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Assessment of Contamination by Petroleum Hydrocarbons in Sediments of Musa Bay, Northwest of the Persian Gulf-Iran

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Abstract. According to the IMO declaration, the Gulf area is the most sensitive and oil-polluted marine area in the world. Due to the sensitivity of this area, the present study was performed in Musa bay, which is located northwest of the Persian Gulf. Sediment samples were collected from the coastal area of the Petrochemical Special Economic Zone (PETZONE) from Feb 2010 to June 2010. The concentration of Total Petroleum Hydrocarbons (TPH) and Polyaromatic Hydrocarbons (PAHs) was determined in sediment samples. The average TPH concentration in the study area was 45.94 μg g^{-1}, as the concentration was greater than the natural background concentration; therefore, the region can be considered slightly polluted. The average concentration of PAHs was 4010.51 ng g^{-1}; thus, the study area can be classified as unpolluted. Despite the high concentration of anthropogenic contaminates including industries, shipping activities and other non-point source pollution; the results of the present study are unexpected. The unusual results may be related to semi-diurnal tide which can cause natural sediment dredging also circulation and current of water which is stronger in northern parts of the Persian Gulf than that other area.

Keywords: IMO, Musa bay, PETZONE, TPH, PAHs

1. Introduction

Nowadays, Petrochemical industries are considered as one of the most important basic industries in all over the world. Although petrochemical industries have too many benefits for our life, the pollution caused by these industries have been a cause for concern and major challenges to save the environment against their adverse impacts in all over the world (Rooney, 2005). One of the most important industries in South of Iran is Petrochemical Special Economic Zone (PETZONE),which was established in the southeast of Iran, near the Musa bay (northwest of the Persian Gulf), in 1997 (Nabavy, 1992; Parsamanesh, 1994). Musa bay is a semi- enclosed aquatic ecosystem with semidiurnal tide and there are about 27 creeks which are branched from it, such as Jafary, Zangi, Ghanam, etc. Since PETZONE was established, some parts of the Musa bay have become enclosed with its roadways and constructions, and in some parts divided into two parts (such as Zangee and Jafari creeks which are connected to the Musa bay via connective canals) (PETZONE, 2001) (Fig.1). According to the IMO (International Maritime organization) declaration, the Gulf area is the most sensitive area in the world and Department of Environment has reported that, the Musa bay is considered as the most sea sensitive area in the Gulf area. Based on the scientific reports, the Persian Gulf holds an estimated about 57-66% of the world oil reserves the most oil-polluted marine area in the world (Al-Awadhi, 1999; Deppe, 1999; Nadim, Bagtzoglou, & Iranmahboob, 2008; Price, 1998).

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Immediately , after the release of crude oil into marine waters, due to the lipophilic characteristics and bio- resistant properties of the petroleum compound, it adsorbs to the suspended particulate matter and accumulate in bottom sediments, and it can remain unchanged and toxic for long term; thereupon, they can have a long-term effect on the structure of the benthic community (Al-Ghadban, & Al-Sarawi, 1996; Mirsadeghi, Zakaria, Yap, & Shahbazi, 2011).

Due to the sensitivity of Gulf area, several studies have been performed on various pollutants and primary sources. In 1996, studies in ROPME sea area showed that the coastal area of Imam Khomeini port (Musa bay) was classified as slightly polluted and TPH concentration in the Persian Gulf sediments was categorized into four levels (guideline μg g^{-1}):Unpolluted area /natural background level (10-15), slightly polluted area / upper permissible limits (15-50), moderately polluted area (50-200), heavily polluted area (> 200) (M. S. Massoud, 1996).

