Petroleum hydrocarbon assessment in the wastewaters of petrochemical special economic zone and sediment benchmark calculation of the coastal area - northwest of the Persian Gulf

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Abstract

Petrochemical industries can potentially impact the environment due to their activities and products. This case study has considered adverse effects of petrochemical industries that are located inside the PETZONE with respect to the presence of polycyclic aromatic hydrocarbons and total petroleum hydrocarbon in wastewater effluents. The average concentrations of ∑PAHs group I and II were lower than the guideline values, thus the effluents of the study area can be considered unpolluted. Also, the average concentration of TPH was lower than the guideline value at all almost stations exceptthe effluent outlets of the Razi and Imam Khomeini petrochemical (BI-PC) companies which are proximal to Khowr-e Musa Bay. Thus, they may have an adverse impact on the aquatic ecosystem of the Bay. Therefore, the concentration of TPH was monitored in the sediments of the Bay (around the PETZONE coastal area) which wasrelatively moderate compared in the study area. Also, the sum ofChronic Potency Ratioof PAHs in sediments showed that the chronic benchmark was not more than the guideline at all stations (it is exceeded when the sum exceeds 1.0) except in the vicinity of the Aromatic effluent outlet of BI-PC.Thus, the chronic benchmark at this station indicates that it has the potential to cause a chronic effect on sediment-residence organisms like crabs, clams and worms. Moreover, PAHs concentration level in this station approached the NOAA sediment quality guideline value (ERL) of 4000 (ng/g dry weight).

Keywords: PETZONE, Khowr-e Musa, TPH, PAHs, Chronic Benchmark, Persian Gulf

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Introduction

Petrochemical industries are those industries in which the hydrocarbons of natural oil and gas are transformed into chemical products (Monavari, 2001; Mostajabi, 2008). Although petrochemical industries yield many benefits, they are considered a point source of pollution (Rooney,2005). Petrochemical industries have been verified as important emission sources and point source of a wide range of chemical substances, such as volatile compounds, heavy metals and POPs (Persistent Organic Pollutants)(Nadal et al., 2011).

In 1997, the Petrochemical Special Economic Zone (PETZONE), was established in south-eastern Iran, at the Persian Gulf shore , within the boundaries of Mahshahr, a district of Bandar-e- Imam Khomeini (BIK) (Mooraki et al., 2008; Abdolahpur Monikh et al., 2012). PETZONE contains fifteen petrochemical companies and five effluent treatment plants. Since PETZONE was established, some parts of Khowr-e Musa Bayparticularly Zangee and Jafari creeks, have become enclosed by roadways and constructions and, in some areas, divided, (PETZONE Report,2001). Due to the presence of diverse industries, Khowr-e Musa Bay has become one of the main economic assets of the north-west coast of the Persian Gulf (Parsamanesh, 1994). Several creeks branch out from theBay, including Zangee, Jafari, Ahmadi , Moavi, Ghanam, and Marimus,… creeks (Purokhshoori, 1999; Mooraki et al., 2008). The wastewaters from PETZONE coastal areas, including the effluents from the Razi and Imam Khomeini petrochemical companies, are directly discharged into the Bay (Höpner and Maraschi, 1999) and other petrochemical companies discharge into the Zangi and Jafari creeks, which are located inside the PETZONE. These creeks are connected to the bay via surface channels, which are directly affected by the semidiurnal tide (Deppe, 2000). Khowr-e Musa Bayis a semi-closed, with a limited connection to the Persian Gulf, low capacity for self-purification and high concentration of suspended solids ecosystem (Deppe, 2000). Therefore, the large amount of wastewater discharged into the bay can be a major water pollution factor, and frequent tides have considerably expanded the scope of the pollution (Malmasi et al., 2010). Moreover, previous researches showed that the Persian Gulf has the highest oil resources and oil transport activities and the most sensitive area in the world (Farzingohar et al., 2011). Also the Iran Department of Environment has reported that, the Khowr-e Musa Bay is the most sensitive marine area in the Persian Gulf. Therefore, Khowr-e Musa Bay is important for In 1996, a research study showed that the coastal area of Imam Khomeini port was classified as slightly polluted owing to the concentration level of TPH, and it was lower than that of most Arab coasts. Owing to this research, the TPH concentration of Persian Gulf sediments was classified into four levels and the concentrations lower than 15 µg / g, as chrysene equivalents are considered as natural background levels in this region(Massoud et al.,1996). The first study of PAHs, in 1998, indicated that "the present level of the PAHs in the sediments of the northern part of Persian

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Gulf, do not appear to impose a biological or ecological threat" (Eghtesadi et al., 2002). While, new researches showed that around the industries which are located in the coastal area of the Persian Gulf, water and sediment contamination are higher than other parts of the Persian Gulf.Therefore, in this study, owing to the sensitivity of the area, the oil polluted wastewater of PETZONE petrochemical companies were monitored and also sediment sampling was performed around the coastal area of the PETZONE.

