Bull. Environ. Contam. Toxicol. (2000) 65:391–398

DOI: 10.1007/s001280000140

Bulletin of Environmental Contamination and Toxicology

# Petroleum Hydrocarbon Pollution in Sharks in the Arabian Gulf

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Received: 15 March 2000/Accepted: 13 June 2000

The Arabian Gulf has distinctive features such as species diversity and extreme climatic conditions. Exploitation of crude oil production resulted in contamination of the marine environment with petroleum hydrocarbons. The contamination has been amplified several times by intentional discharge of crude oil into the Gulf waters during the Iraqi occupation of Kuwait, thus challenging the coastal ecosystem. The predicament was further aggravated by enormous quantities of soot, oil droplets and partially combusted hydrocarbons from the blazing oil wells during the Gulf war.

The marine sediment-associated bioaccumulation of hydrocarbons is related to their hydrophobic character, hence the low molecular weight and water soluble compounds becoming mostly bioavailable (Djomo et al. 1996). Sediment organic carbon content (Knezovich et al. 1987), grain size distribution, interstitial water (Harkey et al. 1995), sediment ageing (Kesley et al. 1997) Polycyclic Aromatic Hydrocarbons (PAHs) and Aliphatic Hydrocarbons (AHs) origin (Murray et al. 1991) are the parameters which influence the contaminant bioavailability. Exposure of organisms to pollution depends on water turbidity (Menon and Menon 1999), location of the organisms in the water column and on their feeding modes (Baumard et al. 1999). Accumulation of hydrocarbon toxicants in marine animals can take place when exposed to petroleum hydrocarbons during feeding and passage of water over their respiratory organs.

Biological disorders like neoplasm (Malins and Hodgins 1981), deleterious effect on vitellogenesis (Nicolas 1999) and DNA damage (Steinert et al. 1998) have been reported after exposure of fish and other marine organisms to PAHs and/or AHs. The noteworthy finding of recent studies using radio-labelled hydrocarbons have shown that the highest concentrations of PAHs and their metabolites, take place in the hepatobiliary system of fish, while edible muscle and other extrahepatic tissues are secondary locations for accumulation of such compounds (Stein et al. 1987). Species specific differences in biochemical and physiological parameters, such as basal levels of xenobiotic-metabolising enzymes and lipid content of tissues, in addition to the potential of other contaminants, appear to affect the metabolism and disposition of PAHs and their metabolites (Varanasi

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and Stein 1991). Therefore, information on the accumulation of these toxic contaminants in fish and other marine organisms, makes them suitable bioindicators. In this study sharks which are wandering predators covering long distances and varied depths of the sea, were selected to assess hydrocarbon pollution in the Gulf waters. We were especially interested to assess the exposure of sharks to hydrocarbon pollution because some inhabitants of the Gulf region consume sharks meat for its nutritional as well as its aphrodisiac characteristics.

## MATERIALS AND METHODS

Different species of sharks were caught in the Arabian Gulf using baited hooks on line at locations shown in table 1. Fishes were dissected for removal of their gills, liver and muscle for analysis of PAHs, and AHs. Each sample was placed in an aluminium

