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Study of the accumulation of Polychlorinated Biphenyls (PCBs) in *Siganus rivulatus* from Latakia city (Syria)

Mulham Askar*, Ahmad Kara-Ali, Hazem Krawi

ABSTRACT

This research focused on determining the concentrations of some polychlorinated biphenyls (PCBs) in marine water and muscle tissue of a type of saltwater fish for human consumption (*Siganus rivulatus*), which were collected in the summer and winter of 2022 in two locations in Latakia city beach (Sports City - South Corniche) using gas chromatography technology GC/MS. The results of this study showed that these areas are affected by polychlorinated biphenyls, which shows the continuous arrival of these combinations into the marine environment as a result of tourism activities, urban construction, sewage channels for homes and restaurants, or movement through river waters that flow directly into these areas. The total concentrations of polychlorinated biphenyls (PCBs) in the water of the studied areas ranged between 22.1037 µg/l and 46.553 µg/l, with the highest value recorded in the South Corniche region during the summer, which was for the combination PCB-101 and amounted to 14.004 µg/l, in contrast the lowest value was recorded in In the Sports City area during the winter, the PCB-151 combination reached 0.0447 µg/l. The total concentrations of polychlorinated biphenyls in the muscle tissue of the studied fish ranged between 61.2154 µg/g and 67.9369 µg/g, with the highest value recorded in the Sports City area during the summer, which was for the combination PCB-199 and amounted to 40.44 µg/g, in contrast the lowest value was recorded. In the southern Corniche area during the winter, the combination PCB-138 reached 0.492 µg/g. The correlation association that was studied between the lengths of the studied fish and the total concentration of PCBs indicated the presence of a significant positive association, R = 0.78. This shows an increase in the concentration of PCBs with the age of the fish, which shows an activity in the arrival of these pollutants into the marine environment.

Keywords: Accumulation, Polychlorinated biphenyls (PCBs), Marine water, Saltwater fish, *Siganus rivulatus* fish, Bioconcentration factor (BCF).

1. INTRODUCTION

The Mediterranean Sea is a semi-enclosed area that is particularly vulnerable to pollution, as it is considered a storehouse of persistent organic pollutants (POPs),

especially polychlorinated biphenyls (PCBs), due to its composition, geographical location, and human activities that occur in it Castro-Jiménez et al., (2013), Marsili et al., (2018), as several studies showed the presence of persistent organic pollutants (POPs) in this region, which confirms its role as a hot zone for the presence of these pollutants in all living organisms present in it (Stuart-Smith and Jepson, 2017; Jepson et al., 2016). POPs enter the marine environment via human activities, industrial effluents, wastewater, deposition from the atmosphere as well as industrial processes listed as potential sources of POPs, electrical industries, chemical oils derived from petrochemical industries (Alaboudi et al., 2019; Pariatamby and Kee, 2016).

These pollutants have been classified within a list of 12 persistent organic pollutants, and among these pollutants are polychlorinated biphenyls (PCBs) Agulló et al., (2017), Yang et al., (2020), as these combinations harm the Ecosystem and all organisms. They also pose a significant threat to human health (Bagale, 2022; Donato et al., 2021). PCBs are non-polar, hydrophobic, and are one of the lipid-soluble substances that remain in the body for a long time Kargarghomsheh et al., (2023), Naghashan et al., (2023) and therefore accumulate mainly in the Muscle tissue of marine mammals (Dron et al., 2022). PCBs in the environment are a significant concern Pironti et al., (2022), Montano et al., (2022), Ricciardi et al., (2022), and concerns regarding potential health effects and their stability within the environment due to their bioaccumulation, carcinogenic properties, and consequently harmful effects.

On human health Weber et al., (2018), Sohail et al., (2018), Qiu et al., (2019), as these combinations are transported in the environment through various natural settings such as fresh water, rivers, air, and marine currents, and they tend to accumulate in specific parts of Ecosystem. These systems are called environmental components and include (air - water - sediments - algae - living tissues) (Percy, 2006). The importance of this study is evident in light of the difficult economic conditions that the country is going through and the heavy reliance on the consumption of saltwater fish as an essential protein source. Therefore, it was necessary to determine the concentrations of polychlorinated biphenyls (PCBs) in the eaten portion of the sandfish *Siganus rivulatus*, which is widely consumed by humans in areas Different from the beach of the city of Latakia, which enjoys different human activities, namely (the Sports City area - the Southern Corniche area).

Importance of the research and its objectives

This study is complementary to other studies on the Syrian coast, which studied the distribution of polychlorinated biphenyls (PCBs) in various phases of the marine environment (water - sediments - algae). The importance of this research stems from the fact that it sheds light on the accumulation of PCBs in *Siganus rivulatus* fish. Of economic value, to know the extent of contamination of this type of fish with PCBs, which will be transmitted to humans through the food chain.

2. RESEARCH MATERIALS AND METHODS

Study sites

The study was conducted on marine water and *Siganus rivulatus* from two locations on the beach of the city of Latakia: The Sports City area, which represents an area open to the sea and far from being directly affected by land sources of pollution, and the Southern Corniche area, where there is a fishing port where boats anchor and several canals flow into it. Sanitation facilities are spread over restaurants and tourist facilities, which may be potential sources of marine pollution. Samples were collected from the studied sites during the summer and winter of 2022. It was transported directly to the laboratories of the Higher Institute for Marine Research at Tishreen University, where it was then stored in a refrigerator at -20 degrees Celsius until the extraction process.

