other areas. The study analyzed Σ13 PCBs concentrations in sediment samples from five stations in Shatt Al-Arab from 2020-2021. Results showed significant seasonal differences, with Al-Hartha having higher concentrations, indicating the influence of environmental and geographical factors on PCB levels.

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Introduction

Water source sediments are a secondary source of contaminants that have an impact on the local organisms. Because these creatures consume foods that contain hydrophobic chemicals, the contaminants are transferred to higher trophic levels (Lee *et al.*, 2001). When urban and industrial garbage is discarded into rivers, lakes, and coastal waters, organic contaminants end up in the water. Compared to the ground, these chemicals are more concentrated in the surface layer. Due to their poor water solubility, they flow with rivers and floods in the direction of the sediments (Al-Asadi and Al-Hejuje, 2019). These chemical molecules have a severe poisonous effect and are extremely unstable, making them difficult to biodegrade or break down (Al-Hejuje *et al.*, 2017). Rain, floods, and river runoff can cause a variety of hydrophobic contaminants, such as polychlorinated biphenyls, to build up in sediments (Smith *et al.*, 1988).

These organic molecules have a strong poisonous effect, are not particularly stable, and are difficult to break down or biodegrade (Habeeb *et al*., 2015). "PCBs" or polychlorinated biphenyls are compounds with the molecular formula C12H10 or (C6H5)2. Two benzene rings joined by a single carbon-carbon bond make up its chemical structure. One to ten chlorine atoms can be attached to the hydrogen atoms in the benzene rings, replacing the hydrogen atoms to differing degrees (Adeyemi *et al*., 2009). About 130 different kinds of PCBs exist. At least fifty uniform PCB compounds may be included in commercial products and oil mixes (You *et al*., 2011).

PCBs are persistent, extremely harmful compounds that are found in large quantities in the environment and bioaccumulate. These substances may be deposited into the environment through volatilization, uncontrolled leaking, leaching from soil, or industrial operations (Combi *et al*., 2016). After leaking from systems that contain them, PCBs move from terrestrial sources to aquatic ecosystems through direct entry points. PCBs are chemically stable due to their lipophilic nature; they only marginally alter during the sedimentation process and accumulate by attaching themselves to particles of organic matter (Gardes *et al*., 2020). Domestic and industrial wastewater are two of the many ways that PCBs used on land can seep into the aquatic environment.

Recently, the amount of PCBs in water bodies has grown to be a serious issue for water quality. This substance interacts with organic matter and builds up in sediments when it enters lakes or rivers. This organic stuff is then consumed by aquatic creatures that reside in these sediments, including phytoplankton, crustaceans, and snails. As a result, fish consume these creatures and absorb PCBs. This implies that PCB contaminants may also be consumed by humans (Iniaghe and Kpomah, 2022). A high adsorption coefficient in sediments and an elevated enrichment factor in aquatic species are the effects of PCBs' restricted solubility in water (Raghad *et al*., 2020).

High quantities of polychlorinated biphenyls (PCBs) have been found at certain of the Tigris River's stations, according to several studies that have examined the sediments of the river. This could be the consequence of human actions that contribute to the release of PCBs into the environment, such as the use of pesticides and fertilizers on adjacent agricultural land and household garbage. This implies that these substances have been sucked up and stored in the sediments (AL-Hasani *et al*., 2024). Another study examined the levels of PCBs in sediment samples from the Shatt al-Arab River in Iraq. The findings showed that highly chlorinated congeners, such as tri- and hexa-PCBs, predominated over the other congeners (Al-Zabad *et al*., 2024). Sediments from the eastern marshes of Al-Hammar, Iraq, contained PCBs. Throughout the year, the current investigation demonstrated differences in PCB concentrations between sites and seasons. Sediments can also be regarded as an indicator of the degree of pollution, even if water analysis is a useful method for evaluating river contamination. Pollutants are stored in the surface sediments of the rivers under study, and as environmental conditions change, the buildup of these pollutants in the sediments could contaminate the water (Al-Hejuje *et al*.,2015).