Materials and methods

Wastewater samples from PETZONE were collected from 18 stationsfrom June 2009 to June 2010 (bimonthly). The sampling sites and sampling stations are shown in Table 1.Wastewater samples were collected in 1000-ml amber glasses, placed on ice after sampling and transported to the laboratoryimmediately for further analysis of the TPH and PAHs and also Chemical Oxygen Demanded (COD), (APHA,1998; MOOPAM ,1999). In laboratory, according to U.S. EPA Method 1664A for extracting oil and grease from water,the liquid-liquid extraction (LLE) with a separator funnel as the means, was used for extraction (US.EPA, 1999b). Extracted samples were fractionated on a silica gel-alumina column and after that concentrated down to 1 to 2 ml using a flow of clean nitrogen.Individual PAHs were quantified based on the retention time with a reliable PAHs mixed standard (Sigma), and concentrations of each PAH were calibrated based on the standard calibration curve. Finally, the concentration of the following PAHs were determined:six low molecular weight, Naphthalene(Na), Acenaphthylene (Acpy), Acenaphthene(Acp), Fluorene(Flur), Phenanthrene(Phen), Anthracene (Ant), and 10 high molecular weight, Fluoranthene (Flu), Pyrene (Py), Benzo(a)anthracene(BaA), Chrysene (Chr), Benzo(b)fluoranthene(BbF), Benzo(k) fluoranthene (BkF), Benzo (a) pyrene(BaP), Dibenzo (a,h) anthracene (DbahA) , Benzo (g,h,i) perylene (BghiP), Indeno (1,2,3-cd) pyrene (IP) (Semlali et al., 2002;D.O.E.A., 2004).

Table 1: Location of sampling stations inside the PETZONE

No.	Station	Full name	N	E
1	M-PC	Marun petrochemical company	30°28'	49°05'
2	ETP2	Effluent treatment plant 2	30°28'	49°05'
3	K-PC	Karoon petrochemical company	30°27'	49°05'
4	FA-PC	Fanavaran petrochemical company	30°27'	49°05'
5	GH-PC	GHadir petrochemical company	30°27'	49°05'
6	Sb-PC	Shimi Baft petrochemical company	30°27'	49°05'
7	F-PC	Fajr petrochemical company	30°27'	49°04'
8	AK-PC	Amir Kabir petrochemical company	30°27'	49°04'
9	ST-PC	Shahid Tondgooyan petrochemical company	30°27'	49°05'
10	STET	Shahid TondgooyanEffluent treatment plant 1	30°27'	49°05'

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Continue Table 1:

11	ETP1	Effluent treatment plant 1	30°27'	49°05'
12	EX-TANKS	Export Tanks	30°26'	49°05'
13	FR-PC	Farabi petrochemical company	30°26'	49°05'
14	Treatment Plant (site 1)	1st Site Treatment Plant	30°27'	49°05'
15	BI-PC 1	Imam Khomeini petrochemical company1	30°25'	49°06'
16	BI-PC 2-pond	Imam Khomeini petrochemical company2	30°26'	49° 06'
17	Razi-PC	Razi petrochemical company	30°25'	49°06'
18	KZ-PC	Khouzestan petrochemical company	30°27'	49°04'

After extraction, each sample was initially analyzed for total petroleum hydrocarbons by UV fluorescence (fixed excitation wavelength: 310 nm; the emission wavelength: 360 nm)and gas chromatography mass spectrometry (GC-MS; GC, Agilent, 6890N,MS: Agilent, 5973N), respectively(MOOPAM, 1999; De Mora et al., 2010).