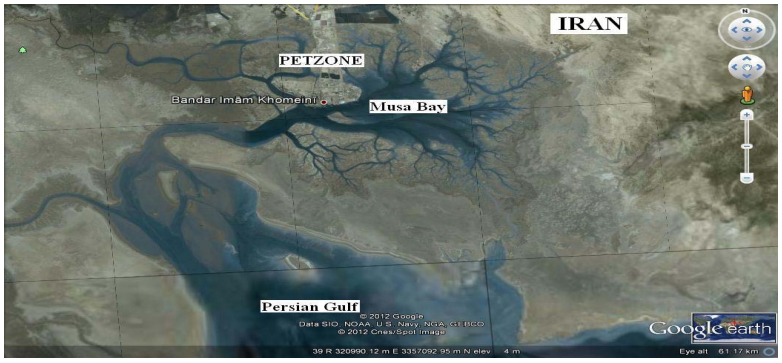

Fig. 1: Musa bay and the PETZONE location

In 2009, concentration of TPH and PAHs in the sediments of Imam Khomeini port were monitored, and the concentration of TPH was 5.44 - 16.66 μg g^{-1} and PAH concentration was 0.19 - 3.52 μg g^{-1}(Taati zadeh, 2009). In 1996, the concentration limits of ΣPAHs for marine sediments were considered 4022 ng g^{-1} and Canadian Environmental Quality Guidelines present this value 7071 ng g^{-1} ,in 2002.(Pozebon et al., 2009).

The present study investigates petroleum hydrocarbon (TPH and PAHs) pollution, to determine the current level of oil pollution in the sediments of the Musa bay.

2. Material and Methods

Sediment samples from Musa bay were collected from seven stations located in the coastal area of the PETZONE from Feb 2010 to June 2010 using an Ekman-Birge grab sampler. The sampling stations are shown in Fig. 2. Top part of the undisturbed sediments sample was carefully removed and stored in a glass vial. Freeze-dried samples were sieved and then homogenized for extraction. TPH and PAHs analysis was carried out in accordance with the ROPME (1999) manuals. Sediment samples were extracted in a Soxhlet extractor with a mixture of dichloromethane and n-hexane. After concentration (approximately 1ml), petroleum hydrocarbons were quantified by fluorescence using a UV fluorescence (UVF- 2500) (ROPME, 1999) .

Fig.2: Study area

For the PAHs measurements, the extract was passed through a silica/alumina column, and proper blanks were analyzed with each set of samples(ROPME, 1999). Finally, gas chromatography mass spectrometry was performed respectively by GC-MS (GC, Agilent, 6890N, MS: Agilent, 5973N). Finally, the concentrations of the sixteen hazardous PAHs were measured (Herzfelder & Golledge, 2004).

TPH values were reported in μg g^{-1} and ΣPAHs values were reported in ng g^{-1} and sampling stations were labelled as Table1.

Table1. Sampling stations of Musa bay study

Station No.	Station name	E	N
1	Junction of Jafari & Zangi Creek	318855.98 m	3369962.11 m
2	BI-PC East Pond	319475.96 m	3368838.07 m
3	BI-PC South East	319142.81 m	3368004.54 m
4	BI-PC Aromatic	318239.61 m	3367628.48 m
5	Razi	317573.46 m	3367386.02 m
6	MUSA1	314791.89 M	3367170.91 M
7	MUSA2	313734.26 M	3365880.86 M

In this research, the contamination factor ($C_f = C_{0-1}/ C_n$) of TPH was determined by Hakanson method, and the level of pollution are arranged as follows: C_f <1 low pollution ,$1 \leq C_f < 3$ middle pollution, $3 \leq C_f < 6$ notable pollution, C_f >6 high pollution- (C_{0-1}: present contamination , C_n :Natural background (Hakanson, 1980). The concentration of ΣPAHs in each sampling station was compared to the guideline (guideline:4022 ng g^{-1})(Pozebon, et al., 2009). Finally, the pollution level of the sediment (sampling stations) was determined according to the results of the TPH and ΣPAHs.

3. Results and Discussion

3.1. Total petroleum hydrocarbon

Total petroleum hydrocarbon concentrations in bottom sediments of the study area are shown in Table 2.

