

## Polycyclic Aromatic Hydrocarbons (PAHs) along the Eastern Caspian Sea Coast, Mazandaran State, Iran

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**Abstract:** PAHs form one of the most important classes of persistent pollutants. Sediment samples were taken from the eastern Caspian Sea coast of Mazandaran state analyzed by (GC-MS) for PAHs. Sediment samples were collected from eastern part of southern Caspian Sea in Mazandaran Province. Stations were Amirabad (10), Sari (5), Babolsar (5) and Noushahr (5) to determinate distribution and to source of PAHs. We analyzed 8 PAHs such as Benz[a]anthracene, Benz[a]pyrene, Fluoranthene, pyrene, Chrysene, Benz[e]pyrene, Benz[k] Fluoranthene and Benzo [ghi] perylene in this research. Result of this study showed that Concentrations of all PAHs except Pyr, B (a) A and B (a) P in Amirabad are below the concentration to elicit toxic effects in benthic organisms (Effects Range-Low). There was high spatial variability in the PAH concentrations that ranged from 12 to 453ng/g. To elucidate sources, two molecular indices (Pyr/Fluo, BaA/ (BaA+Chr) ratios were used to determine the pyrogenic and petrogenic sources. Amirabad-Behshahr region receives input primarily from oil activity; therefore, it can be inferred that the main source of PAH could be petrogenic (Pyr/Fluo =1.07). The PAH source in Sari is pyrogenic for Neka power plant that uses fossil fuels (BaA/ (BaA+Chr) =0.38).

**Key words:** Pollution • Sediment • Gas chromatography

### INTRODUCTION

Polycyclic aromatic hydrocarbons (PAHs) are of global environmental concern because they cause many health problems including cancer and inflammation of tissue in humans. PAH with increasing environmental pollution and anthropological disturbances to ecosystems.

The hazardous pollutants PAHs are poorly studied. PAHs consist of two or more benzene rings, which make these molecules highly persistent in the environment. Examples include naphthalene, Benz[a]anthracene and Benz[a]pyrene, which contain 2-5 aromatic rings.

Many PAHs in the environment are by-products in petroleum-based manufacturing. They are present in coal tar, asphalt, tires and other oil-containing products and are released into the environment during incomplete combustion and through oil spills, for instance [Committee on In Situ Bioremediation, 1993] in animals, PAHs have a broad impact on health. They interact with DNA resulting in mutations and cancer, Benz[a]pyrene being one of the most toxic and carcinogenic compounds known [1]. There are two types of anthropogenic sources

of PAHs: petrogenic and pyrogenic. Petrogenic sources include crude oil and petroleum products such as kerosene, gasoline, diesel fuel, lubricating oil and asphalt. Pyrogenic sources form by the incomplete combustion of organic matter (e.g., coal, petroleum and wood) in industrial operations and power plants that use fossil fuels, smelting, garbage incinerators and vehicle engines powered by gasoline or diesel fuel and forest fires. PAHs are also derived from some natural sources such as oil seeps, ancient sediment erosion and early diagenesis. However, in many areas affected by human activities, natural sources are overwhelmed by anthropogenic sources of all PAHs except perylene [2].

The distributions of PAHs in sediments have been studied since the mid-1970s. PAHs are distributed globally, from inland lakes and urban rivers to the open ocean, over a wide range of concentrations [3]. Very few reports indicated the predominance of petrogenic PAHs, which were mostly associated with accidental oil spills or were localized [4- 5]. Pyrogenic sources predominated in the East China Sea, whereas both sources were comparable in the coastal sediment of the Pearl River, China [6-7].

Petrogenic PAHs may be more available for biological uptake than pyrogenic PAHs, since it tends to bind more strongly to sedimentary particles. Hence, to evaluate the risks of PAHs to aquatic biota, source-distinction is essential [8-9].

