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Evaluation of the changes of total petroleum hydrocarbons pollution in the coastal sediments of Pars-e Jonubi

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ABSTRACT

Total petroleum hydrocarbons (TPHs) contamination results in environmental pollution and adversely affects the marine ecosystem and health of aquatic organisms. This study evaluated the changes of total petroleum hydrocarbons concentrations in the coastal sediments of Pars-e Jonubi. A total number of 30 sediment samples were taken from 10 stations within the sewage effluent of the natural gas refineries in Pars-e Jonubi. The standard method of the American Association of Environmental Protection (USEPA-SW-846#3540C) has been used to extract and prepare TPHs from the sediment phase. Gas chromatography (GC-FID) VARRIAN, model CP-38001, was used to measure the concentration of TPHs in sediments. Results indicated that the mean concentration of TPHs in sediment samples was 6.35 ± 2.42, and the values ranged from 3.20 to 10.89 mg/kg. A significant negative correlation was observed between TPHs concentrations and distance from the shoreline (r = –0.598, P-value: 0.001). It is necessary that a continuous monitoring program be conducted for Pars-e Jonubi coasts to confirm that the concentration of TPHs is within the unpolluted level established in the present study.

Keywords: Total petroleum hydrocarbons; Contamination; Sediments; Pars-e Jonubi

1. Introduction

Development of gas industry plants around the Persian Gulf area has caused high volume of petroleum pollutions to be entered into the coastal water [1,2]. Total petroleum hydrocarbons (TPHs) are the main toxic contaminants of the environment and harmful to humans [3,4]. TPHs describes several group of chemicals from crude oil and gas condensates, it is the quantifiable volume of petroleum-based hydrocarbons in the environment [5].

Although these contaminants exist in low concentrations in the marine sediments, greater amounts are derived from petrogenic and pyrogenic sources [6–8]. Experimental evidence indicates that bottom sediments, where oxidation processes may occur for several years, absorb approximately 56% of the spilled oil in the sea [9]. Bottom sediments, which are the habitat of numerous aquatic organisms, are known as a possible gathering place of the petroleum hydrocarbons in aquatic environments, and pose risk of bioaccumulation [10–12]. Therefore, petroleum contamination is one of the

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most important contaminants threatening the marine ecosystem and health of aquatic organisms [1,13].

The pollutants in sediment can be released back into water phase, causing the compound or pollutant trapped in the sediment to be remobilized [14]. Determination of the physicochemical parameters of the sediments is highly significant, since their quality can affect the biological properties of the environmental media [15–17]. In addition, the examination of the petroleum hydrocarbons in marine sediments can provide useful information about their sources and diagenetic processes and reveal the anthropogenic effects on the environment [18–20]. The content of these contaminants depends on different parameters, such as geographical locations, pollutants entering rivers, and layer depth of tested sediments [21,22].

Protection of the marine environment from industrial pollutions is particularly important to preserve the marine water resources and marine ecosystem. Furthermore, discharge of industrial effluents with the minimum pollution load due to the large volume discharge of these pollutants causes the accumulation of pollution loads in discharge areas.

Pars-e Jonubi is a wide industrial region located along the Persian Gulf, east of Bushehr Province and near the Nayband Bay. Pollution from natural gas refinery facilities in this region has become one of the serious threats on the shores of the Nayband Bay and has created many problems for people of this region. Therefore, it is necessary to study the concentration of TPHs in the coastal sediments of the Nayband Bay to estimate the pollution caused by these pollutants in the effluent of refinery; this provides a suitable basis for determining practical solutions to control the pollution in Nayband Bay shores. Hence, this study aimed to determine the changes of the pollution of total petroleum hydrocarbons concentrations in the coastal sediments of Pars-e Jonubi.

