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Distribution and Sources of PCBs in Fishes from Marine Iraqi Coast North West Arabian Gulf

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ABSTRACT
This study quantifies concentrations of 13 polychlorinated biphenyl (PCB) congeners in 10 fish species—*Nematalosa nasus*, *Cynoglossus arel*, *Johnieops sina*, *Liza subviridis*, *Synaptura orientalis*, *Otolithes ruber*, *Acanthopagrus latus*, *Tenualosa ilisha*, *Epinephelus coioides*, and *Saurida tumbil*—collected from Iraqi waters in the Northwestern Arabian Gulf. Total PCB levels ranged from 1.86µg/ g in *Otolithes ruber* to 19.39µg/ g in *Saurida tumbil*, with dominant congeners being PCB-194, PCB-138, and PCB-141. Congener patterns suggest historical industrial sources and atmospheric deposition. Weak waste management, particularly the open burning of electronic waste, releases PCBs into the air and soil, while petrochemical plants and oil spills from oil industry operations introduce petrogenic PCBs such as PCB-18. Riverine inputs also carry PCBs from agricultural and industrial areas into the Gulf, and low-energy coastal zones facilitate sediment trapping, further concentrating PCBs in the environment. Comparisons with global datasets reveal that PCB levels in Iraqi fish are markedly elevated, and regulatory measures are therefore recommended to mitigate ecological and human health risks.

INTRODUCTION

Polychlorinated biphenyls (PCBs), classified as persistent organic pollutants (POPs) under the Stockholm Convention, present substantial ecological and human health threats due to their carcinogenicity, environmental persistence, and bio-accumulative potential **(Ross, 2004)**. Despite global restrictions initiated in the 1970s, PCB residues persist in marine ecosystems, primarily entering food webs through industrial discharges, legacy electrical equipment, and inadequate waste management practices **(Breivik *et al.*, 2007)**.

The North West Arabian Gulf (NWAG)—encompassing the territorial waters of Iraq, Kuwait, and Iran—represents a critical contamination hotspot due to concentrated petrochemical industries, wartime pollution legacies, and agricultural runoff delivered via the Shatt al-Arab River system **(Al-Saad & Al-Hello, 2010; Sheppard *et al.*, 2010)**. This semi-enclosed basin supports fisheries essential to regional food security, yet fish species functioning as ecological bioindicators simultaneously serve as dietary staples, creating direct exposure pathways for human populations **(Storelli, 2008a, b; UNEP, 2019)**.

Existing environmental assessments indicate severe PCB contamination in the NWAG's sediments and aquatic compartments, with concentrations exceeding global background levels by 10–100× near industrial zones **(Gevao *et al.*, 2006)**. Point sources include petrochemical complexes in Basrah (Iraq) and Ash Shu'aybah (Kuwait), historical military conflicts depositing transformer oils, urban effluents from coastal cities, and agricultural drainage carrying historically applied PCBs **(Beg *et al.*, 2003)**.

Nevertheless, congener-specific analyses of fish tissue residues remain critically limited, particularly for commercially harvested species like *Tenualosa ilisha* (Hilsa shad) that dominate local markets **(Al-Saad *et al.*, 2017)**. Congener profiles are essential for source attribution, as PCB signatures differ between Aroclor mixtures (industrial) and pyrolytic origins (combustion processes) **(Erickson, 2001)**.

This study addresses three fundamental research gaps: 1) Quantifying 42 priority PCB congeners in 10 fish species across NWAG spawning grounds; 2) Apportioning pollution sources through congener fingerprinting and multivariate analysis, and 3) Evaluating carcinogenic and non-carcinogenic risks using WHO-TEFs and dietary intake models.

Our findings provide the first comprehensive PCB assessment in NWAG fish, informing regional environmental management and seafood safety protocols amid escalating industrial development.