There have been proposed many molecular markers to identify contribution from sources of PAHs. Some unique compounds, specific to certain fuels have been reported. For example, retene 1, 7-dimethylphenanthrene has been proposed as tracers of wood combustion. However, any universal compounds generated through all the fuels for combustion (e.g., biomass, coal and petroleum) have not been reported. One approach is to focus on the difference in thermodynamic stability among PAH species to distinguish pyrogenic and petrogenic PAHs. Thermodynamically stable species of PAHs are enriched in combustion products because thermodynamically unstable species disappear during combustion. There are some other homolog series including fluoranthene-pyrene group and chrysene-benz[a]anthracene group and individual homologs sometimes have different sources [10].

It is estimated that approximately 6.1 million metric tons of petroleum products are released to global oceans annually, the majority of which is derived from anthropogenic sources and which pass through the coastal zone before being carried out to sea [11].

Worldwide, major inputs of petroleum into the marine environment occur via industrial discharge and urban runoff (37%), vessel operations (33%), tanker accidents (12%), atmospheric deposition (9%), natural resources (8%) and exploration production (2%) [12].

However, very limited information on the environmental distribution of PAHs in Caspian Sea is available, although industrialization and urbanization have proceeded rapidly during the last few decades and the associated increase in PAHs is of concern in this region.

The Iranian coast of the Caspian Sea stretches for nearly 700 km from Azerbaijan in the west to Turkmenistan in the east (Figure 1). This coastline is now becoming increasingly polluted with massive loads of contaminants discharged into the Caspian Sea from various anthropogenic sources. Motavalli (1999) reported that the World Bank estimated that a million cubic meters of untreated industrial wastewater is discharged directly into the Caspian, with the bulk coming from oil and mining operations. The Volga River is one of the major contributors of a wide variety of industrial and agricultural contaminants collected from its extensive river basin. The Report by Neville mentioned scientific estimates of annual average discharges of 60,000 metric tonnes of petroleum

byproducts, 24,000 tonnes of sulfites and 400,000 tonnes of chlorine [13].

Given the fact that the Caspian is a non-tidal sea and is landlocked, the bulk of the discharged contaminants remain trapped within its basin. Sea currents transport and circulate the entrapped pollutants along the Iranian coast of the Caspian Sea. A large percentage of the more than 10 million people who reside in the Iranian coastal provinces bordering the Caspian Sea are therefore exposed to high concentrations of toxic contaminants. For instance, coastal residents regularly eat sturgeon and other fish from the Sea. The pollutants accumulating in the fish, especially the sturgeon is transferred to the human food chain. Questions have been raised as to whether the higher rates of cancer recorded in the study area could be associated with fish consumption [14].

Other than having detrimental impacts on human health, several studies have also reported that pollution and contamination are contributing factors to the precipitous decline in sturgeon catch from the Caspian Sea. According to the Caspian Environmental Program web site (<http://www.caspianenvironment.org/newsite/Caspian-EnvironmentalIssues.htm>), sturgeon landings have decreased from 30,000 tonnes in 1985 to only 5,672 tonnes in 1995. Here it should be emphasized that 85 to 90% of the world's sturgeon fish is obtained from the Caspian Sea which yields approximately 95% of the world's black caviar. The decline in sturgeon catch is not only threatening the survival of the caviar industry, but also affecting the domestic economy in Iran [13].

Ecosystems, especially in the nearshore marine environment of the Iranian coast, are now under severe stresses from the cumulative impacts of a mixture of highly toxic contaminants. Marine flora and fauna are threatened and being decimated. One example of detrimental impacts on aquatic life could be found in the account by the Energy Information Administration (2003) which reported that thousands of seals that live in the Caspian Sea have died since (2000) because of the consequences of pollution that affected their immune systems. The existing and potential problems to aquatic and human life from toxic pollutants, therefore, requires investigating the current concentrations of contaminants in the study area. The study has been made following frequent proposals by world organizations, FAO, WHO, based on defining the amount of some PAHs.