**Table 1**. Sample collection locations

| S | Common Name | Scientific Name | Sample Location | Col. Date | Lati. N | Long. E |
|---|---|---|---|---|---|---|
| 1 | Milk Sharks (0,1,2) | Rhizoprinodon acutus | Al-Riksah | 05 11 96 | $29^0$ 25.25' | $48^0$ 10.73' |
| 2 | Saw-toothed Reef Shark | Carcharhius sorrah | Sunken trawler | 27 06 97 | $29^0$ 20.14' | $48^0$ 10.73' |
| 3 | White Cheek Shark | Carcharhius dussumieri | Sunken trawler | 27 06 97 | $29^0$ 20.14' | $48^0$ 10.73' |
| 4 | Arabian Carpet Nurse Shark | Chilosyllim arabicum | Yacht Club Salmiyah | 16 10 97 | $29^0$ 21.41' | $48^0$ 04.77' |
| 5 | Black Tip Reef Shark | Carcharhius melanopterus | Auha | 13 06 97 | $29^0$ 22.48' | $48^0$ 28.30' |
| 6 | Arabian Carpet Nurse Shark | Chilosyllim arabicum | Kuwait Bay | 23 05 98 | $29^0$ 27.08' | $47^0$ 59.63' |
| 7 | Gray Black Fin Shark | Carcharhins limatus | Cirus oil field area | 19 12 97 | $29^0$ 03.19' | $49^0$ 30.03' |
| 8 | Gray Black Fin Shark | Carcharhins limatus | Kuwait Bay | 30 04 98 | $29^0$ 27.08' | $47^0$ 59.63' |
| 9 | Gray Black Fin Shark | Carcharhinus limatus | Kuwait Bay | 30 04 98 | $29^0$ 27.08' | $47^0$ 59.63' |
| 10 | Gray Black Fin Shark | Carcharhinus limatus | Kuwait Bay | 30 04 98 | $29^0$ 27.08' | $47^0$ 59.63' |

foil and kept in a clean dark glass bottle, labelled and stored frozen at - $80^0$ C until analysed. Anhydrous sodium sulfate and potassium hydroxide were of analytical grade, and were purchased from Fluka, Switzerland. All solvents used in this study were of HPLC grade and were purchased from either Fluka, Switzerland or BDH, England.

A modified procedure of Kristiina et al. (1986) was followed for the extraction of PAHs and AHs from fishes. Fish organs and muscle ((5 gm., wet weight) were dried between folds of filter paper, weighed and then crushed in a Mortar and Pestle after the addition of anhydrous sodium sulfate (10 gm. ). The crushed sample was taken in a thimble, pre-eluted with water : methanol mixture (1:9 V/V) and Soxhlet extracted for 4 hours with 100 mL of the same solvent mixture containing 3.5 gm. of solid potassium hydroxide. The extract was cooled and mixed with 100 mL of water : methanol mixture (2:8 V/V), and extracted twice with cyclohexane (100 mL). The organic extract was first washed with 100 mL of water : methanol mixture (1:1 V/V ) and then twice with 100 mL of water. The cyclohexane extract was dried over anhydrous sodium sulfate and concentrated to 1 mL at $30^{o}$ C on a rotary evaporator. A chromatographic column (40 cm x 0.8 cm ID ), packed with 6.5 g. of florisil (60-100 mesh) deactivated with 5% water, was prepared with 80 mL of toluene. Concentrated cyclohexane extract was loaded on top of the column. Elution of the column was made with 30 mL toluene and the eluent was evaporated to dryness on a rotavapor at 35 - $40^{o}$ C. The residue was dissolved in 10 mL hexane and extracted twice with 10 mL of Dimethyl Sulphoxide (DMSO). The combined DMSO extracts were diluted with 40 mL water and re-extracted with cyclohexane (2 x 20 mL). The combined cyclohexane extracts were washed twice with water (40 mL) and dried over anhydrous sodium sulfate. Cyclohexane was evaporated to dryness at $30^{o}$ C and the residue was re-dissolved in 50 μL of dichloromethane containing d-10 acenaphthene as an internal standard and analysed by Gas Chromatography/Mass Spectrometry (GC/MS) for PAHs. The residual hexane solution, after the extraction with DMSO, was dried with anhydrous sodium sulfate and the solvent was evaporated to dryness. The residue was re-dissolved in dichloromethane containing eicosene, as an internal standard and analysed for AHs by GC/MS.