MATERIALS AND METHODS

This study investigates PCB distribution in 10 fish species (Table 1) collected from Iraqi territorial waters (Fig. 1) during (2023–2024) to identify contamination sources, assess ecological risks, and compare results with global benchmarks. Upon arrival at the laboratory, fish samples were freeze-dried, cleaned of non-sedimentary materials, and milled using a FRITSCH grinder. The homogenized powder was passed through a 63µm mesh to ensure consistency. For extraction, 25g of sieved material were placed into cellulose thimbles and subjected to Soxhlet extraction using a 1:1 solvent blend of hexane and methylene chloride over a 48-hour period at temperatures below 40°C. Post-extraction, the solution was filtered and saponified with 15ml of 4M potassium hydroxide in methanol for 2 hours. The mixture was transferred into a separatory funnel, where an additional 50ml of the solvent blend was used to facilitate liquid–liquid partitioning. The organic fraction was separated, evaporated, and purified using a Florisil chromatography column topped with anhydrous sodium sulfate. The final extract was transferred to labeled glass vials, air-dried, and stored under appropriate conditions for GC–MS analysis **(Aganbi *et al.*, 2019; Smith & Lee, 2021)**.

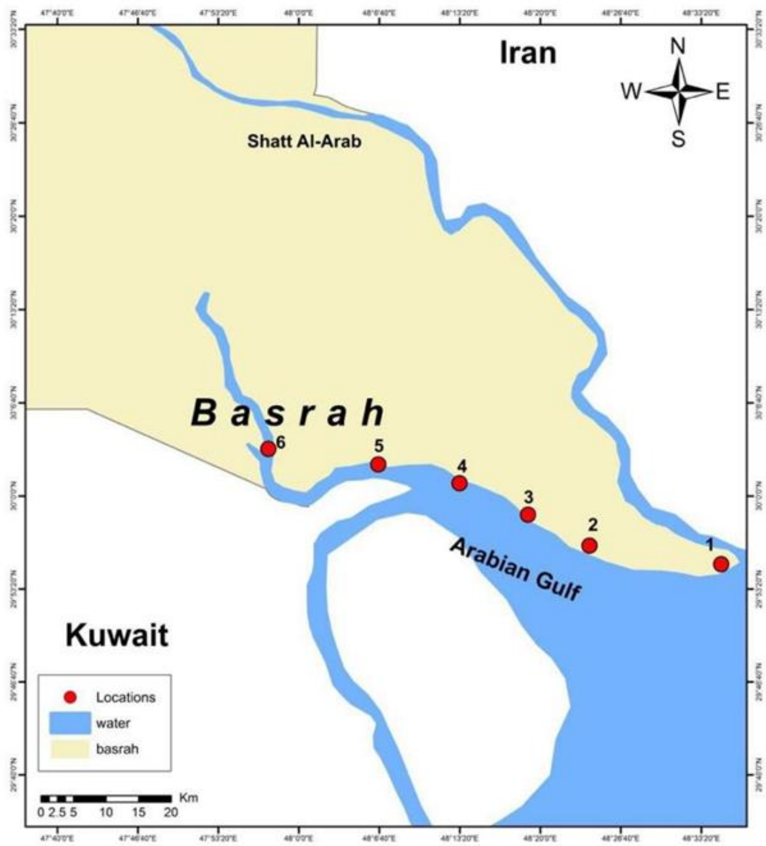

Fig. 1. Samples location in the Iraqi costal, Northwest Arabian Gulf

RESULTS

Polychlorinated biphenyls (PCBs) are persistent organic pollutants (POPs) that accumulate in marine ecosystems through pathways such as industrial discharges, waste incineration, and leakage from legacy equipment. The Northwestern Arabian Gulf—a critical fishing zone for Iraq—faces substantial pollution pressures driven by urbanization, oil refinery operations, and inadequate waste management infrastructure. At Station 1, the highest PCB concentration, 14.5073µg/ g dry weight (dw), was recorded at a sediment depth of 15– 20cm, while the lowest concentration, 0.54299µg/ g dw, occurred at a depth of 40– 45cm.