## **MATERIALS AND METHODS**

Polycyclic Aromatic Hydrocarbon (PAH) concentrations were measured in Total Suspended Particulate Matter (TSPM) from December 2008 to

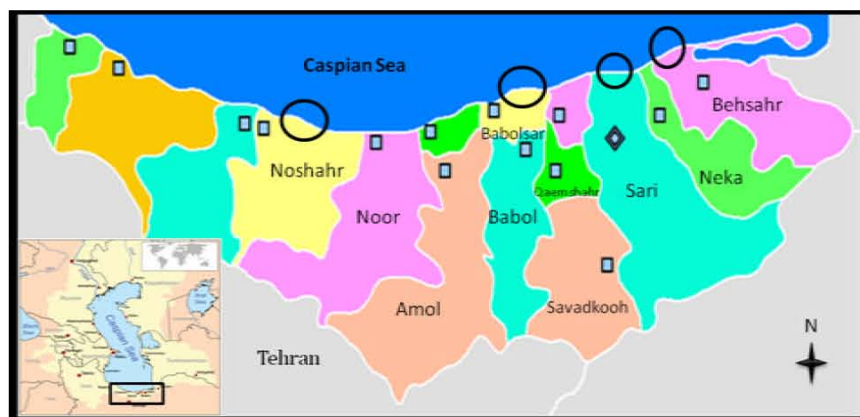


Fig. 1: Location of Sampling Sites along the eastern Coast of the Caspian Sea

August 2009 at eastern Caspian Sea (Iran). The sampling stations are Behshahr (ten station of Amir Abad port for oil products transportation) Sari (five stations of Khazar Abad, Goharbaran and Neka) Babolsar (five stations for tourism and industry) Noshahr port (five stations for Industry and shipping) were analyzed for individual Polycyclic Aromatic Hydrocarbons (PAHs) Fig. 1.

Surface sediments (0–5cm) were collected using a Van Veen grab sampler. After collection, pebbles and twigs were removed and then samples were freeze dried and ground with a mortar and pestle. Samples were stored in HDPE (high density polyethylene) bottles at  $-20^{\circ}\text{C}$  until extraction and were extracted using dichloromethane with ultrasonication. PAHs were quantified using a Hewlett Packard 5890 series II gas chromatograph equipped with a 5972 series mass spectrometer detector. A fused silica capillary column (30m 0.25mm i.d.) coated with DB-17 [(50% phenyl)-methyl polysiloxane J&W Scientific, Folsom, CA, USA] at 0.25 mm film thickness was used. The column oven temperature was programmed from  $80^{\circ}\text{C}$  (1 min hold) to  $100^{\circ}\text{C}$  at a rate of  $25^{\circ}\text{C}/\text{min}$  and then ramped at a rate of  $5^{\circ}\text{C}/\text{min}$  to  $100^{\circ}\text{C}$  with a final holding time of 6 min. The injector and detector temperatures were maintained at  $250$  and  $300^{\circ}\text{C}$ , respectively. The PAH standard (AccuStandard, New Haven, CT, USA) consisted of 8 priority pollutant PAHs identified by the U.S. Environmental Protection Agency (U.S. EPA Method 8310). The mass spectrometer was operated under selected ion monitoring (SIM) mode using the molecular ions selective for individual PAHs. Concentrations based on individually resolved peaks were summed to obtain the PAH concentrations. The detection limits of individual PAHs in sediment samples were  $10 \text{ ng/g}$ , dry wt.