GC/MS was performed on Autospec Q (Fisons) GC/MS-MS equipped with split/splitless injection system, magnetic scan detector. The extract was analysed in the split/splitless mode using a fused silica capillary column DB - 5 MS ( 30 m x 0.25 mm ID, 0.25 μm film thickness, J & W Scientific) and helium as a carrier gas. The oven temperature was programmed from $90^{o}$ C (held for one min.) to $300^{o}$ C at a rate of $5^{o}$ C $min^{-1}$ and maintained at $300^{o}$ C for 30 min. The MS temperature program for transfer line was $280^{o}$ C and ion source temperature was $200^{o}$ C. The MS was operated in EI mode (70 eV) scanning from 42 to 550 amu at 1200 resolution.

The quantification of PAHs and AHs was based on an application of internal standard as well as reference standard materials. To ensure appropriate quality of analyses, reagent blanks and reference materials were also analysed. All samples were run in triplicate and the mean value was taken.

## RESULTS AND DISCUSSION

Sharks were analysed for hydrocarbon pollution (PAHs and AHs). The level of identified PAHs and AHs is shown in table 2 and 3. The highest concentration of total PAHs 72.96 μg/g wet weight, was found in Saw-toothed Reef Shark, where

**Table 2**. Levels of PAHs in sharks μg/g (wet wt.)

| S.N | Local Name | Org. | Na | Ac | F | Ph | An | Flu | Py | BA | Ch | Bb | Bk | Ba | Ind | Di | Ben | Tot. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Gray Black Fin | Liver | 0.38 | ND | ND | 0.38 | ND | ND | 0.56 | ND | ND | ND | ND | ND | ND | ND | ND | 1.32 |
| | shark female | Gills | ND | ND | ND | 0.29 | ND | ND | 0.45 | ND | ND | ND | ND | ND | ND | ND | ND | 0.74 |
| | K.Bay | Total | 0.38 | ND | ND | 0.68 | ND | ND | 1.01 | ND | ND | ND | ND | ND | ND | ND | ND | 2.07 |
| 2 | Gray Black Fin | Liver | 0.13 | ND | 0.12 | 0.29 | 0.43 | 0.19 | 0.44 | ND | ND | 3.11 | 1.89 | ND | ND | ND | ND | 6.60 |
| | shark male | Mus | 0.33 | ND | 0.14 | 0.28 | ND | 0.72 | ND | 2.12 | 1.67 | ND | ND | ND | ND | ND | ND | 5.26 |
| | K.Bay | Total | 0.46 | ND | 0.26 | 0.57 | 0.43 | 0.92 | 0.44 | 2.12 | 1.67 | 3.11 | 1.89 | ND | ND | ND | ND | 11.87 |
| 3 | Gray Black Fin | Liver | 0.17 | ND | ND | 0.16 | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | 0.33 |
| | shark unborn | Mus. | ND | ND | ND | 0.15 | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | 0.15 |
| | K.Bay | Gills | ND | ND | ND | 0.63 | ND | ND | 1.08 | ND | ND | ND | ND | ND | ND | ND | ND | 1.71 |
| | | Total | 0.17 | ND | ND | 0.94 | ND | ND | 1.08 | ND | ND | ND | ND | ND | ND | ND | ND | 2.19 |
| 4 | Arabian Carpet | Liver | 0.11 | ND | ND | 0.35 | ND | 0.29 | ND | ND | ND | ND | 1.68 | 3.35 | ND | ND | ND | 5.78 |
| | Nurse shark | Mus. | 0.13 | ND | ND | 0.35 | ND | 0.19 | 0.48 | ND | ND | ND | ND | ND | ND | ND | ND | 1.15 |
| | Yacht club | Gills | ND | ND | ND | 0.34 | ND | 0.21 | 0.45 | ND | ND | ND | ND | ND | ND | ND | ND | 1.00 |