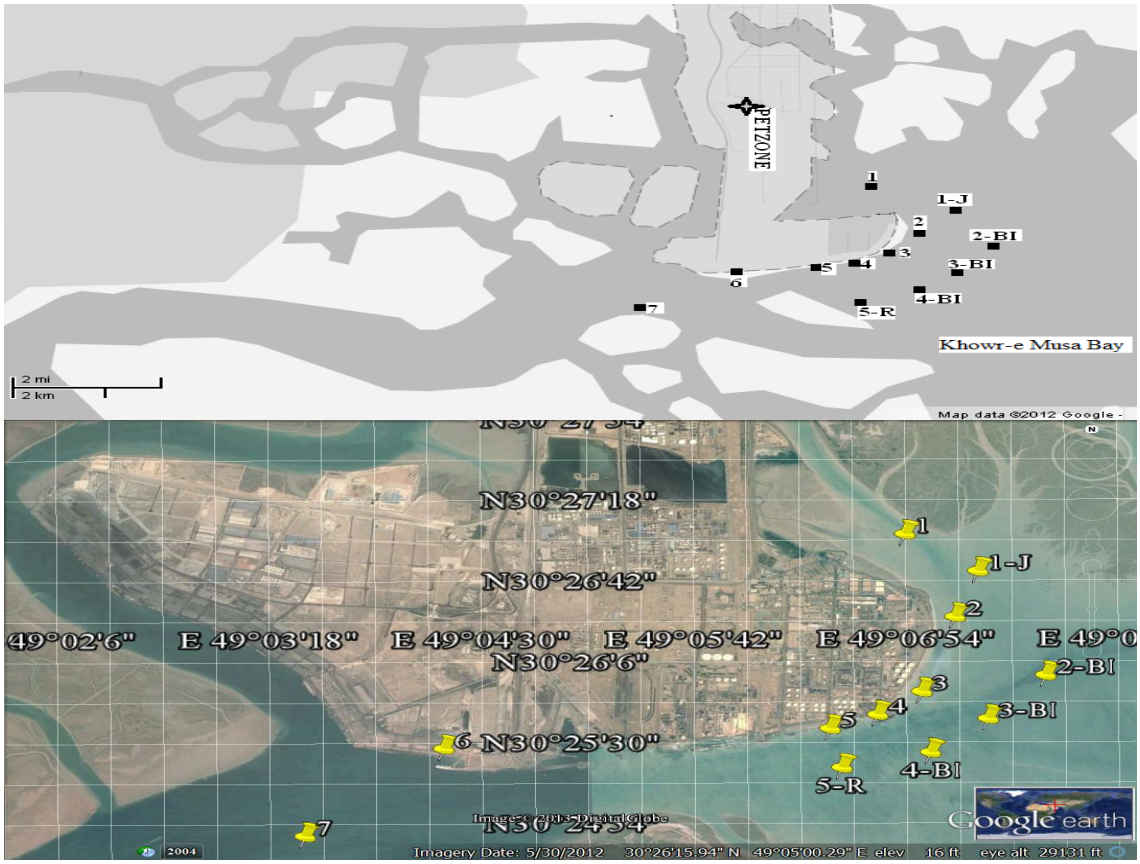

Figure 1: Location of the study area and sampling stations in Khowr-e Musa Bay (Extracted from Google map2013)

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Sediment samples from Khowr-e Musa Bay were collected from 7 stations located in the coastal are of the Petrochemical Special Economic Zone (PETZONE) from June 2009 to June 2010 using an Ekman-Birge grab sampler (225 cm^2) - every 3months, at low tide. The sampling sites are shown in Figure 1and Table 2. Five (1-5) sampling stations were in the proximity of PETZONE wastewater discharge points. The study area is covered with fine-grained sediments and the top 5 or 10 cm from each grab samples was obtained to provide an appropriate sample of surface sediment. Then, sediment samples were stored in aluminum foil and placed on ice after sampling, immediately transported to the laboratory and kept in the refrigerator at -20°C until further analysis for measuring organic contaminants (TPH and PAHs), total organic carbon (TOC) (Paul et al., 1992).

Table 2: Sampling stations of Khowr-e Musa Bay

Station No.	Station name	E	N
1	Junction of Jafari & Zangi Creeks	49° 6'48.50"E	30°26'53.50"N
2	BI-PC East Pond	49° 7'12.44"E	30°26'17.34"N
3	BI-PC South East	49° 7'0.47"E	30°25'50.09"N
4	BI-PC Aromatic	49° 6'26.87"E	30°25'37.39"N
5	Razi	49° 6'2.06"E	30°25'29.16"N
6	MUSA1	49° 4'17.99"E	30°25'20.64"N
7	MUSA2	49° 3'39.19"E	30°24'38.17"N