Table2. The Concentration and contamination factor of TPH (μg g^{-1}) in bottom sediments of the study area

Station No.	STATION	Mean TPH	Minimum	Maximum	Std.	Guideline[1]	Contamination Factor (C_f)
1	Junction of Jafari & Zangi Creek	88.81	77.86	99.76	1.54856E1	10-15	5.92
2	BI-Pc East pound	57.32	42.47	72.17	2.10011E1	10-15	3.82
3	BI-PC Southeast	32.73	10.29	55.17	3.17350E1	10-15	2.18
4	BI-PC Aromatic	45.93	43.81	48.06	3.00520	10-15	3.06
5	Razi	17.51	4.88	30.14	1.78615E1	10-15	1.16
6	MUSA1	40.05	37.44	42.67	3.69817	10-15	2.67
7	MUSA2	39.25	34.78	43.73	6.32861	10-15	2.61
8	Total	45.94	4.88	99.76	2.50056E1	10-15	3.06

1-(M. S. Massoud, 1996)

The TPH concentration of sediment samples presented an average value of 45.94 (μg g^{-1}) and ranged from 4.88 to 99.76 (μg g^{-1}). The highest TPH level was observed at station 1 (88.81μg g^{-1}), as shown in **Fig.3**. The TPH concentrations of the stations can be arranged as follows1>2>4>6>7>3>5.

At all the stations, the concentration of TPH was greater than the natural background value (10-15 μg g^{-1}) (M. S. Massoud, 1996).

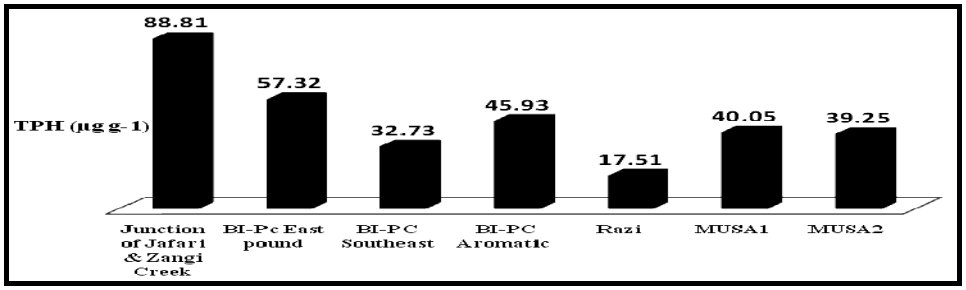

Fig.3: Average concentration of TPH (μg g^{-1}) in sampling stations

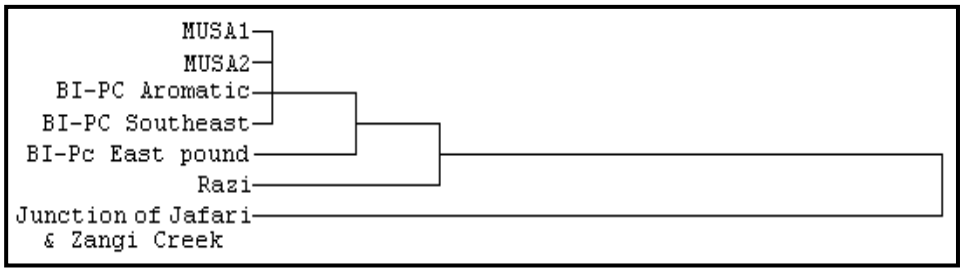

Fig. 4: A dendrogram representation of a hierarchical cluster analysis of the Total Petroleum Hydrocarbon

Moreover, calculation of the contamination factor based on the Hakanson method showed that, the concentration of TPH in this area is categorized into the notable pollution level (Hakanson, 1980), as it shown in Table 2 . The average cluster analysis results for TPH showed that this factor can be classified into four groups. (Fig. 4).

First station showed the significant difference with other stations , due to its closeness to the main and highly polluted PETZONE outlets (junction of the Zangi & Jafari creeks), decreasing of current and depth and the mangrove line around the site (Fig. 2). The Mangrove Afforestation Program of Imam Khomeini port (Musa bay), which was initiated in 2000 (PETZONE, 2008), could be one of the most important reasons. According to the characteristics of the mangrove forests, the presence of fine sediment and decreasing in the hydrodynamic energy time, can increase the sedimentation rate in such areas (Cunha-Lignon et al., 2009; Furukawa, Wolanski, & Mueller, 1997).

3.2. Polyaromatic hydrocarbon

The concentrations of PAHs obtained in the present investigation are shown in Table 3.