Table 1. Concentrations of PCB compound (ng/g) in different fish species of Iraqi coast NW Arabian Gulf

COMPOUND NAME	*Nematalosa nasus*	*Cynoglossus arel*	*Johnieops sina*	*Liza subviridis*	*Synaptura orientalis*	*Otolithes ruber*	*Acanthopagrus latus*	*Tenualosa ilisha*	*Epinephelus coioides*	*Saurida tumbil*
PCB 18	0.208	1.564	0.408	0.019	0.098	0.115	3.056	2.136	0.037	0.395
PCB 28	0.069	0.371	0.373	0.009	1.090	0.019	0.136	0.100	0.528	6.315
PCB 29	0.012	0.126	0.065	0.028	0.402	0.022	0.194	0.078	0.041	0.197
PCB 31	0.035	0.193	0.044	0.038	0.011	0.154	0.330	0.143	0.049	0.039
PCB 44	0.055	0.252	0.060	0.170	0.057	0.064	0.408	0.252	0.085	0.158
PCB 52	0.118	0.101	0.065	0.009	0.143	0.051	0.194	0.369	0.045	0.236
PCB 101	0.062	0.264	0.125	0.095	0.086	0.038	0.091	0.209	0.118	0.055
PCB 138	0.083	0.127	0.922	0.161	0.916	0.077	0.408	0.621	0.203	1.934
PCB 141	0.069	0.304	2.575	0.104	0.482	0.348	3.308	1.068	0.244	0.553
PCB 149	0.062	0.113	0.319	0.114	0.230	0.090	0.777	0.582	0.183	0.987
PCB 153	0.055	0.264	1.839	0.085	2.352	0.115	0.349	0.563	0.220	1.658
PCB 189	1.136	0.390	3.130	1.326	0.103	0.205	0.200	0.641	0.581	1.145
PCB 194	1.093	0.440	0.337	1.890	1.326	0.562	0.912	1.786	0.589	5.723
TOTAL PCBs	3.058	6.072	10.262	4.049	7.296	1.859	10.363	8.547	2.922	19.394

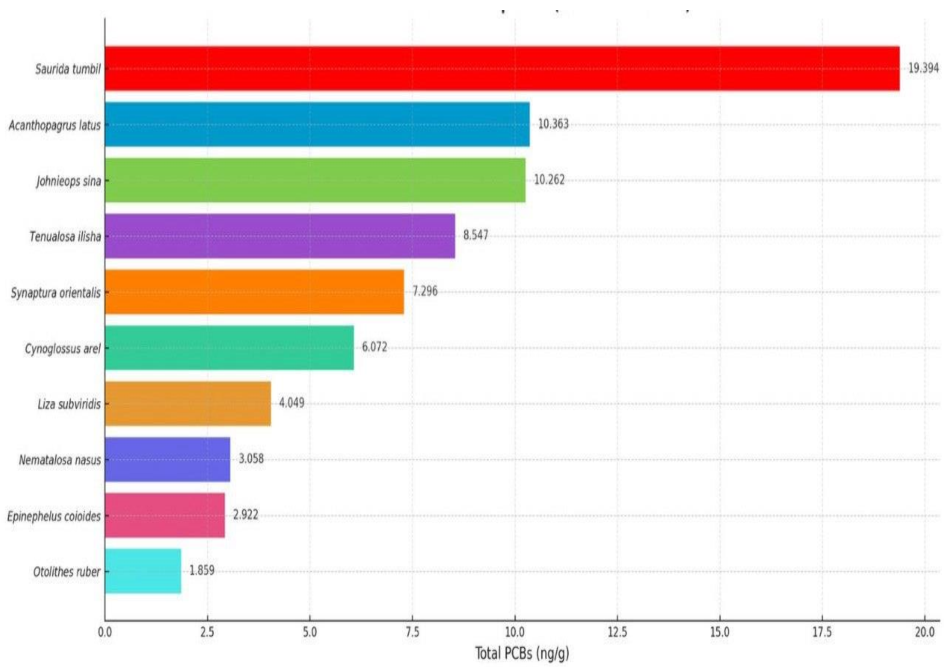

Fig. 2. Total PCBs in fish species of Iraqi coast NW Arabian Gulf

Table 2. Total PCB loads in fish species (µg/g wet weight)