2. Materials and methods

2.1. Sample collection

Sediment samples were collected from Pars-e Jonubi coasts (Fig. 1). This study was conducted in May 2019. The length of the study area was 450 m, which the first station was selected in front of the sewage effluent, and 9 other stations were selected along the coastline with uniform distances. A total of 30 sediment samples were collected using the Van Veen Grab Sampler from 10 stations (3 points with different distances from coastline in high tide mode) within the sewage effluent of the natural gas refinery in Pars-e Jonubi. Surficial sediment samples (0–1 cm) were directly obtained in a range of 100 m on one side of the sewage effluent channel and 400 m wide from the shore in high tide mode. sediment samples were taken at different depths (1.5–4.8 m) of water. Sediment samples were wrapped in aluminum foil and placed in a proper box at 4°C, and transported to the laboratory on the day of sampling.

2.2. Petroleum hydrocarbons analysis

To extract and prepare petroleum hydrocarbons (*n*-alkanes: C10-C35) from the sediments, this study used the standard method of the American Association of Environmental Protection (USEPA-SW-846#3540C) so-called "SOXHLET" [23]. As sediment are mixed with anhydrous Na_2SO_4 and extracted through hexane/

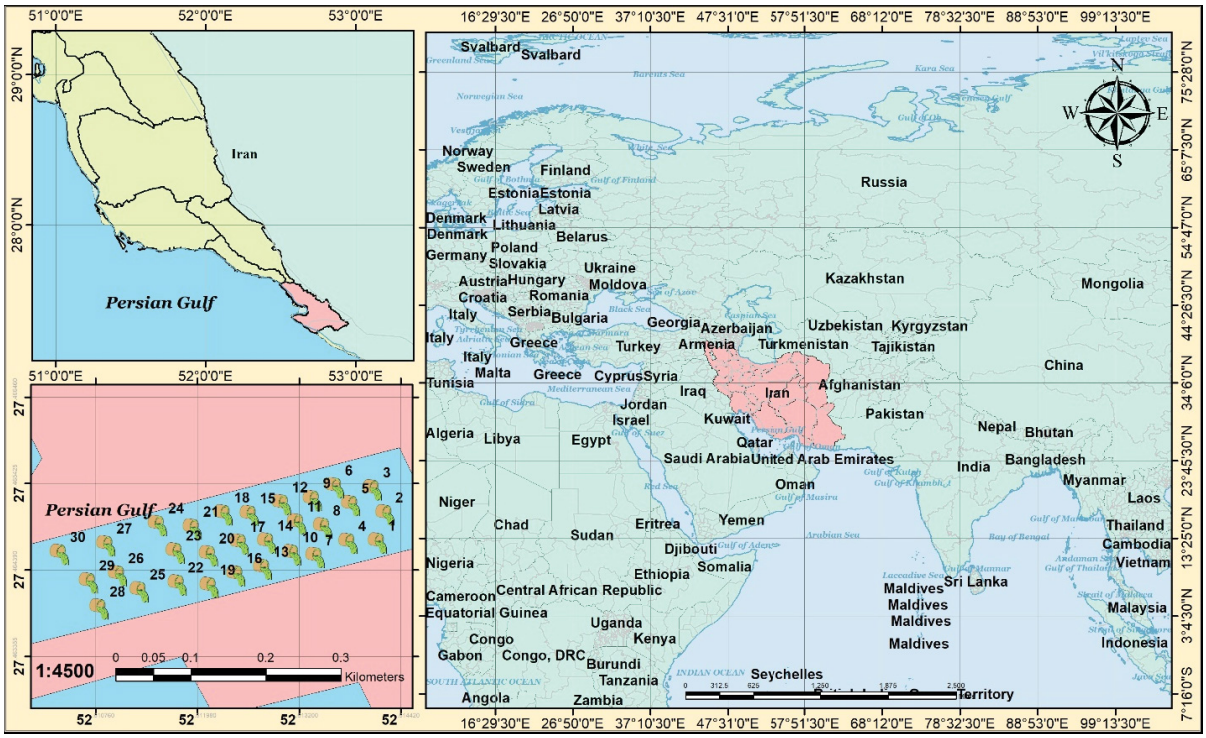

Fig. 1. Locations of the study area and sampling points.