Laboratory work

Extraction of water samples

The aqueous samples (1L) were extracted using a liquid-liquid method using a separating funnel and with 80ml of n-hexane organic solution, stirring continuously several times. After that, the sample was left to rest, at which time the aqueous layer (at the bottom) separated from the organic layer (at the top). The extract was then collected, and the separation process was repeated twice; then the two sections were combined. Anhydrous sodium sulfate Na2SO4 was then added to the section to withdraw moisture. The sample was concentrated using a rotary evaporator until it reached a volume of (5ml), then the extract was transferred to a clean tube, and the model was concentrated using a gentle stream of nitrogen until it reached 1ml, after which it was ready for separation on the chromatographic column (PBM, 2022).

Fish samples

5 g of fish muscle tissue was mashed in a mortar for homogeneity. After that, it was placed in a 40 ml glass jar, 3 g of anhydrous sodium sulfate was added. Then, 20 ml of n-hexane extraction solvent was added and mixed well. The glass vessel was immersed

in a water bath in an Ultrasonic device for 60 minutes at a temperature of 45 ºC. The mixture was then placed in a sifter at 4000 rpm for 5 minutes to separate the solvent from the precipitate, and this process was repeated twice (Rocco et al., 2008; Ozcan et al., 2009). The solvent was concentrated using a rotary evaporator to 5ml. The sample was transferred to a clean tube, and the model was concentrated using a gentle stream of nitrogen to 1ml, and then it was ready for purification.

Separation and purification

The sample was prepared in a burette with a length of 7.6cm and an inner diameter of 1.3cm. The burette was filled from bottom to top with 1g of anhydrous sodium sulfate, 2g of activated silica, and 2g of activated silica modified with sulfuric acid. After that, 2g of anhydrous sodium sulfate was added. The multilayer silica column was washed with 20ml of n-hexane before use Nevado et al., (2010), after which the sample was introduced to the queue, and purification was performed. The final extract was then collected and evaporated using a gentle stream of nitrogen to concentrate the sample. The sample was then analyzed on a gas chromatograph (GC/MS).

Sample analysis

The samples (water - fish) were analyzed using gas chromatography (GC/MS) technology. A TRP-5 capillary column with a length of (30 m) and an inner diameter of (0.32 m) was used to separate the combinations. The flow of the mobile phase was 1 ml/min according to the system. The following thermal programming:

$$70\ ^{\circ}C\ (1\ min) \xrightarrow{4\ ^{\circ}C/\ min} 280\ ^{\circ}C\ (10\ min)$$

The qualitative analysis process was carried out using the external standard solution method by comparing the retention times of sample combinations with the retention times of typical combinations of specific identity and concentration. Figure 1 shows the chromatogram of a mixture of polychlorinated biphenyls (PCBs).

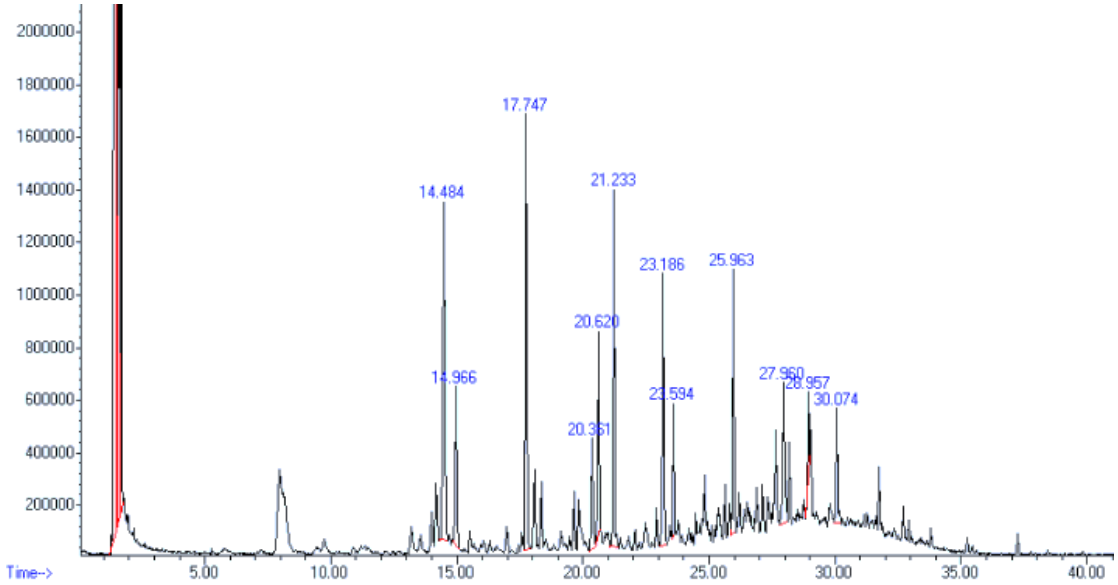

Figure 1 Chromatogram of a mixture of PCBs.