| | | Total | 0.24 | ND | ND | 1.04 | ND | 0.69 | 0.93 | ND | ND | ND | 1.68 | 3.35 | ND | ND | ND | 7.93 |
| 5 | Arabian Carpet | Liver | ND | ND | ND | ND | ND | 0.13 | ND | ND | ND | ND | ND | ND | ND | ND | ND | 0.13 |
| | Nurse shark | Mus. | Tr. | ND | ND | Tr. | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | Tr. |
| | K.Bay | Gills | 0.13 | ND | ND | 0.36 | 0.46 | 0.15 | 0.35 | 0.72 | 0.66 | ND | ND | ND | ND | ND | ND | 2.83 |
| | | Total | 0.13 | ND | ND | 0.36 | 0.46 | 0.29 | 0.35 | 0.72 | 0.66 | ND | ND | ND | ND | ND | ND | 2.97 |
| 6 | Saw-toothed | Liver | 0.55 | ND | 0.39 | 0.77 | ND | 1.26 | 1.49 | ND | ND | ND | 3.33 | ND | 8.23 | 8.65 | 8.79 | 33.46 |
| | Reef shark | Mus. | ND | ND | 0.31 | 0.71 | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | 1.02 |
| | Sunken trawler | Gills | 0.17 | ND | 0.39 | 0.75 | ND | 1.14 | 1.37 | 1.00 | 1.20 | 0.30 | 2.67 | 4.66 | 7.11 | 9.82 | 7.86 | 38.44 |
| | | Total | 0.73 | ND | 1.09 | 2.22 | ND | 2.40 | 2.86 | 1.00 | 1.20 | 0.30 | 6.00 | 4.66 | 15.3 | 18.5 | 16.7 | 72.96 |
| 7 | Black Tip | Liver | 0.13 | ND | ND | 0.42 | ND | 0.60 | 0.85 | ND | ND | ND | ND | ND | ND | ND | ND | 2.00 |
| | Reef shark | Mus. | ND | ND | ND | 0.36 | ND | 0.21 | 1.09 | ND | ND | ND | ND | ND | ND | ND | ND | 1.66 |
| | Auha | Gills | ND | ND | ND | 0.40 | ND | 0.23 | 0.54 | ND | ND | ND | ND | ND | ND | ND | ND | 1.17 |
| | | Total | 0.13 | ND | ND | 1.18 | ND | 1.05 | 2.48 | ND | ND | ND | ND | ND | ND | ND | ND | 4.84 |
| 8 | White Cheek | Liver | 0.49 | ND | 0.34 | 0.73 | ND | 1.50 | ND | ND | ND | ND | ND | ND | ND | ND | ND | 3.06 |
| | shark | Mus. | ND | ND | ND | 0.71 | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | 0.71 |
| | | Gills | 0.17 | ND | ND | 0.75 | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | 0.92 |
| | Sunken trawler | Total | 0.66 | ND | 0.34 | 2.19 | ND | 1.50 | ND | ND | ND | ND | ND | ND | ND | ND | ND | 4.69 |
| 9 | Gray Black Fin | Liver | 0.26 | ND | ND | ND | ND | 0.24 | 0.54 | ND | ND | ND | ND | ND | ND | ND | ND | 1.04 |
| | shark | Mus. | 0.06 | ND | ND | 0.19 | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | 0.25 |
| | Cirus oil field | Gills | 0.23 | 0.11 | 0.29 | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | 0.63 |
| | | Total | 0.54 | 0.11 | 0.29 | 0.19 | ND | 0.24 | 0.54 | ND | ND | ND | ND | ND | ND | ND | ND | 1.91 |
| 10 | Milk shark 0 | Liver | 0.36 | ND | 0.34 | 0.73 | 0.68 | 1.17 | 1.40 | 0.95 | 0.94 | 3.16 | 2.70 | ND | ND | ND | ND | 12.43 |
| | Al-Riksah | Mus. | 0.31 | ND | ND | 0.77 | ND | ND | ND | ND | ND | 3.53 | ND | ND | ND | ND | ND | 4.61 |
| | | Gills | ND | ND | 0.35 | 0.79 | ND | 0.89 | 1.19 | ND | ND | ND | ND | ND | ND | ND | ND | 3.22 |
| | | Total | 0.67 | ND | 0.69 | 2.30 | 0.68 | 2.06 | 2.59 | 0.95 | 0.94 | 6.69 | 2.70 | ND | ND | ND | ND | 20.27 |

Cont.