Studying PCBs has become crucial in the field of environmental research because of their strong chemical affinity for lipids, their possible carcinogenic effects, and the bioaccumulation that results (Cortazar *et al*., 2002). This present study aims to examine the distribution of polychlorinated biphenyls (PCBs) in the sediments of fish farming cages in different parts of Shatt al-Arab in Basra, Iraq.

Methodology

Sediment sampling

Composite sediment samples were collected from fish farming cages in different areas of Shatt al-Arab. Five stations were chosen along Shatt Al-Arab during (2020-2021).(Al-musahab, Abu Al-Khasib, Alharitha , Al-Nashwa and Al-Nujaira) (Figure 1). Sediment samples are wrapped with aluminums foil, kept in refrigerator until determination.

Sample extraction, clean-up and determination

A measured weight of sample (approximately 2 to 30 g of sediment) is extracted using METHOD 8082A (2007). Sediment sample are extracted with Hexane-acetone (1:1), using (Soxhlet), cleanup with Florisil, after cleanup, the extract is analyzed by injecting a measured aliquot into a GC-mass (Agilent5975 , USA) , Type of column: 30-m x 0.25-mm ID fused-silica capillary column ,HP-5MS , 0.25 µm film thickness.

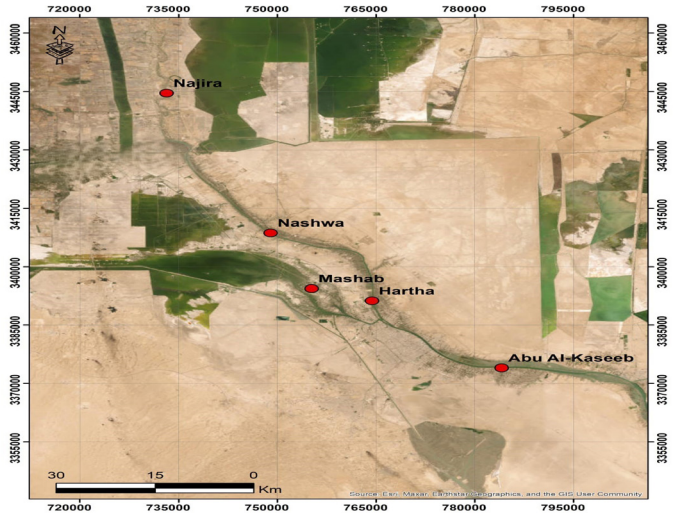

Figure 1: *Map of the study area.*

Table 1: *PCB concentrations (ng/g dry weight) in the sediments of the study stations during Autumn.*

Com. name	Almash-ab	Abu Al-Kha-sib	Alhar-itha	Nash-wat dakhil	Nu-jayrat dakhil
PCB 18	0	1.85512	0	0	0.35
PCB-29	0	0	0	0	0
PCB 31	0	0	0	0	0
PCB 28	0	0.127519	0	0	0
PCB 44	0.239428	0.461298	0.354	0.162	0.366
PCB 52	0	0	0	0	0
PCB 101	0	0	0	0	0
PCB 141	0	0	0	0	0
PCB 149	0	0	0	0	0
PCB 138	0	0	0	0	0
PCB 153	0	0	0	0	0
PCB 189	0	0	0	0	0
PCB 194	0	0	0	0	0
Total	0.24	2.44	0.35	0.16	0.72
Mean	0.018	0.188	0.027	0.013	0.055
±SD	±0.066	±0.517	±0.098	±0.059	±0.135

Statistical analysis

Data of current study were analyzed by using F test (ANOVA) used to compare between three numeric variables or more. Numeric data were described by mean ± standard deviation (SD).A level of significance of α=0.05 was applied to test. (SPSS v.26 and excel 2013) programs used to analyze current data..