The process of quantitatively determining the concentrations of combinations present in water and fish samples was carried out through the following association:

$$C_{\mu l/L} = \frac{R_f \,.\, A_{rea} \,.\, V_{ext}}{V_{inj} \,.\, V_i}$$

Each symbol shows the following:

Rf: Response factor.

Area: The peak height of the combination in the sample.

Vext: Volume of extract (1000 µL).

Vinj: Volume of sample injected (1 µL).

Vi: Sample volume (L).

3. RESULTS AND DISCUSSION

Distribution of PCBs in aqueous samples

Distribution of PCBs in water samples from the South Corniche area

Fifteen isomers of polychlorinated biphenyls (PCBs) were detected in the waters of this region. Table 1 shows the total concentration of polychlorinated biphenyls Σ PCBs in the waters of this region during the two seasons of the study. We find that the lowest value of the total concentration of PCBs was 23.05 µg/l during the winter, in contrast the highest value was 46.55 µg/l during the summer. The reason for the decrease in the value of the total concentration of PCBs *Σ* in the winter and its increase in the summer in this region may be due to the rise in human and tourist activities in the summer and the decrease of these activities in the winter, as both of them negatively affect water quality (Needham and Ghosh, 2019; Undeman et al., 2022).

Table 1 Concentrations of PCBs (µg/l) present in the water of the South Corniche region

Combination name	PCB.No	The Summer	The Winter
4,4` - Dichlorobiphenyl	PCB - 15	8.916	7.822
2,2`,4,5,5` - Pentachlorobiphenyl	PCB – 101	14.004	11.579
2,3`,4,4`,5 - Pentachlorobiphenyl	PCB – 118	6.878	2.871
2,2`,3,4,4`,5` - Hexachlorobiphenyl	PCB – 138	0.152	Nd
2,2`,3,4,5,5` - Hexachlorobiphenyl	PCB – 141	3.648	Nd
2,2`,3,5,5`,6 - Hexachlorobiphenyl	PCB – 151	0.095	0.0447
2,2`,4,4`,5,5` - Hexachlorobiphenyl	PCB – 153	1.349	Nd
2,2`,3,3`,4,4`,5 - Heptachlorobiphenyl	PCB – 170	1.57	Nd
2,2`,3,4,4`,5,5` - Heptachlorobiphenyl	PCB – 180	1.139	Nd
2,2`,3,4`,5,5`,6 - Heptachlorobiphenyl	PCB – 187	1.289	Nd
2,2`,3,3`,4,4`,5,5` - Octachlorobiphenyl	PCB – 194	0.157	Nd
2,2`,3,3`,4,4`,5,6 - Octachlorobiphenyl	PCB – 195	1.347	Nd
2,2`,3,3`,4,4`,5,6` - Octachlorobiphenyl	PCB – 196	1.223	Nd
2,2`,3,3`,4,5,5`,6` - Octachlorobiphenyl	PCB - 199	3.603	0.735
Decachlorobiphenyl	PCB - 209	1.183	Nd
	Σ PCBs	46.553	23.0517

Nd: not detected.

The total concentrations of PCBs varied between the summer and winter seasons, as their value increased in the summer and decreased in the winter. We also note that there is a clear difference in the distribution of PCBs during the two seasons of the study, especially compounds with low molecular weight, and this is attributed to the tendencies of these compounds become more soluble in marine waters in summer as a result of rising temperatures, as the solubility of low molecular weight PCBs increases with increasing temperature (Shiu et al., 1997). PCB-101 recorded the highest value of 14.004 µg/l in the summer, in contrast the lowest value was for PCB-151, which reached 0.095 µg/l in the summer, and in the winter, it went 0.0447 µg/l. The concentrations of combinations PCB-15, PCB-101, PCB-118, PCB-151, and PCB-199 were monitored only in the winter, in contrast the other combinations were below the detection limit (Figure 2).

Distribution of PCBs in water samples from the Sports City area

A mixture of polychlorinated biphenyls (PCBs) was detected in the water of this region. Table 2 shows the total concentration of polychlorinated biphenyls (Σ PCBs) in the water of this region during the two seasons of the study, where we find that the lowest value for the total concentration of Σ PCBs was 22.1037 µg/l during the winter, in contrast the highest value of total concentration was 28.044 µg/l during the summer. The reason for the decrease in the value of the total concentration of PCBs in the winter and its increase in the summer in this region may be due to the reduction of these activities in the winter in addition to the open nature of the area which is affected by solid sea currents (Swackhamer and Skoglund, 1993). Low water temperature also enhances the migration of these lipophilic pollutants to adhere to organic materials suspended in the aqueous phase (Swackhamer and Skoglund, 1993).