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 11 | Milk shark 1 Al-Riksah | Liver | 0.11 | ND | 0.27 | 0.61 | 0.61 | ND | 2.27 | ND | ND | 2.59 | 2.16 | ND | 6.16 | 5.88 | 5.96 | 26.62 |
| | | Mus. | 0.99 | ND | ND | 0.76 | ND | ND | ND | ND | 0.93 | ND | ND | ND | ND | ND | ND | 2.68 |
| | | Gills | ND | ND | 0.08 | 0.22 | 0.23 | 0.27 | 0.42 | 0.19 | 0.19 | 0.78 | 0.65 | ND | ND | ND | ND | 3.03 |
| | | Total | 1.10 | ND | 0.35 | 1.59 | 0.84 | 0.27 | 2.69 | 0.19 | 1.12 | 3.37 | 2.81 | ND | 6.16 | 5.88 | 5.96 | 32.33 |
| 12 | Milk shark 2 Al-Riksah | Liver | 0.09 | ND | 0.67 | 0.83 | 0.75 | 1.43 | 2.53 | 0.93 | 1.10 | 3.16 | 2.71 | ND | 6.48 | ND | ND | 20.68 |
| | | Mus. | 0.61 | ND | ND | 0.75 | ND | ND | 1.14 | ND | 0.90 | 3.03 | 2.58 | 5.01 | 7.00 | 6.93 | 6.89 | 34.84 |
| | | Gills | ND | ND | 0.36 | 0.86 | 0.74 | 1.23 | 1.31 | ND | ND | ND | ND | ND | ND | ND | ND | 4.50 |
| | | Total | 0.70 | ND | 1.03 | 2.44 | 1.49 | 2.66 | 4.98 | 0.93 | 2.00 | 6.19 | 5.29 | 5.01 | 13.48 | 6.93 | 6.89 | 60.02 |

Na = Naphthalene; Ac = Acenaphthene; F = Fluorene; Ph = Phenanthrene; An = Anthracene; Flu = Fluoranthene; Py = Pyrene; BA = Benzo [a] anthracene; Ch = Chrysene; Bb = Benzo[b] fluoranthene; Bk = Benzo [k] fluoranthene; Ba = Benzo [a] pyrene; Ind = Indeno [123-cd] pyrene; Di = Dibenzo[ah] anthracene; Ben = Benzo [ghi] perylene;