Results

The current study, showed that the concentration of PCB compunds in different areas of Shatt al-Arab. Five stations were chosen along Shatt Al-Arab during (2020-2021). (Al-musahab, Abu Al-Khasib, Alharitha , Al-Nashwa and Al-Nujaira) during Autumn, winter, and winter.

In Present study, ,during Autumn , the highest concentration of PCB 18 (1.85 ng/g d.w.) occurred at Abu Al-Khasib while, the concentrations were low in the other PCP types across most stations in this study, Table 1 and Figure 2.

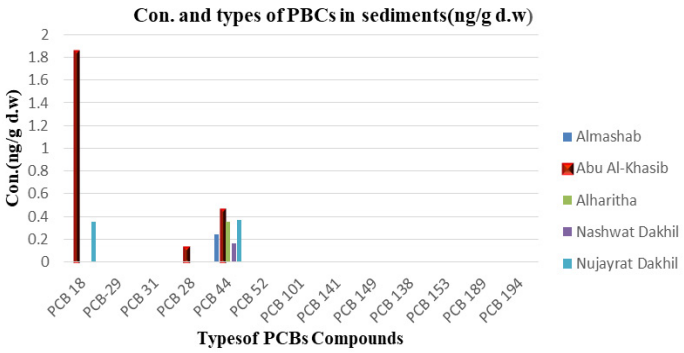

Figure 2: *Concentration and types of PCBs in different areas of Shatt al-Arab during Autumn.*

Table 2: *PCB concentrations (ng/g dry weight) in the sediments of the study stations during winter*

Com. Name	Al-mashab	Abu Al-Kha-sib	Alhar-itha	Nash-wat dakhil	Nu-jayrat dakhil
PCB 18	0	0.58	0	0.3	0
PCB-29	0	0	0	0.57	0
PCB 31	0	0	0	0	0
PCB 28	0	0	0	0	0
PCB 44	0.35	0.23	0.35	0.48	0.83
PCB 52	0	0.08	0	0	0
PCB 101	0	0	0	0.27	0
PCB 141	0	0	0	0	0
PCB 149	0	0	0	0	0
PCB 138	0	0	0	0	0
PCB 153	0	0	0	0	0
PCB 189	0	0	0	0	0
PCB 194	0	0	0	0	0
Total	0.35	0.88	0.35	1.62	0.83
Mean	0.027	0.068	0.027	0.125	0.064
±SD	±0.097	±0.166	±0.097	±0.208	±0.229

In winter, the highest concentration of PCB 44 (0.828 ng/g d.w.) occurred at Nujayrat Dakhil while the concentrations were low in the other PCP types across most stations in this study, Tables 2 and Figure

3.

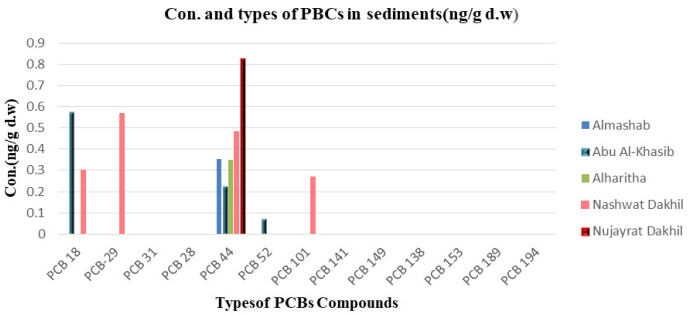

Figure 3: *Concentration and types of PCBs in different areas of Shatt al-Arab during winter.*

Table 3: *PCB concentrations (ng/g dry weight) in the sediments of the study stations during Spring*