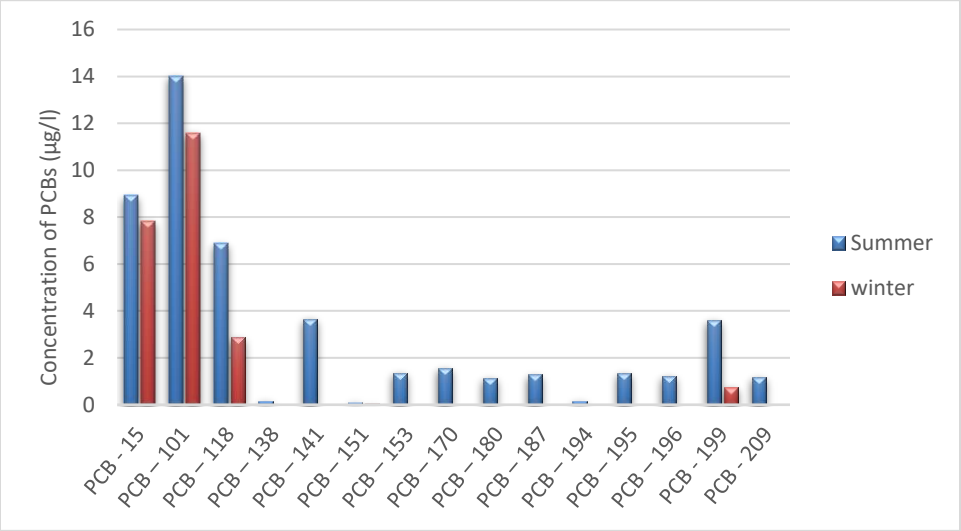

Figure 2 Concentrations of PCBs (µg/l) in the water of the South Corniche area.

Table 2 Concentrations of PCBs (µg/l) present in the water of the Sports City area.

Combination Name	PCB.No	The summer	The winter
4,4` - Dichlorobiphenyl	PCB - 15	8.068	7.415
2,2`,4,5,5` - Pentachlorobiphenyl	PCB – 101	11.441	9.976
2,3`,4,4`,5 - Pentachlorobiphenyl	PCB – 118	7.87	4.299
2,2`,3,4,4`,5` - Hexachlorobiphenyl	PCB – 138	Nd	Nd
2,2`,3,4,5,5` - Hexachlorobiphenyl	PCB – 141	Nd	Nd
2,2`,3,5,5`,6 - Hexachlorobiphenyl	PCB – 151	0.0534	Nd
2,2`,4,4`,5,5` - Hexachlorobiphenyl	PCB – 153	Nd	Nd
2,2`,3,3`,4,4`,5 - Heptachlorobiphenyl	PCB – 170	Nd	Nd
2,2`,3,4,4`,5,5` - Heptachlorobiphenyl	PCB – 180	Nd	Nd
2,2`,3,4`,5,5`,6 - Heptachlorobiphenyl	PCB – 187	Nd	Nd
2,2`,3,3`,4,4`,5,5` - Octachlorobiphenyl	PCB – 194	Nd	Nd
2,2`,3,3`,4,4`,5,6 - Octachlorobiphenyl	PCB – 195	Nd	0.048
2,2`,3,3`,4,4`,5,6` - Octachlorobiphenyl	PCB – 196	Nd	Nd
2,2`,3,3`,4,5,5`,6` - Octachlorobiphenyl	PCB - 199	0.612	0.3657
Decachlorobiphenyl	PCB - 209	Nd	Nd
	Σ PCBs	28.044	22.1037

Nd: not detected.

PCB-101 recorded the highest concentrations among the studied combinations, as its concentration reaching 11,441 µg/l during the summer, in contrast its concentration was 9.976 µg/l. The lowest value for the combination PCB-195 was recorded during the winter and amounted to 0.048 µg/l, in contrast its concentration during the summer was below the detection limit. The other minimum value for the combination PCB-151 was recorded during the summer and amounted to 0.0534 µg/l, in contrast its concentration was during the winter without limit of detection. The concentrations of combinations PCB-15, PCB-101, PCB-118, PCB-151, PCB-195, and PCB-199 were monitored only in the summer and winter. In contrast, the attention of other combinations was not observed because they were below the detection limit, (Figure 3).

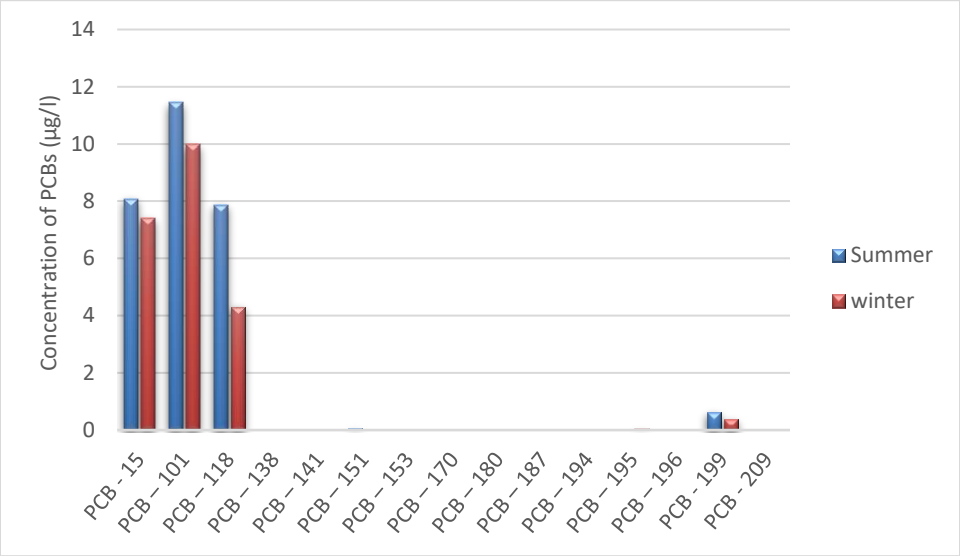

Figure 3 Concentrations of PCBs (µg/l) in the water of the Sports City area.