**Table 3.** Alkanes in sharks µg/g (wet wt.)

| S.N | Local Name | Organ | $C_{14}$ | $C_{15}$ | $C_{16}$ | $C_{17}$ | $C_{18}$ | $C_{19}$ | $C_{20}$ | $C_{21}$ | $C_{22}$ | $C_{23}$ | $C_{24}$ | $C_{25}$ | $C_{26}$ | $C_{27}$ | $C_{28}$ | $C_{29}$ | $C_{30}$ | $C_{32}$ | Tot. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Gray Black Fin shark female | Liver | 0.01 | 0.02 | Tr. | 0.07 | Tr. | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | 0.10 |
| | | Mus. | 0.02 | 0.03 | 0.03 | 0.04 | 0.02 | 0.01 | 0.03 | Tr. | 0.01 | Tr. | 0.01 | 0.01 | 0.01 | ND | ND | ND | ND | ND | 0.22 |
| | | Gills | 0.01 | 0.03 | 0.04 | 0.04 | 0.01 | Tr. | 0.01 | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | 0.14 |
| | | Total | 0.04 | 0.08 | 0.07 | 0.15 | 0.03 | 0.01 | 0.04 | Tr. | 0.01 | Tr. | 0.01 | 0.01 | 0.01 | ND | ND | ND | ND | ND | 0.46 |
| 2 | Gray Black Fin shark male | Liver | 0.08 | 0.20 | 0.03 | 0.26 | 0.01 | 0.14 | 0.05 | ND | ND | ND | 0.09 | 0.13 | 0.39 | 0.37 | ND | 0.41 | 0.32 | 0.28 | 2.76 |
| | | Mus. | 0.24 | 0.14 | 0.07 | 0.05 | 0.01 | 0.01 | 0.24 | ND | ND | 0.02 | 0.05 | 0.07 | 0.18 | 0.08 | 0.02 | 0.02 | ND | ND | 1.20 |
| | | Gills | 0.07 | 0.05 | 0.03 | 0.04 | 0.01 | 0.02 | 0.04 | ND | 0.02 | 0.04 | 0.07 | ND | 0.03 | 0.23 | 0.01 | 0.11 | 0.07 | 0.05 | 0.89 |
| | | Total | 0.39 | 0.39 | 0.13 | 0.35 | 0.03 | 0.17 | 0.33 | ND | 0.02 | 0.06 | 0.21 | 0.21 | 0.60 | 0.68 | 0.03 | 0.54 | 0.39 | 0.33 | 4.85 |
| 3 | Gray Black Fin shark unborn | Liver | 0.08 | 0.06 | 0.04 | 0.07 | 0.02 | ND | ND | ND | ND | ND | 0.01 | 0.02 | 0.02 | ND | ND | ND | ND | ND | 0.32 |
| | | Mus. | 0.04 | 0.03 | 0.03 | 0.03 | 0.02 | 0.01 | 0.02 | Tr. | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | 0.18 |
| | | Gills | 0.05 | 0.06 | 0.05 | 0.05 | 0.02 | 0.02 | 0.01 | 0.04 | 0.03 | 0.02 | 0.01 | 0.01 | ND | ND | ND | 0.01 | ND | ND | 0.38 |
| | | Total | 0.17 | 0.14 | 0.12 | 0.15 | 0.06 | 0.03 | 0.03 | 0.04 | 0.03 | 0.02 | 0.02 | 0.03 | 0.02 | ND | ND | 0.01 | ND | ND | 0.87 |
| 4 | Arabain Carpet Nurse shark Yacht club | Liver | 0.01 | 0.01 | Tr. | ND | ND | Tr. | ND | ND | ND | ND | ND | ND | Tr. | ND | ND | ND | ND | ND | 0.02 |
| | | Mus. | 0.24 | 0.22 | 0.17 | 0.19 | 0.06 | 0.02 | 0.04 | 0.01 | Tr. | ND | ND | ND | ND | ND | ND | ND | ND | ND | 0.95 |
| | | Gills | 0.17 | 0.14 | 0.12 | 0.18 | 0.05 | 0.02 | 0.04 | 0.02 | 0.01 | Tr. | Tr. | 0.01 | ND | ND | ND | ND | ND | ND | 0.76 |
| | | Total | 0.42 | 0.37 | 0.29 | 0.37 | 0.11 | 0.04 | 0.08 | 0.03 | 0.01 | Tr. | Tr. | 0.01 | Tr. | ND | ND | ND | ND | ND | 1.73 |
| 5 | Arabain Carpet Nurse shark Kuwait Bay | Liver | 0.04 | 0.02 | 0.01 | 0.01 | ND | Tr. | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | 0.08 |
| | | Mus. | 0.04 | 0.03 | 0.03 | 0.04 | 0.02 | 0.01 | 0.04 | ND | 0.02 | 0.01 | 0.02 | 0.02 | ND | 0.02 | Tr. | 0.01 | ND | ND | 0.31 |
| | | Gills | 0.07 | 0.07 | 0.06 | 0.09 | 0.04 | 0.02 | 0.05 | 0.02 | 0.01 | Tr. | Tr. | Tr. | ND | ND | ND | ND | ND | ND | 0.43 |
| | | Total | 0.15 | 0.12 | 0.10 | 0.14 | 0.06 | 0.03 | 0.09 | 0.02 | 0.03 | 0.01 | 0.02 | 0.02 | ND | 0.02 | Tr. | 0.01 | ND | ND | 0.82 |
| 6 | Black Tip Reef shark Auha | Liver | 0.02 | 0.02 | 0.01 | 0.01 | 0.01 | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | 0.07 |
| | | Mus. | 0.03 | 0.04 | 0.04 | 0.04 | 0.02 | 0.01 | 0.02 | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | 0.20 |
| | | Gills | 0.10 | 0.08 | 0.07 | 0.05 | 0.03 | 0.02 | 0.04 | 0.01 | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | 0.40 |
| | | Total | 0.15 | 0.14 | 0.12 | 0.10 | 0.06 | 0.03 | 0.06 | 0.01 | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | 0.67 |
| 7 | Gray Black Fin shark Cirus oil field | Liver | 0.02 | 0.03 | 0.04 | 0.07 | 0.04 | 0.04 | 0.09 | ND | ND | ND | 0.04 | ND | 0.02 | ND | ND | 0.08 | 0.02 | ND | 0.49 |
| | | Mus. | 0.02 | 0.02 | 0.02 | 0.03 | 0.02 | 0.01 | 0.03 | 0.01 | 0.01 | Tr. | Tr. | Tr. | ND | ND | ND | ND | ND | ND | 0.17 |
| | | Gills | 0.01 | 0.01 | 0.02 | 0.03 | 0.02 | 0.02 | 0.06 | ND | 0.02 | Tr. | Tr. | ND | ND | ND | ND | ND | ND | ND | 0.19 |
| | | Total | 0.05 | 0.06 | 0.08 | 0.13 | 0.08 | 0.07 | 0.18 | 0.01 | 0.03 | Tr. | 0.04 | Tr. | 0.02 | ND | ND | 0.08 | 0.02 | ND | 0.85 |