Com. Name	Al-mash-ab	Abu al-Khasib	Alhar-itha	Nash-wat dakhil	Nu-jayrat dakhil
PCB 18	0.29	0.29	0.32	0.773	0.613
PCB-29	0.79	0.023	0.15	0.073	0
PCB 31	0	0.053	0	0	0.071
PCB 28	0	0	0.22	0	0
PCB 44	0.14	0.035	0.03	0.103	0.094
PCB 52	1.16	1.879	2.56	1.59	1.34
PCB 101	0.45	1.043	4.26	0.99	2.017
PCB 141	0	0	0.11	0.09	0.146
PCB 149	0	0	0	0	0
PCB 138	0.89	0.774	0.65	0.85	0.52
PCB 153	0.46	0	0	0	0
PCB 189	0.41	1.013	0	0.68	0
PCB 194	0.49	1.299	2.18	0.89	0.66
Total	5.10	6.411	10.47	6.05	5.47
Mean	0.39	0.615	1.33	0.53	0.65
±SD	±0.378	±0.636	±1.34	±0.52	±0.625

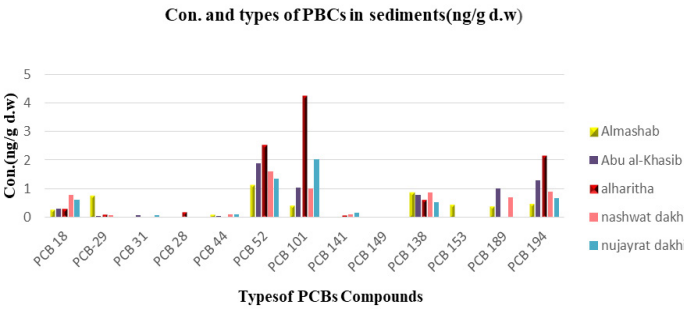

Figure 4: *Concentration and types of PCBs in different areas of shatt al-Arab during spring.*

In Spring, the highest concentration of PCB 101(4.257 ng/g d.w.) occurred at alharitha, while,PCB 28 and PCB 149 were lowest in all stations in this study, Table 3 and Figure 4.

In Summer, the highest concentration of PCB 52 (3.35 ng/g d.w.) occurred at alharitha, while,PCB 28 and PCB 149 were lowest in all stations in this study, Table 4 and Figure 5.

Table 4: *PCB concentrations (ng/g dry weight) in the sediments of the study stations during summer*

Com. name	Al-mash-ab	Abu al-Kha-sib	Alhar-itha	Nash-wat dakhil	Nu-jayrat dakhil
PCB 18	0.25	0.29	0.24	0.21	0.33
PCB-29	0.06	0.07	0.07	0.05	0.07
PCB 31	0.11	0.30	0.20	0.25	0.25
PCB 28	0	0	0	0	0
PCB 44	0.09	0.12	0.09	0.09	0.093
PCB 52	1.41	1.48	3.35	1.87	1.89
PCB 101	1.18	0.15	2.33	1.65	1.76
PCB 141	0.09	0.45	0	0.06	0.14
PCB 149	0	0	0	0	0
PCB 138	0.69	1.12	0.67	0.59	1.02
PCB 153	0.92	0.09	0	0.14	0
PCB 189	0	0.24	0	0	0
PCB 194	0.37	0.22	1.49	0.57	0.58
Total	5.17	4.55	8.44	5.49	6.14
Mean	0.74	0.65	1.21	0.79	0.88
±SD	±0.49	±0.45	±1.08	±0.63	±0.67

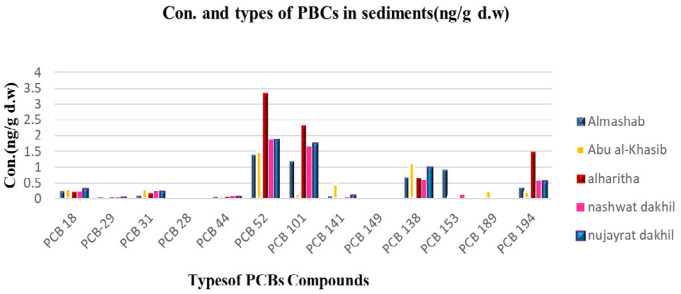

Figure 5: *Concentration and types of PCBs in different areas of Shatt al-Arab during summer.*