methylene chloride and by the use of Soxhlet means and then condensate from reading. In this method, by adding a substitute and placing the solution against the extracting solvent for 14–24 h and collecting and concentrating the extract with K-D device, the compounds were extracted from sediments. Gas chromatography device (GC-FID) type VARRIAN, model CP-38001, was used to measure the concentration of *n*-alkanes in sediments. The carrier gas in this device was helium, which was set on a flow rate of 1.1 mL/min at an oven temperature of 60°C to 150°C for 10°C/min. The temperature was first kept at 60°C for 2 min, and then at a temperature of 6°C/min, it reached 150°C and was kept at this temperature for 10 min. Data analysis (ANOVA and Pearson correlation) was conducted using the IBM SPSS Statistics 26 with a level of significance set at 0.05.

3. Results

The TPHs (*n*-alkanes in the range C10-C35) were analyzed in the sample sediments of Pars-e Jonubi coasts. The results revealed that the mean concentration of TPHs in the sediment samples was 6.35 ± 2.42 mg/kg, and the values ranged from 3.20 to 10.89 mg/kg (Table 1). As Table 1 shows, the highest concentration of TPHs was observed in sample 2, followed by sample 1, while the lowest concentration was observed in sample 30.

Fig. 2 presents the comparison of changes of TPHs concentrations to changes in distance from the shoreline. The results of the Pearson correlation analysis revealed a significant correlation between TPHs concentrations and distance from the shoreline (*P*-value: 0.001) (Table 2). The concentration levels of TPHs at the lowest (24 m) and highest (412.50 m) distance from the shore were 10.89 and 3.20 mg/kg, respectively.

Fig. 3 depicts the comparison of changes of TPHs concentrations to changes in the depth of sampling (m). The results of the Pearson correlation analysis showed a non-significant correlation between TPHs concentrations and depth of sampling (*P*-value: 0.21) (Table 2). The concentration levels of TPHs in the lowest (1.5 m) and highest (4.8 m) depth were 7.86 and 3.2 mg/kg, respectively.

Table 1
The mean ± SD concentrations levels of TPHs (normal alkanes: C10-C35) (mg/kg) in sediment samples

Sample	Meridian	Latitude (m)	Longitude (m)	Depth of water (m)	Distance from shore (m)	TPH ± SD (mg/kg)
1	39	27.464710	52.614140	1.8	42.00	10.49 ± 2.08
2	39	27.465050	52.614230	2.1	24.00	10.89 ± 2.19
3	39	27.465350	52.614080	3.2	30.00	10.10 ± 2.05
4	39	27.464708	52.613785	1.6	77.00	9.489 ± 2.16
5	39	27.465161	52.613821	1.9	61.00	9.77 ± 1.80
6	39	27.465372	52.613624	3.4	75.00	9.25 ± 2.02
7	39	27.464540	52.613390	1.7	118.00	8.37 ± 1.70
8	39	27.464890	52.613480	2.1	99.00	8.76 ± 1.88
9	39	27.465220	52.613360	3.0	102.00	8.49 ± 1.90
10	39	27.464570	52.613112	1.5	147.00	7.86 ± 1.75
11	39	27.464940	52.613170	2.5	129.50	6.82 ± 1.69
12	39	27.465170	52.612989	3.1	139.00	7.15 ± 1.60
13	39	27.464400	52.612760	3.2	182.00	6.13 ± 1.68
14	39	27.464710	52.612810	2.3	168.00	5.16 ± 1.63
15	39	27.465040	52.612600	2.8	181.00	5.48 ± 1.45
16	39	27.464320	52.612440	1.8	215.00	6.86 ± 1.44
17	39	27.464700	52.612480	2.2	200.00	5.87 ± 1.32
18	39	27.465050	52.612290	3.5	211.50	5.38 ± 1.48
19	39	27.464180	52.612120	3.1	249.00	4.31 ± 1.30
20	39	27.464560	52.612110	2.8	239.00	4.71 ± 1.29
21	39	27.464880	52.611920	3.6	250.00	4.62 ± 1.34
22	39	27.464211	52.611735	3.3	286.00	4.20 ± 1.25
23	39	27.464591	52.611712	3.1	279.00	4.28 ± 1.32
24	39	27.464921	52.611500	3.5	290.00	4.01 ± 1.22
25	39	27.464125	52.611280	2.5	333.50	4.00 ± 1.15
26	39	27.464320	52.611020	3.5	350.00	3.92 ± 1.09
27	39	27.464680	52.610880	4.4	354.50	3.77 ± 1.19
28	39	27.463920	52.610800	2.8	383.00	3.7 ± 1.10
29	39	27.464232	52.610670	3.9	385.00	3.57 ± 1.31
30	39	27.464575	52.610320	4.8	412.50	3.20 ± 1.17