ND = Not Detected; Tr. = Traces; Mus. = Muscle the most potent carcinogens benzo [a] pyrene and dibenzo [ah] anthracene were present at concentrations 4.66 μg/g and 18.5 μg/g wet weight, respectively. The high levels of these potent carcinogens reflect on the hazardous level of Gulf waters contamination.

Three newly born Milk Sharks (0,1 and 2) were investigated for the presence of PAHs. They showed high levels of 20.27μg/g, 32.33 μg/g and 60.02 μg/g wet weight of PAHs respectively. Benzo [a] pyrene was also observed in the muscle of Milk Shark 2 as shown in table 2. The presence of mutagenic substances in these tender, baby sharks indicated that these PAHs either entered their system through the gills, or as part of their diet, or through a combination of both.

Gray Black Fin Sharks both male and female were caught in Kuwait Bay and were analysed for PAHs and AHs. Upon dissection the female shark was found to be carrying two fully developed unborn baby sharks. These unborn sharks (combined together) were also analysed for PAHs and AHs. The female, male and unborn sharks showed the presence of PAHs in the following concentrations : 2.07 μg/g, 11.87 μg/g and 2.19 μg/g wet weight respectively. This finding was very interesting to us since the mother and the unborn babies showed the same level of accumulated PAHs, suggesting an unconstrained transfer of the toxicants from mother to its unborn babies. If this is extrapolated to humans, pregnant mothers consuming shark flesh from polluted waters can unequivocally convey toxicants to their babies. The investigated sharks showed different levels of AHs as shown in table 3. A ratio of 4.5 PAHs/AHs in the female shark indicated that this fish contained high levels of carcinogenic PAHs.