In the laboratory, 10 to 20 g of freeze-dried sediment sample (freeze-drier model: Operon), ground and sieved at 125 µm, are put in the glass tube of the reactor. The extraction was conducted using a microwave oven (temperature 115°C, 20 min). A 15 g aliquot of freeze-dried sediment sample was put in the glass tube of the reactor with 40 ml of hexane:methylene chloride (1:1v/v). Sulfur was removed using activated elemental copper in order to avoid potential interferences during gas chromatography, and the extracts were concentrated using a rotary evaporator. Sediment samples were fractionated on a silica gel-alumina column. After passing the extract through the system, the extract was placed in 5 ml vials and then the extract was dried with anhydrous sodium sulfate and transferred in a graduated tube and concentrated down to 1 to 2 ml using a flow of clean nitrogen. Finally, the concentration of the 16 PAHs were determined, as same as wastewater samples (MOOPAM, 1999; De Mora et al., 2010; Monazami Tehrani et al., 2013).

Moreover, Total Organic Carbon was measured in surface sediment by using a Perkin-Elmer 2400 (CHN) and elemental analyzer at a 950°C combustion temperature. Because, Polycyclic aromatic hydrocarbons bind to organic carbon when they are peresent in sediments so it can decrease their bioavailability and toxicity (US.EPA, 2010a).

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Results

The concentrations of TPH obtained in the present investigation are shown in Table 3. The average TPH concentration in wastewater samples was 4.61 (mg /l), with a range of 0.06 to 35.33 (mg /l), as shown in Figure 2.

Table 3: TPH concentration (mg/l) in the sampled wastewater discharges

No.	Station	Mean	Minimum	Maximum	Effluent Limit based on Daily maximum[1]
1	AK-PC	2.19	0.10	5.26	10
2	BI-PC 2	20.13	17.60	22.66	10
3	BI-PC 1	13.10	10.19	20.00	10
4	ETP1	1.70	0.10	4.00	10
5	ETP2	2.13	0.10	7.83	10
6	EX-TANK	2.13	0.06	6.40	10
7	F-PC	2.21	0.10	8.10	10
8	FA-PC	4.36	0.10	17.00	10
9	FR-PC	2.35	0.12	4.20	10
10	GH-PC	3.27	0.10	10.15	10
11	K-PC	1.05	0.07	4.40	10
12	Kz-PC	2.52	0.97	4.07	10
13	M-PC	3.14	0.91	5.33	10
14	R-PC	17.64	10.56	35.33	10
15	SB-PC	2.95	0.10	6.83	10
16	Treatment Plant (site 1)	1.98	0.10	5.85	10
17	ST-PC	7.57	2.00	10.93	10
18	STET	0.64	0.10	1.76	10
-	Total	4.61	0.06	35.33	10

[1](UWI, 2004)

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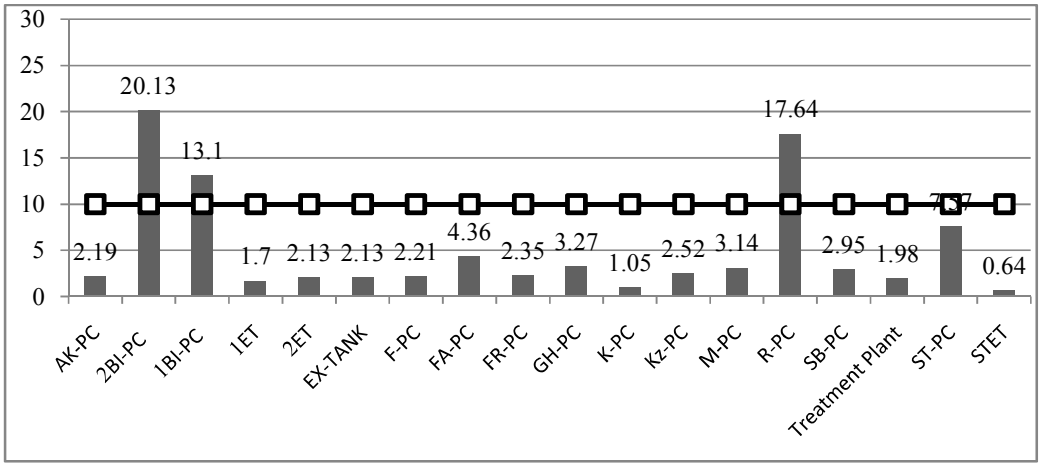

Figure 2: The average Concentration of TPH (mg/l)at sampling stations

At all of the stations, the average concentration of TPH was lower than the guideline value, with the exception of three sampling stations labeled as follows: BI-PC 1, BI-PC 2 and R-PC. The high concentration of TPH at the aforementioned stations may be related to the nature of the petrochemical products and also it may be related to their old technologies which are established more than 30 years ago. The Razi Petrochemical Company produces natural condebsate,sulphuric acid, Di ammonium phosphate, granulled sulphur, Amonia, urea and phosphoric acid ; the Imam Khomeini petrochemical company produces aromatics, polymers, chemicals, and fuel. Moreover, these petrochemical companies have been established more than 30 years ago.