Distribution of PCBs in fish samples

Distribution of PCBs in fish samples from the South Corniche region

Fifteen isomers of polychlorinated biphenyls (PCBs) were detected in the *Siganus rivulatus* of this region. Table 3 shows the total concentration of polychlorinated biphenyls Σ PCBs in the *Siganus rivulatus* of this region during the two seasons of the study, where we find that the lowest value of the total concentration is for PCBs, it reached 61.2154 µg/g during the winter, in contrast the highest value of the total concentration for PCBs reached 62.916 µg/g during the summer. The total concentrations of PCBs in fish collected during the two seasons of the study converged, with a slight increase in their engagements during the summer, which shows the continued arrival of PCBs into the marine environment in this region and their accumulation in the muscle tissue of fish. An apparent accumulation of combinations containing a more significant number of chlorine atoms was observed in the fish studied due to their resistance to decomposition and metabolism and their unique system of distributing chlorine in their molecular structure (Bright et al., 1995).

Table 3 Concentrations of PCBs (µg/g) present in *Siganus rivulatus* fish in the South Corniche region

Combination Name	PCB.No	The Summer	The Winter
4,4` - Dichlorobiphenyl	PCB - 15	3.31	1.99
2,2`,4,5,5` - Pentachlorobiphenyl	PCB – 101	4.683	1.165
2,3`,4,4`,5 - Pentachlorobiphenyl	PCB – 118	3.301	3.4032
2,2`,3,4,4`,5` - Hexachlorobiphenyl	PCB – 138	0.844	0.492
2,2`,3,4,5,5` - Hexachlorobiphenyl	PCB – 141	Nd	Nd
2,2`,3,5,5`,6 - Hexachlorobiphenyl	PCB – 151	0.794	0.658
2,2`,4,4`,5,5` - Hexachlorobiphenyl	PCB – 153	Nd	Nd
2,2`,3,3`,4,4`,5 - Heptachlorobiphenyl	PCB – 170	Nd	Nd
2,2`,3,4,4`,5,5` - Heptachlorobiphenyl	PCB – 180	0.748	0.5292
2,2`,3,4`,5,5`,6 - Heptachlorobiphenyl	PCB – 187	0.704	1.093
2,2`,3,3`,4,4`,5,5` - Octachlorobiphenyl	PCB – 194	Nd	Nd
2,2`,3,3`,4,4`,5,6 - Octachlorobiphenyl	PCB – 195	0.723	0.666
2,2`,3,3`,4,4`,5,6` - Octachlorobiphenyl	PCB – 196	Nd	Nd
2,2`,3,3`,4,5,5`,6` - Octachlorobiphenyl	PCB - 199	14.665	15.309
Decachlorobiphenyl	PCB - 209	33.144	35.91
	Σ PCBs	62.916	61.2154

Nd: not detected.

Figure 4 shows the concentrations of polychlorinated biphenyl isomers (PCBs), where PCB-209 recorded the highest value, reaching 35.91 µg/g during the winter. In contrast, PCB-138 recorded the lowest value, reaching 0.492 µg/g during the winter as well. PCB-199 and PCB-209 recorded high concentrations in both seasons of the study compared to the rest of the combinations, and the attention of each of them were higher in the winter compared to their attention in the summer.

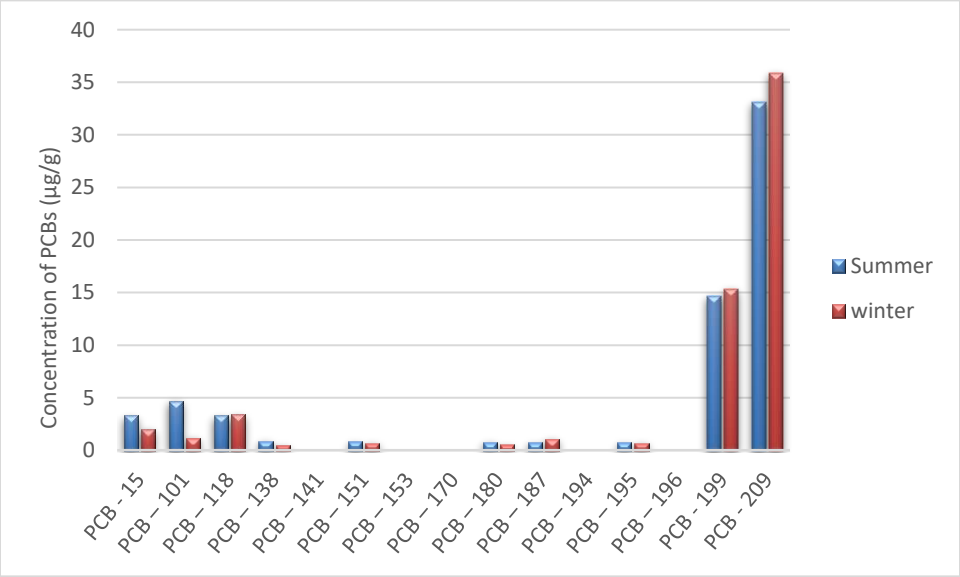

Figure 4 Concentrations of PCBs (µg/g) in *Siganus rivulatus* in the South Corniche area.