## RESULTS AND DISCUSSION

The study data are shown in Table 1. Many other compositional parameters have been used for the differentiation of petrogenic and pyrogenic sources, including the ratios of pyrene to fluoranthene (Pyr/Fluo), benz[a]anthracene to benz[a]anthracene + chrysene (BaA/BaA + Chry) [4-15]. We examined the validity of these ratios for source differentiation with our source materials (Table 2) although they are useable for source-distinction; they are not definitive, since there are many exceptions. For example, although most of the crude oil samples have  $\text{Pyr}/\text{Fluo} > 1$ , showing a petrogenic source.  $\text{BaA}/(\text{BaA} + \text{Chry}) \approx 0.35$ , implying a pyrogenic source and having  $\text{Anth}/(\text{Anth} + \text{Phe}) < 0.1$ , shows a petrogenic source of PAHs. All brick manufacturing soot samples and most cooking soot samples with strong pyrogenic characteristics show  $\text{IP}/(\text{IP} + \text{BghiP}) < 0.5$  (i.e., petrogenic). Hence, these ratios can give a rough idea of the source, but they are not authoritative enough to be exact. Highest concentrations were present in sediments collected from Amirabad-Behshahr (mean,  $275 \text{ ng/g}$ ,  $n=20$ ) and were a consequence of oil products transportation in this port. Low levels of PAHs were also found in sediments adjacent to boat landing and mooring areas around Babolsar ( $60 \text{ ng/g}$ ,  $n=10$ ) the other site showed moderate values (sari and Noshahr) Table 1.

$\Sigma 8 \text{ PAHs}$  is used as total PAHs in this paper to facilitate the comparison of our data with those reported by many researchers who normally measured parental PAHs. Ratios of Pyr/fluo and BaA/ (BaA+Chr) in Caspian Sea sediments are reported in Table 2. The petrogenic sources have higher value of ratios than the pyrogenic sources. Crude oil has highest values of Pyr/Fluo.

Table 1: PAH concentrations in Caspian Sea sediments

Parameter	Sari (n=10)	Amirabad-Behshahr (n=20)	Noushahr (n=10)	Babolsar (n=10)	Effects Range Low [16]	Apparent Effects Threshold [16]
B(ghi)P	192±25	226 ± 23	151±66	120±26	----	----
Pyr	64±9.1	453 ± 15	41±13	32±15	350	1000
B(a)A	67 ± 9.0	270± 22	15± 6.8	12±5.2	230	550
Chry	105±10	352 ± 30	81 ± 15	82±21	400	900
B(e)P	141 ± 24	155 ± 21	115 ± 20	91±42	----	----
B(k)F	83 ± 17	110 ± 19	73 ± 28	65±31	----	----
B(a)P	57 ± 16	410±32	62 ± 34	35±9.0	400	700
Flu	72±19	420 ± 24	53±9.0	45±6.1	600	1000
Sum of 8PAHs	781	2392	591	482		

(All concentrations ng /g dry w)

Table 2: The ratios of some component's PAHs in Caspian Sea

Location	Pyr/Fluo	BaA/(BaA+Chr)
Sari	0.88	0.38
Amirabad-Behshahr	1.07	0.43
Babolsar	0.71	0.12
Noushahr	0.77	0.16

All the amirabad sediments showed a strong petrogenic signature with pyr/fluo=1.07 for oil port and Crude oil transportation.

Sari sediments showed a pyrogenic signature with BaA/ (BaA+Chr) =0.38 for Neka power plant that uses fossil fuels.

Long and Morgan assembled and evaluated biological effects data from a wide variety of methods and produced informal guidelines that can be used to screen sedimentary data. The PAH concentrations observed or predicted by the different methods to produce biological effects were ranked and the lower 10th percentile (identified as Effects Range-Low), median and overall Apparent Effects Thresholds were identified. The Effects Range-Low and Apparent Effects Thresholds for individual PAH are presented in Table 1 along with concentrations for Caspian Sea sediments [16].

For our Caspian Sea data, concentrations of all PAHs except Pyr, B(a)A and B(a)P in Amirabad are below the concentration to elicit toxic effects in benthic organisms (Effects Range-Low) Table 1. Distributions indicate that These PAHs likely have an origin in petroleum hydrocarbons in crude oil that transport in this oil port.

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