Table 5: *Mean concentrations of PCBs in different areas of Shatt al-Arab during the four seasons*

Com. Name	Al-mashab	Abu Al-Kha-sib	Alhari-tha	Nash-wat Dakhil	Nu-jayrat Dakhil
Summer	0.388	0.399	0.695	0.479	0.556
Spring	0.393	0.493	0.805	0.465	0.421
Winter	0.0271	0.0679	0.027	0.1248	0.0637
Autumn	0.0184	0.188	0.0272	0.0125	0.0551

In Present investigation,the statistical analysis using one-way ANOVA showed that high significant differences between the seasons (P<0.05) among all studied group of the PCBs, in different areas of Shatt al-Arab, but this study was found that the concentrations were higher in Al-Hartha compared to other areas , Table 5 and Figure 6.

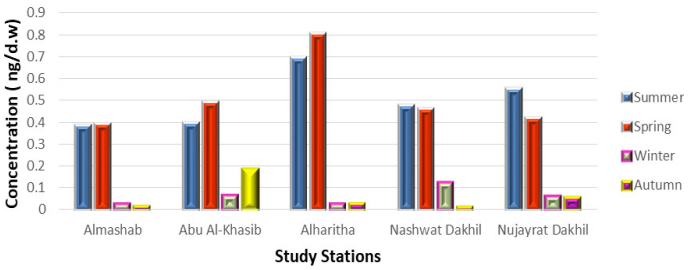

Figure 6: *Mean concentrations of PCBs in different areas of Shatt al-Arab during the four seasons.*

Discussion

The properties of PCBs compounds, including heat resistance, low flammability, and high dielectric constant, make them suitable for multiple industrial applications, such as refrigerants and insulation fluids for condensers and electrical transformers. It is also used in the manufacture of PVC wrappers, pesticides, cutting oils, flame retardants, hydraulic fluids, sealants, adhesives, paints, and carbon-free printing paper (Brinkman and de KOK, 1980).These sources may supply rivers with high concentrations of PCBs compounds. PCBs used on land can travel to the aquatic environment through various pathway routes including wastewater discharged by industry, municipal wastewater, river input, air transport and sedimentation (Yang *et al.*, 2012),once transported to the aquatic environment, PCBs.can be absorbed by molecules and then incorporated into sediment because they were difficult to dissolve in water, which can lead to pollution (Yang *et al.*, 2011),sediments are a clear evidence of aquatic environmental pollution as large quantities of PCBs show that sediment is a reservoir and will be a clear environmental deposit of these pollutants in the aquatic environment.

Polychlorinated Biphenyls (PCB) are persistent, toxic, bioaccumulative, and widely distributed in the environment because of their high stability and tendency to accumulate in the bodies of living organisms, causing serious health effects(AL-Hasani *et al.*, 2024).

The results showed that the highest concentration of PCBs was recorded during spring, followed by summer, then autumn, while the lowest concentration was detected in winter. Additionally, it was found that the concentrations were higher in Al-Hartha compared to other areas, including Abu Al-Khasib, Al-Nashwa, Najiran, and Al-Mishkhab. this increase may be attributed to the fact the sediment texture in Al-Hartha station was silty clay, which is different from the rest of the stations that were sand-silt sediments, as the silt–clay sediments accumulated organic compounds; in addition, the smallest size of the grains in the sediments can accumulate greater amounts of PCBs. In addition, the values of PCBs in clay sediments have increased more than those in sandy sediments (Al-Zabad *et al.*, 2021).A study by Barakat *et al.* (2013) indicated that sediments that are close to cities often have high concentrations of PCBs according to the local use of these pollutants. The results showed that the increase in the concentrations of PCBs in the sediments of Alharitha station in the summer may be due to the main roads adjacent to Shatt al-Arab , where they are affected by waste from means of transportation and activated fishing boats that increase water pollution and then settle in sediments.