Distribution of PCBs in fish samples from the Sports City area

Fifteen isomers of polychlorinated biphenyls (PCBs) were detected in *Siganus rivulatus* from this region. Table 4 shows the total concentration of polychlorinated biphenyls Σ PCBs in *Siganus rivulatus* from this region during the two seasons of the study, where we find that the lowest value for the total concentration is for PCBs, it reached 64.7086 µg/g during the winter, in contrast the highest value of the total concentration reached 67.9369 µg/g during the summer. We note that there is a diversity of combinations accumulated in *Siganus rivulatus* fish. We also note that combinations with larger molecular weights had higher concentrations in the studied fish. A decrease in the attention of most of the PCBs was observed during the summer and their clarity in the winter due to photo-oxidation processes and high temperatures in the summer season, which leads to increased rates of biodegradation by microorganisms such as fungi, bacteria, and germs (Bamforth and Singleton, 2005).

Table 4 Concentrations of PCBs (µg/g) present in *Siganus rivulatus* fish in the Sports City area.

Combination Name	PCB.No	The Summer	The Winter
4,4` - Dichlorobiphenyl	PCB - 15	1.779	1.4107
2,2`,4,5,5` - Pentachlorobiphenyl	PCB – 101	1.4119	1.28
2,3`,4,4`,5 - Pentachlorobiphenyl	PCB – 118	3.008	2.887
2,2`,3,4,4`,5` - Hexachlorobiphenyl	PCB – 138	Nd	2.405
2,2`,3,4,5,5` - Hexachlorobiphenyl	PCB – 141	Nd	1.238
2,2`,3,5,5`,6 - Hexachlorobiphenyl	PCB – 151	Nd	1.5809
2,2`,4,4`,5,5` - Hexachlorobiphenyl	PCB – 153	1.402	13.637
2,2`,3,3`,4,4`,5 - Heptachlorobiphenyl	PCB – 170	Nd	5.362
2,2`,3,4,4`,5,5` - Heptachlorobiphenyl	PCB – 180	Nd	1.893
2,2`,3,4`,5,5`,6 - Heptachlorobiphenyl	PCB – 187	Nd	5.984
2,2`,3,3`,4,4`,5,5` - Octachlorobiphenyl	PCB – 194	Nd	2.81
2,2`,3,3`,4,4`,5,6 - Octachlorobiphenyl	PCB – 195	5.121	1.248
2,2`,3,3`,4,4`,5,6` - Octachlorobiphenyl	PCB – 196	0.819	3.908
2,2`,3,3`,4,5,5`,6` - Octachlorobiphenyl	PCB - 199	40.44	9.918
Decachlorobiphenyl	PCB - 209	13.956	9.147

	Σ PCBs	67.9369	64.7086

Nd: not detected.

The concentrations of PCBs in the winter were relatively close to those attention in the summer. Figure 5 shows the attention of the isomers of PCBs, where PCB-199 recorded the highest value, reaching 40.44 µg/g, and it was during the summer. At the same time, it was the lowest value for the combination PCB-196 and went 0.819 µg/g during the summer. Concentrations of PCB-138, PCB-141, PCB-151, PCB-170, PCB-180, PCB-187, and PCB-194 were not monitored in the summer as they were below the detection limit. PCB-199 and PCB-209 recorded high concentrations in study seasons because these combinations contain a more significant number of substituted chlorine atoms and, therefore, have a significant molecular weight. This makes the ability of fish to metabolize these combinations weak, and thus, they remain accumulated in the muscle tissue of fish for a long time (Shaw, 1993).

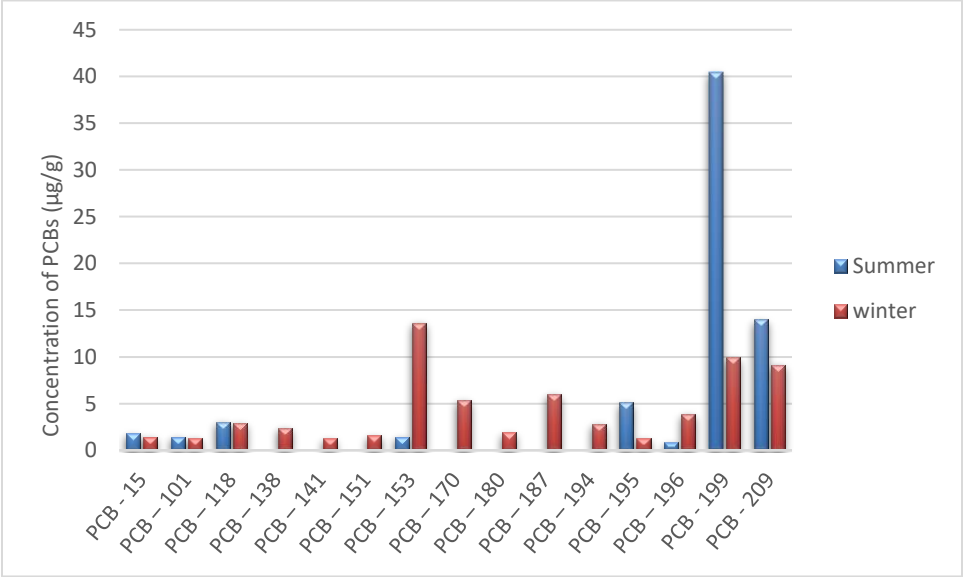

Figure 5 Concentrations of PCBs (µg/g) in *Siganus rivulatus* in the Sports City area.