Two Arabian Carpet Nurse Sharks caught at different locations showed 7.93 (μg/g PAHs and 1.73μg/g of AHs (Salmiya) and 2.97 μg/g of PAHs and 0.82 μg/g of AHs (Kuwait Bay). Nurse Shark caught from Salmiya showed benzo [a] pyrene with a high concentration of 3.35 μg/g in its liver. However, the Gray Black Fin Shark caught far away from the coast (Cirus oil field) showed low concentrations of 1.91 μg/g wet weight of PAHs and 0.85μg/g wet weight of AHs. These results indicated that the deep off shore waters of Cirus were less impacted with toxic PAHs and AHs.

In all the analyzed sharks, two, three and four ring compounds were more common, compared to higher membered ring compounds. This may be due to the relative solubility of these compounds in water, which facilitates their uptake by marine animals (Djomo et al. 1996; Baumard et al. 1999). The most prevalent PAHs in these samples were naphthalene, phenanthrene, fluoranthene and pyrene. Figure 1 shows the percentage frequency of occurrence of PAHs in these fishes. Analysis for parent PAHs in tissue samples from fish captured in polluted areas showed only traces of PAHs, even though the sediments contained high concentration of these compounds (Krahn et al. 1984). The values obtained in this study may reflect partially on the true concentration of total PAHs, since these could be readily metabolised and excreted (Varanasi and Gmur 1981).

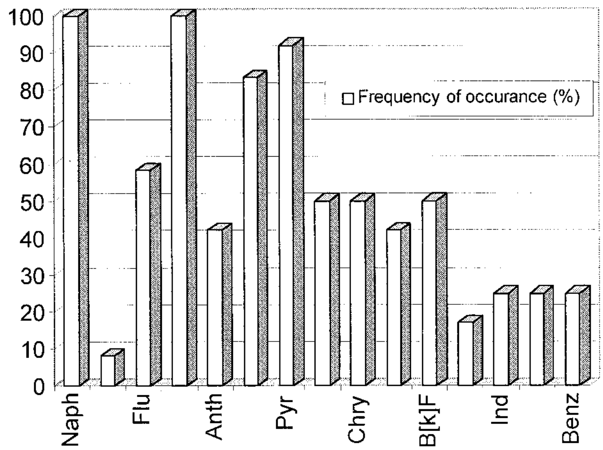


**Figure 1**. Frequency of occurrence of individual PAHs in sharks

In most of the samples included in this study, homologues of $C_{14}$ to $C_{30}$ were identified and a dominance of n-alkanes $C_{18}$ to $C_{24}$ suggested a relatively recent oil input (Readman et al. 1986).

Our study indicated that sharks accumulated noticeable levels of PAHs and AHs, irrespective of the depth of their mobility in the Gulf waters, their feeding modes and the areas in which they were caught. Gulf waters are known to contain oil derived pollutants through oil transportation activity, oil spills and intentional discharge of oil. Our results suggest that shark meat consumers in the Gulf should be alarmed about the contamination of the fish by potent carcinogens which may afflict many consumers, especially pregnant mothers. We suggest a periodic and long term check on the levels of PAHs and AHs in sharks at different locations to monitor these toxicants at different periods of the year.

*Acknowledgments.* The authors acknowledge with gratitude the financial and constant moral support rendered to this study by His Highness Sheikh Jaber Al-Ahmad Al-Sabah, the Amir of Kuwait. We especially thank His Excellency Sheikh Nasser Mohammad Al-Ahmad Al-Sabah, Minister for Ameri Diwan for his help and support. We are grateful to Mr. Mohammed Al-Naki for his trust and donation of the research boat "Balsam Al-Kuwait-2" and to the family of Dr.J.M.Al-Hassan for partial financial support. We acknowledge with thanks the partial support rendered by Kuwait University to project No. SB 031and SAF at KU for GC/MS analyses of samples.

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