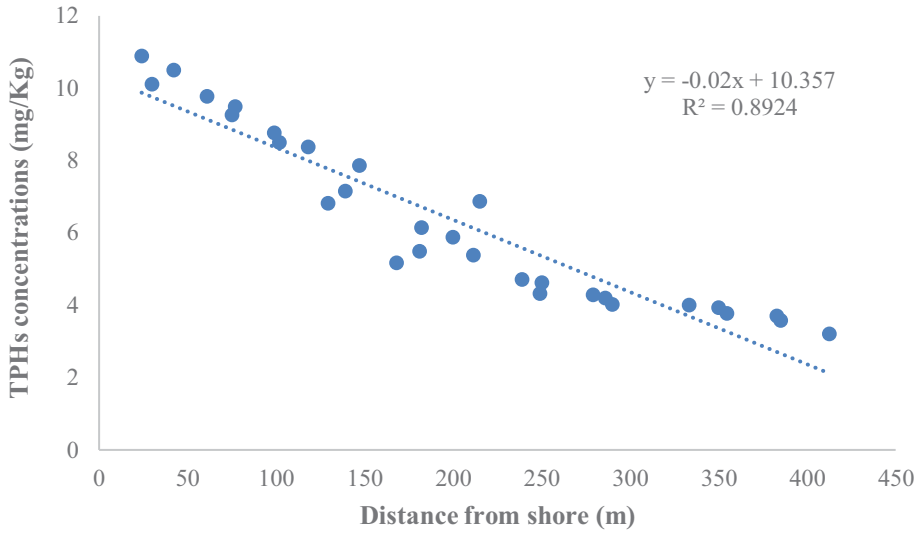

Fig. 2. Scatter plot showing the relationship between changes of TPHs concentrations and changes in the distance from the shoreline.

Table 2
Matrix of the Pearson correlation between TPHs concentrations and depth of sampling (m) and distance from the shoreline

	TPHs concentrations	Depth of sampling (m)	Distance from the shoreline
TPHs concentrations	1	–	–
Depth of sampling (m)	–0.598	1	–
Distance from the shoreline	–0.889*	–	1

*Correlation is significant at the 0.05 level (2-tailed).