Discussion

The results show that the distribution of polychlorinated biphenyls (PCBs) in the saltwater waters of the coast of Latakia appears clearly throughout the studied areas. This shows the continuous arrival of these combinations into the marine environment through several sources, including sewage channels, tourism activities, and agricultural activities (Needham and Ghosh, 2019; Undeman et al., 2022). We also note that the concentrations of PCBs were relatively high in the South Corniche area compared to the Sports City area, especially in the summer. The reason for this is attributed to the increase in tourist activities in the summer, the presence of sewage channels, and the increase in external sources of pollution in general, in contrast the Sports City area is considered far away. Relatively from the direct sources of pollution, our results also show that there is a difference in the distribution of the isomers of polychlorinated biphenyls (PCBs) in saltwater waters, as we find that the combinations that contain fewer chlorine atoms are the most distributed isomers, especially di- and pentachlorobiphenyls, and this is due to their tendency to dissolve in saltwater waters is greater than that of combinations containing a more significant number of chlorine atoms (Shiu et al., 1997).

The results showed that the concentrations of PCBs were high in the exotic fish collected from the southern Corniche area compared to the samples collected from the Sports City area. This is due to the presence of fishing boats, tourist activities (the company of many tourist restaurants along the Corniche), or canals. The water whose waste is discharged directly into water without prior treatment (Needham and Ghosh, 2019; Undeman et al., 2022). We note from the above a difference in the distribution of polychlorinated biphenyls in exotic fish collected from the study areas, as we find that combinations that contain a lower number of chlorine atoms accumulate in the studied fish, but in lower concentrations than combinations that contain a more significant number of chlorine atoms, such as PCB combinations PCB-209, 199. This is because combinations with higher molecular weights have a more remarkable, ability to accumulate and have a higher resistance to decomposition and metabolism, thus causing them to get more (Shaw, 1993).

As for the combinations octachlorobiphenyl and ecachlorobiphenyl, they were found in large concentrations in fish, and this is due to their ability to accumulate significantly in the muscle tissue of fish and the difficulty of metabolizing these combinations in

fish (Josefsson et al., 2006; ATSDR, 1990). The correlation association that was studied between the concentration of PCBs and the lengths of the studied fish indicated the presence of a strong direct association. This shows an increase in the concentration of PCBs with the increasing size of the fish, which means the continuity of the accumulation of these combinations in living organisms over time. Exposure to these pollutants is as shown in (Figure 6).

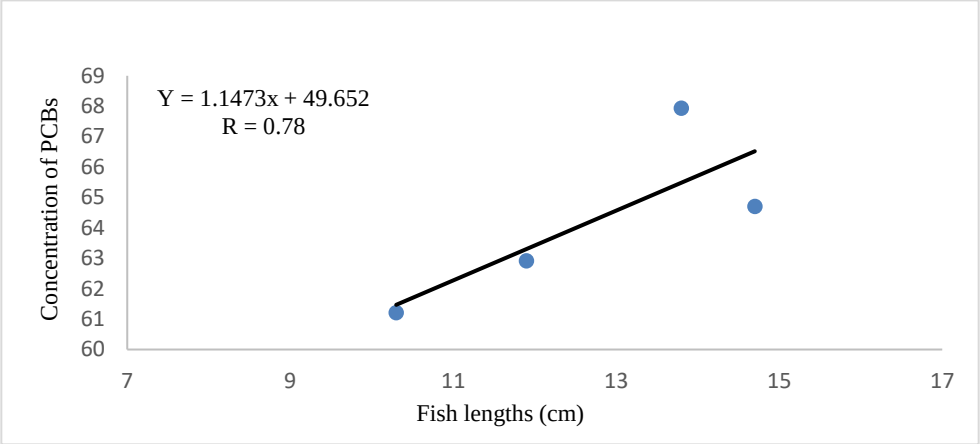

Figure 6 Correlation between the total concentration of PCBs and the length of the *Siganus rivulatus*.

These results are consistent with studies Szlinder-Richert et al., (2009), Yurdakul and Kucuksezgin, (2020), where the results showed that the concentration of PCBs increased proportionally with the length of the fish, which shows that these combinations continued to accumulate over time, which may pose a threat to the food chain. The values of the logarithm of the bioconcentration factor between water and exotic fish ranged between 2.0026 L/Kg and 4.82 L/Kg, where an increase in the importance of the logarithm of the bioconcentration factor Log BCF was observed with increasing importance of the logarithm of the distribution coefficient between octanol and water Log Kow. Figure 7 represents the correlations between the bioconcentration coefficient between the water and the studied fish, Log BCF, and the distribution coefficient between octanol and water, Log Kow.