The average cluster analysis results for TPH demonstrated three significant groups which are BI-PC 1, BI-PC 2, R-PC and also ST-PC (Fig. 3).

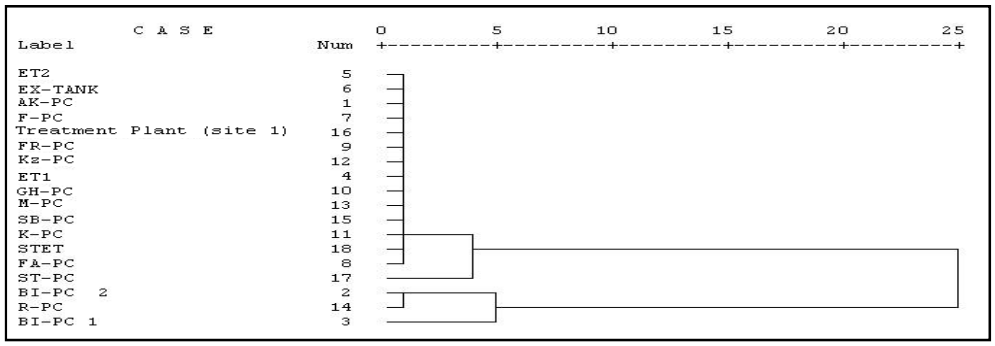

Figure 3: A dendrogram representation of a hierarchical cluster analysis of the TPH

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The products of this company are: Shahid Tondgoyan petrochemical company produces PET (bottle grade, textile grade and film grade), amorphous-grade polyethylene terephthalate (amorphous chips) andpurified terephthalic acid (PTA)[۱۳]. In conclusion, because the TPH concentration at almost all sampling stations was lower than the guideline value (10mg/l), the wastewaters of the PETZONE can be considered unpolluted. However, the effluents of the Razi and Imam Khomeini petrochemical companies (BI-PC 1, BI-PC 2 and R-PC sampling stations) had high concentrations of TPH in their outlets that were greater than the guideline value. Because the a fore mentione dsampling stations directly discharge their effluents to Khowr-e Musa Bay, these high concentrations may have an adverse impact on the aquatic ecosystem of the bay.

The concentrations of PAHs obtained in this study and related effluent limit guidelines are shown in Table 4.

[۱۳] http://www.stpc.ir/fa/main/default.aspx

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Table 4: Concentration of ∑ PAHs (ng/l) in the effluents of selected petrochemical companies

No.	Station	∑PAH AVE (ng/l)	∑PAH(ngL) AVE (∑Group I ng/l)	Effluent Limit (∑GroupI ng/l)[1]	∑PAH(ngL) AVE (∑Group IIng/l)	Effluent Limit (∑GroupII ng/l)[1]
1	M-PC 1SS	6836.10	355.01	10000	6481.09	100000
2	ET2	769.69	100.22	10000	669.47	100000
3	K-PC MIX	126.57	9.44	10000	117.13	100000
4	Treatment Plant (site 1)	101.39	36.66	10000	64.72	100000
5	FA-PC	66.78	6.40	10000	60.37	100000
6	SB-PC	214.74	24.98	10000	189.75	100000
7	GH-PC	148.79	32.14	10000	116.64	100000
8	ET1	89.61	10.13	10000	79.48	100000
9	STET	1258.16	3.57	10000	1254.58	100000
10	ST-PC	840.10	229.76	10000	610.32	100000
11	AK-PC	279.44	39.62	10000	239.81	100000
12	F-PC	50.83	3.311	10000	47.51	100000
13	EX-TANK	449.43	20.82	10000	428.61	100000
14	FR-PC	1844.87	76.72	10000	1768.15	100000
15	BI-PC	500.91	14.9	10000	486.00	100000
16	R-PC	153.06	219.95	10000	149.44	100000
17	Kz-PC	203.86	2.23	10000	201.62	100000
Total	-	13934.32	1185.88	10000	12964.78	100000

[1]-(US EPA New England, 2010c)