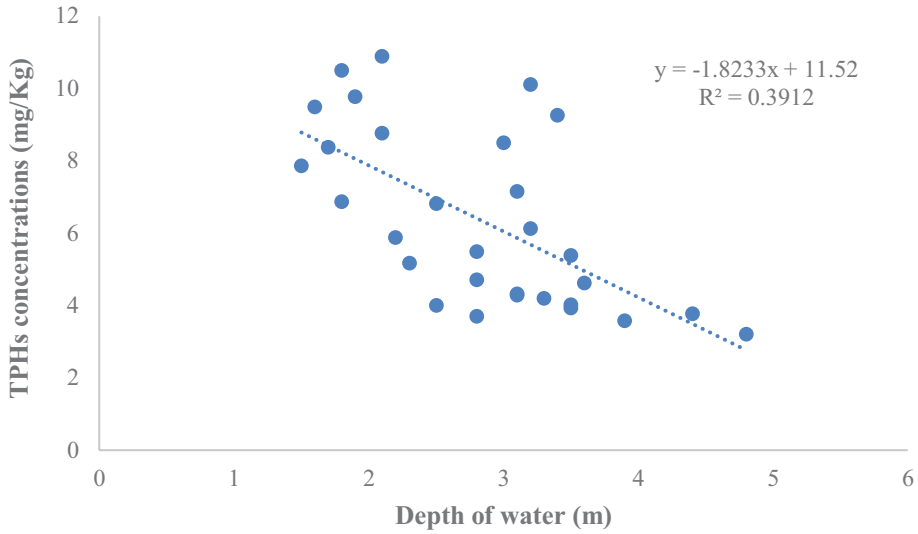

Fig. 3. Scatter plot showing the relationship between changes of TPHs concentrations and changes in the depth of sampling (m).

4. Discussion

The lowest concentration of TPHs in the sediment samples was obtained from sample 30 with a depth of 4.8 m, which could probably be associated with the higher depth of water at the station 24. Stations of samples 1 and 2, which is located near the coastline (42 and 24 m distance from the shore, respectively), have the highest concentration of TPHs. However, the station of sample 30, which is located far from the coastline (412.5 m distance from the shore), have the lowest concentration of TPHs. In general, as the distance from the shoreline increases, the concentration of TPHs decreases. Furthermore, the results of this study indicated that with increasing the depth, the amount

of TPHs decreased in the sediments. Previous researches demonstrated that organic compounds were not simply deposited into bottom sediments, where there are strong water flows [24,25]. Moreover, the concentration of TPHs in sediments depends on several physicochemical parameters, of which sediment organic carbon and texture are the key factors [26,27], as well as interaction of numerous processes, such as bio-concentrations, volatilization, solubilization of sediment, and biodegradation [28,29]. In addition, the variation of temperature in different seasonal affected the degradation ratio of existing TPHs in the surface layer further the fast degradation taking place in the surface layer catching the water bottom which characterized with oxygen plentiful [30]. Sediment contaminations by TPHs may be related to extensive coastal anthropogenic and industrial activities in the area that introduced the main source of TPHs in addition to the natural source.

Although no sediment standard is in place for TPHs, four levels of petroleum hydrocarbon pollutions (unpolluted: <15 mg/kg; slightly polluted: 15–50 mg/kg; moderately polluted: 50–200 mg/kg, and heavily polluted statuses >200 mg/kg) were recommended for the valuation of marine sediments [31]. The comparison of the mean concentration of TPHs in the present study (6.35 ± 2.42 mg/kg) with these suggested levels indicated that the studied sediments were in the unpolluted category. TPHs contents of sediments in this study region were found lower than reported levels in sediments from Ceuta Harbor, North Africa [32], and Arabian Gulf, Kuwait [31]. However, unpolluted sediments were found in different studies, such as coastal area of Putatanand Papar, Sabah [33]; Tamil Nadu Coast, India [34]; Main Outfall Drain in Al-Nassiriya, Southern Iraq [35]; Pulicat Lake, Southeast Coast of India [36], and coastline and mangroves of the northern Persian Gulf [37].

5. Conclusion

This study demonstrates that the levels of TPHs in sediments of Pars-e Jonubi coasts are low and within the unpolluted levels (unpolluted level: <15 mg/kg: according to the classification of the study by Massoud et al. [31]). Owing to the rapid increase of anthropogenic activities, such as urbanization and industrialization, coastal environments are under serious threat. This study provides the baseline information of the TPHs contamination in Pars-e Jonubi. It is suggested that a constant monitoring program for the Pars-e Jonubi coasts of the Asaluyeh region should be formulated and conducted to confirm that the concentration of TPHs is within the unpolluted levels established in the present study.

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