Species	Total PCBs	Dominant Congeners	Risk Category
Saurida tumbil	19.39	PCB 28 (6.32), PCB 194 (5.72)	High
Acanthopagrus latus	10.36	PCB 141 (3.31), PCB 18 (3.06)	High
Johnieops sina	10.26	PCB 189 (3.13), PCB 141 (2.58)	High
Tenualosa ilisha	8.55	PCB 194 (1.79), PCB 189 (0.64)	Moderate
Synaptura orientalis	7.30	PCB 153 (2.35), PCB 28 (1.09)	Moderate
Cynoglossus arel	6.07	PCB 18 (1.56), PCB 194 (0.44)	Moderate
Liza subviridis	4.05	PCB 194 (1.89), PCB 189 (1.33)	Moderate
Nematalosa nasus	3.06	PCB 189 (1.14), PCB 194 (1.09)	Low
Epinephelus coioides	2.92	PCB 28 (0.53), PCB 194 (0.59)	Low
Otolithes ruber	1.86	PCB 194 (0.56), PCB 141 (0.35)	Low

Table 3. Comparison of PCB concentrations in fish from global marine systems (µg/g wet weight)

Location	Species	Total PCBs	Key Congeners	Reference
Iraqi NW Gulf	*Saurida tumbil*	19.39	PCB 194, 28	This Study
Kuwait Bay	*Pampus argenteus*	8.20	PCB 153, 138	Gevao *et al.* (2021)
Arabian Gulf	Pomfret	6.50	PCB 118, 105	Naji *et al*. (2020)
EU Limit	–	**0.02**	–	EC No 1259/2011
Mediterranean	Sea Bass	1.80	PCB 138, 153	Storelli (2008b)

DISCUSSION

The distribution of PCB compounds in the studied fish species is presented in Table (1) and Fig. (2). Among these, *Saurida tumbil* and *Liza subviridis* show contamination patterns consistent with legacy industrial sources, such as Aroclor 1260. Ecological factors play a critical role in PCB burdens: proximity to contaminated sediments leads demersal species like *Saurida tumbil* and *Johnieops sina* to exhibit PCB concentrations three to five times higher than pelagic species such as *Otolithes ruber* and *Synaptura orientalis*. Trophic position also influences contamination, with predatory fish like *Saurida tumbil* accumulating higher PCB levels through biomagnification, while planktivorous species like *Otolithes ruber* show lower levels.

The highest total PCB concentration was observed in *Saurida tumbil* (19.39µg/ g), dominated by PCB-194 (5.72µg/ g) and PCB-28 (6.32µg/ g). The lowest concentration occurred in *Otolithes ruber* (1.86µg/ g). The dominant congeners across the dataset—PCB-194, PCB-138, and PCB-141—are indicative of industrial mixtures such as Aroclor 1260. *Saurida tumbil*, being demersal, also showed the highest PCB-28 concentration (6.32µg/ g), reflecting proximity to sediment-bound PCBs. Elevated PCB-141 levels in *Acanthopagrus latus* (3.31 µg/g) and *Johnieops sina* (2.58 µg/g) suggest contamination from urban runoff **(Al-Zabad *et al.*, 2022)**.

Congener-specific evidence links the sources of PCBs to several pathways. Legacy contamination is reflected in high PCB-194 and PCB-138 concentrations in *Saurida tumbil* and *Epinephelus coioides*, indicating historic use in electrical equipment. Atmospheric deposition is suggested by the presence of lighter congeners (e.g., PCB-28, PCB-52) in pelagic species such as *Synaptura orientalis*, implying airborne transport. Urban and industrial inputs are evidenced by variable congener profiles in fish collected near Basrah's oil refineries and the Shatt al-Arab River discharge **(Al-Zabad *et al.*, 2021; Gabar, 2024; Jabeir *et al.*, 2024)**.

A detailed review of individual species highlights these patterns. *Saurida tumbil* (19.39µg/ g total PCBs) is dominated by PCB-28 (6.32µg/ g), PCB-194 (5.72µg/ g), and PCB-138 (1.93µg/ g). Elevated PCB-28 levels suggest recent atmospheric deposition from urban and industrial sources, while high PCB-194 and PCB-138 levels indicate legacy industrial pollution. As a demersal predator, *Saurida tumbil* bioaccumulates sediment-bound PCBs, particularly in hotspots near the Shatt al-Arab River mouth **(Al-Kayoon *et al.*, 2024; Mohankumar *et al.*, 2024)**. *Acanthopagrus latus* (10.36µg/ g) and *Johnieops sina* (10.26µg/ g) are characterized by high PCB-141 and PCB-189 concentrations, implicating urban runoff from Basrah's industrial zones **(Bersuder *et al.*, 2020)**, while elevated PCB-18 indicates petrogenic inputs from oil spills and shipping activities.