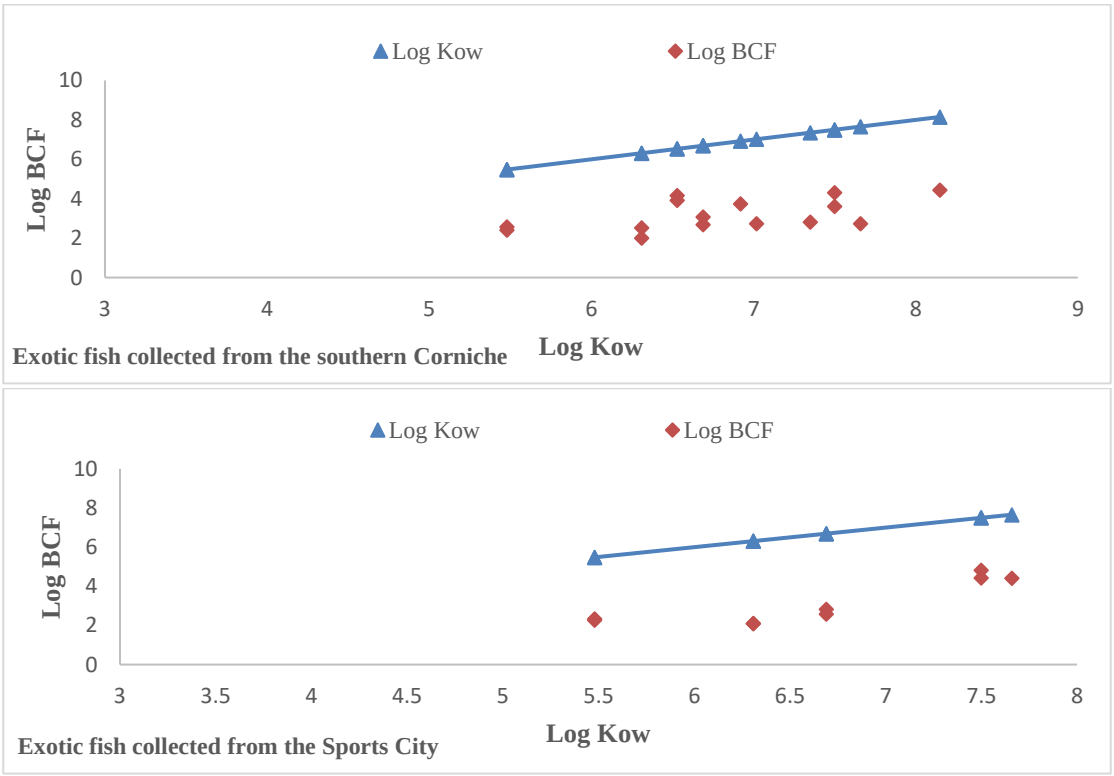

Figure 7 Log Kow and Log BCF associations between the water and the studied fish.

The straight line represents a (1:1) association between Log BCF and Log Kow, in contrast the points indicate Log BCF values between fish and water versus the Log Kow values corresponding to these combinations. All BCF values were lower than the corresponding Log Kow values. This may be due to the lipophilic property of the combinations, which causes them to accumulate on the lipid layer of the cell membrane and not move into the cell (Wang et al., 2018; Cocci et al., 2018). Also, combinations with high Log Kow values are large and cannot pass, or they pass slowly through the cell membrane, which reduces the amount of their accumulation in fish.

Therefore, when they accumulate on the membrane, there becomes a state of balance between the membrane and water, so no additional quantities are transferred to the membrane, and thus, this reduces the process of their accumulation within fish (Adewale et al., 2022; Onyegeme-Okerenta et al., 2022). PCBs with high molecular weights also have an increased ability to adsorb to dissolved organic matter (DOM), which reduces their bioavailability and makes it difficult for marine organisms to absorb them.

4. CONCLUSIONS

There is a real presence of polychlorinated biphenyls (PCBs) in the coastal waters of the Sports City and South Corniche areas.
An accumulation of these combinations was observed in exotic fish collected from the study areas. Most PCB concentrations were higher in summer than in winter. The total concentration of polychlorinated biphenyls (PCBs) in the studied fish was more significant than in saltwater waters. PCB isomers, which have a smaller number of chlorine atoms, was observed in all water and fish samples. There was an apparent accumulation of PCB isomers, which have a more significant number of chlorine atoms, in all fish samples.

Recommendations

Setting restrictions on activities that contribute to the arrival of these pollutants into the marine environment.
Limiting the access of PCBs to the marine environment by implementing relevant laws in the field of the domain.
The necessity of treating wastewater in an effectively manner to reduce its adverse effects on the marine environment.

Author contributions

All authors are equal in work

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Informed consent

Not applicable.

Ethical approval

The Animal ethical guidelines are followed in the study.

Conflicts of interests

The authors declare that there are no conflicts of interests.

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Data and materials availability

All data associated with this study are present in the paper.

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