This finding was consistent with the study conducted by AL-Hasani *et al.*, (2024), where PCB levels were found to increase during the summer season.These seasonal and geographical variations can be explained based on environmental, hydrodynamic, and anthropogenic factors affecting the deposition and distribution of PCBs in the Shatt Al-Arab environment, particularly in fish farming cages.The Effect of Temperature on PCB Deposition and Accumulation:PCBs are hydrophobic compounds, meaning they tend to bind to organic matter and sediments rather than remain dissolved in water. As temperature increased during spring and summer, the rates of chemical and biological reactions affecting the movement and redistribution of these compounds were also elevated. Several key factors may explain this increase:Enhanced microbial activity: Higher temperatures led to an increase in bacterial activity, which may have contributed to the decomposition of organic matter in sediments, leading to the release and redistribution of PCBs (Jazaa, 2009).

Volatilization of lighter PCB congeners: Some PCBs evaporated or migrated from water to sediments at higher rates due to increased temperature. Increased

biological activity of fish and other aquatic organisms, which resulted in sediment disturbance and redistribution of pollutants such as PCBs.

The Effect of Water Flow and River Currents: During winter, the water flow rates and river currents in Shatt Al-Arab were higher due to increased rainfall and rising water levels. This increase led to: Dilution of PCB concentrations in sediments, as stronger currents dispersed contaminants.The transport of some contaminated sediments away from the sampling sites, reducing the accumulation of PCBs in those areas.

In contrast, during spring and summer, water flow decreased, and evaporation rates were higher, leading to increased PCB concentrations in sediments due to reduced dilution and greater retention of pollutants.

The Effect of Geographical Factors on PCB Concentration Differences Between Areas: The results indicated that the highest PCB concentrations were found in Al-Hartha, compared to other areas such as Abu Al-Khasib, Al-Nashwa, Najiran, and Al-Mishkhab. This variation can be attributed to several factors: Proximity to industrial pollution sources (Mills and Chichester, 2005): Al-Hartha is an industrial area containing factories and oil refineries, which may have contributed to the discharge of large amounts of pollutants, including PCBs, into Shatt Al-Arab.

Lower water flow compared to other regions: Reduced water currents in some parts of Al-Hartha led to higher PCB accumulation in sediments due to lower dispersion and dilution rates.

Direct impact of fish farming cages: Waste from fish and feed materials may have promoted the accumulation of organic matter, enhancing PCB absorption in sediments (Al-Asadi and Al-Hejuje, 2019).

The Effect of Human and Industrial Activities: During spring and summer, industrial and agricultural activities surrounding Shatt Al-Arab increased, leading to greater discharge of untreated industrial wastewater and agricultural runoff containing organic pollutants such as PCBs.

Summer was also characterized by intensified fishing and fish farming activities, which may have caused sediment disturbances and redistribution of pollutants. In Al-Hartha, industrial activity was likely more significant, explaining the higher PCB levels in sediments compared to other locations (Hsu, 2004).

Conclusions and Recommendations

The study determined and analyzed the concentrations of Σ13 PCBs compound in sediment samples at five stations were chosen along Shatt Al-Arab during (2020-2021). Current investigation, showed that high significant differences between the seasons ($P<0.05$) among all studied group of the PCBs, in different areas of Shatt al-Arab, but this study was found that the concentrations were higher in Al-Hartha compared to other areas.These findings reflect the strong influence of environmental and geographical factors, such as temperature, water flow, and industrial and agricultural activities, on PCB levels in sediments.

Novelty Statement

This study provides the first comprehensive assessment of spatial distribution patterns of polychlorinated biphenyls (PCBs) in sediments associated with fish farming cages across multiple locations in the Shatt Al-Arab River, Basrah, Iraq.

Author's Contribution

Balqees S. Al-Ali: Writing of the manuscript, corrections and data analysis
Dhafar Dhaher Al- Khion: Research work, writing and sample field work

Generative AI and AI-assisted technology statement
The authors declare that no generative AI and AI assisted technology was used in the creation of this manuscript.

Conflict of interest
The authors have declared no conflict of interest.

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