Table 3. Concentration of ΣPAHs (ng g^{-1}) in bottom sediments of the study area

Station No.	STATION	Mean ΣPAHs	Minimum	Maximum	Std.	Guideline[1]
1	Jafari & Zangi creeks Junction	703.24	611.08	795.39	1.30327E2	4022
2	BI-Pc East pound	1314.08	787.02	1841.15	7.45382E2	4022
3	BI-PC Southeast	2713.33	2294.03	3132.64	5.92987E2	4022
4	BI-PC Aromatic	21040.19	14878.51	27201.88	8.71394E3	4022
5	Razi	1453.38	1099.16	1807.62	5.00957E2	4022
6	MUSA1	627.13	489.75	764.51	1.94285E2	4022
7	MUSA2	222.25	199.75	244.75	3.18198E1	4022
8	Total	4010.51	199.75	27201.88	7.65418E3	4022

1- (Pozebon, et al., 2009)

At all the stations, the concentration of ΣPAHs was lower than the guideline (4022 ng g^{-1}). The concentration of ΣPAHs varied from 199.75 to 27201.88 ng g^{-1}, and the average concentration was 4010.51 ng g^{-1}(Fig.5). The average cluster analysis results for ΣPAHs showed that it can be classified into two groups. (Fig.6).

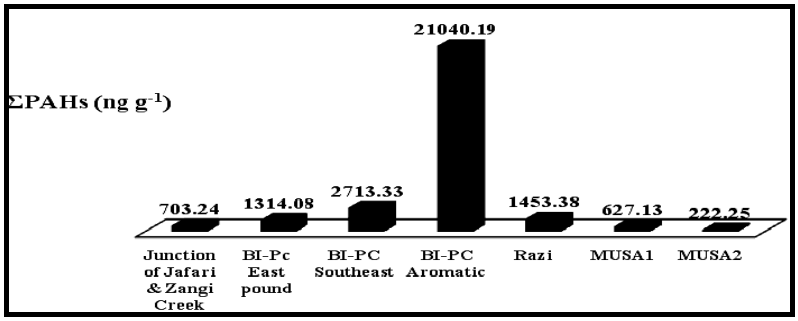

Fig.5: Average concentration of ΣPAHs (ng g^{-1}) in Musa Bay sediment (sampling stations)

The highest ΣPAHs level was observed at station 4 (27201.88 ng g^{-1}). Due to the location of the sampling points, the depth of station 4 was low. In addition, station 4 (BI-PC Aromatic) was located near the aromatic outlet of Bandar-e-Imam Khomeini petrochemical company; thus, pollution at station 4 may be related to the outlet.

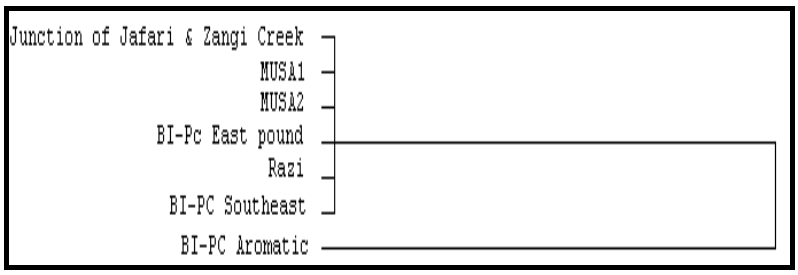

Fig.6: A dendrogram representation of a hierarchical cluster analysis of the polyaromatic Hydrocarbon

In conclusion, the average TPH concentration in the study area was 45.94 μg g^{-1}, as the concentration was greater than the natural background concentration; therefore, the region can be considered slightly polluted. The average concentration of ΣPAHs was 4010.51 ng g^{-1}; thus, the study area can be classified as unpolluted. Despite the high concentration of anthropogenic contaminates including industries (such as PETZONE), shipping activities and other non-point source pollution; the results of the present study are unexpected. The unusual results may be related to semi-diurnal tide, which can cause natural sediment dredging also circulation and current of water, which is stronger in northern parts of the Persian Gulf than that other areas in the southern part (Price, 1998).

Moreover, due to the scarce information about the level of oil pollution in the sampling area, this information can be used as a basic data to manage and monitor the Musa bay.

4. Acknowledgment

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