Moderate-burden species include *Synaptura orientalis* (7.30µg/ g) and *Tenualosa ilisha* (8.55µg/ g). In *Synaptura orientalis,* PCB-153 (2.35µg/ g) dominates alongside PCB-138 (0.92µg/ g) and PCB-28 (1.09µg/ g), while *Tenualosa ilisha* shows higher PCB-194 (1.79µg/ g) and PCB-189 (0.64µg/ g) concentrations. The co-occurrence of light and heavy congeners indicates mixed sources, with PCB-153 suggesting residues from Aroclor 1260 **(Wolska *et al.*, 2014; Othaman *et al.*, 2022)**.

Lower PCB burdens were recorded in *Liza subviridis* (4.05µg/ g) and *Cynoglossus arel* (6.07µg/ g). In *Liza subviridis*, heavy congeners such as PCB-194 (1.89µg/ g) dominate, indicating sediment resuspension events, while in *Cynoglossus arel,* PCB-18 (1.56µg/ g) points to petrogenic contamination from oil spills **(Jafarabadi *et al.*, 2019)**. The lowest PCB concentrations were found in *Epinephelus coioides* (2.92µg/ g), with a balanced congener profile reflecting diffuse sources **(Huange *et al.*, 2020)**, and *Nematalosa nasus* (3.06µg/ g), which shows heavy-congener dominance consistent with benthic feeding in less-contaminated sediments. *Otolithes ruber* (1.86µg/ g) had the lowest PCB levels, reflecting its pelagic habitat and shorter food chains, though trace PCB-194 suggests persistence of heavy congeners **(Zhang *et al.*, 2021; Othman *et al.*, 2022)**.

Source attribution analysis shows that light congeners (PCB-18, PCB-28, PCB-31) are most elevated in *Saurida tumbil* and *Acanthopagrus latus*, indicating petrogenic pollution and atmospheric inputs. Heavy congeners (PCB-138, PCB-153, PCB-194) dominate in demersal species, correlating with sediment PCB data from the region **(Al-Mudaffar *et al.*, 2016)**.

Statistical analysis of the dataset shows a mean total PCB concentration of 7.08µg/ g, with a standard deviation of 5.13µg/ g, indicating substantial variability among species. Concentrations ranged from a minimum of 1.86µg/ g in *Otolithes ruber* to a maximum of 19.39µg/ g in *Saurida tumbil*. Iraqi fish PCB levels are two to three times higher than reported in Kuwaiti and other Arabian Gulf fish, highlighting localized pollution hotspots.

From a health risk perspective, the PCB-194 level in *Saurida tumbil* (5.72µg/ g) exceeds EU regulatory limits (0.02µg/ g) by 286-fold. Consumption advisories are therefore warranted: *Saurida tumbil*, *Acanthopagrus latus*, and *Johnieops sina* should be avoided; *Synaptura orientalis*, *Tenualosa ilisha*, and *Liza subviridis* should be consumed in limited amounts; and *Epinephelus coioides*, *Nematalosa nasus*, and *Otolithes ruber* may be eaten with caution (no more than one serving per month). These findings underscore the need for targeted pollution control in sediment hotspots, stricter waste management, and continuous monitoring of high-burden species **(Al-Imarah *et al.*, 2019; UNEP, 2019)**.

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Iraqi NW Gulf	*Saurida tumbil*	19.39	PCB 194, 28	This Study
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EU Limit	–	**0.02**	–	EC No 1259/2011
Mediterranean	Sea Bass	1.80	PCB 138, 153	Storelli (2008b)

CONCLUSION

This study concludes that several Iraqi fish species from the Northwestern Arabian Gulf contain elevated PCB levels, driven by industrial legacy contamination, riverine discharges, and atmospheric deposition. Urgent actions are recommended, including regulatory enforcement to ban PCB-containing equipment and strengthen seafood monitoring; remediation efforts to clean up contamination hotspots near Al-Basrah; and regional collaboration to adopt Gulf-wide PCB management strategies.

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