-Group I PAHs: a. Benzo(a) Anthracene, b. Benzo(a) Pyrene, c. Benzo(b)-Fluoranthene, d. Benzo(k)Fluoranthene, e. Chrysene, f. Dibenzo(a,h) Anthracene, g. Indeno(1,2,3-cd) Pyrene

-Group II PAHs: a. Acenaphthene, b. Acenaphthylene, c. Anthracene, d. Benzo(ghi)-Perylene, e. Fluoranthene, f. Fluorene, g. Naphthalene, h. Phenanthrene, i. Pyrene

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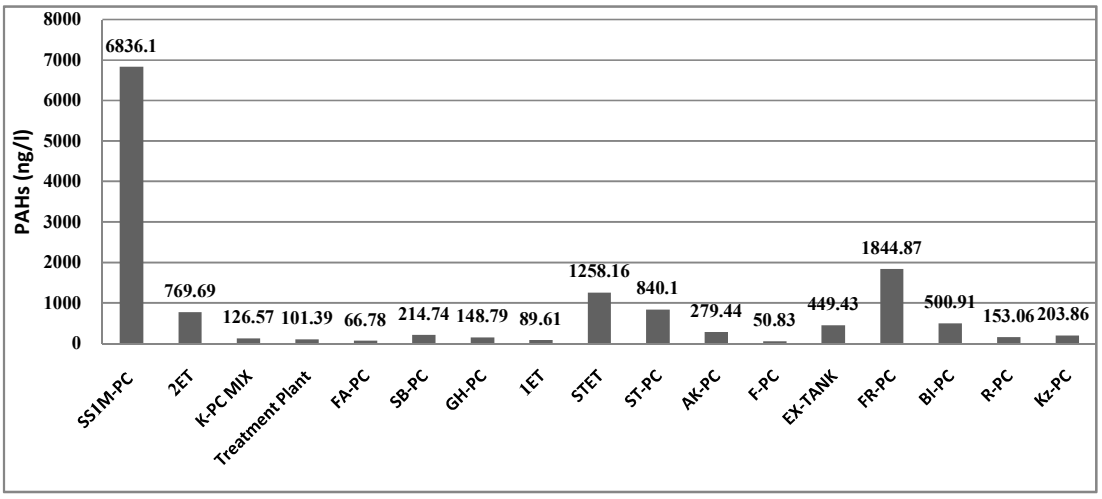

Figure 4: Concentration of PAHs (ng/l) in the selected sampling stations

The average concentration of ∑PAHs was 819.66 (ng/l) and ranged from 50.83 to 6836.10 (ng/l), as it was shown in Figure 4.

In conclusion, the average concentrations of ∑PAHs group I and group II (based on the guidelines) were 1.185 and 12.965 (µg/l) which means it still meets the guideline; therefore, the wastewater effluents of the study area can be considered unpolluted.

Moreover, when effluents measured at the "end of pipe", it means that they were measured before releasing into the bay, thus they are subsequently diluted in the Bay. Therefore, if the discharge concentration of PAHs is more than the guideline, it does not necessarily have a significant risk or it does not indicate that it may be contributing to a water quality standard exceedance in Khowr-e Musa Bay.

The average concentrations of TPH obtained in the present investigation are shown in Table 5.The TPH concentration of sediment samples presented an average value of 45.94 $\mu g g^{-1}$. The TPH concentrations of the stations can be arranged as follows: 1>2>4>6>7>3>5.

Table 5: The average concentration of TPH in the sampling stations

Khowr-e Musa Bay	TPH µg/g	
Station code	**Mean**	**Guideline**
1	88.81	Moderately polluted
2	57.32	Moderately polluted
3	32.73	Slightly polluted
4	45.93	Slightly polluted
5	17.51	Slightly polluted
6	40.05	Slightly polluted
7	39.25	Slightly polluted
Total	45.94	Slightly polluted

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At all of the stations, the concentration of TPH was greater than the natural background value which was 10-15 µg/g, and categorized in slightly polluted area except stations 1 and 2 which are located in the vicinity of the main effluent outlets of PETZONE (connective canals of Zangi and Jafari creeks) (Jazani et al., 2013; Monazami Tehrani et al., 2013). In addition, the lowest concentration of TPH was observed at station 5 which is may be related to the high water depth at the site.

Concentrations of PAHs in sediment samples obtained in the present investigation are shown in Table 6.

Table 6: PAHs concentrations in the sampling sediments of Khowr-e Musa Bay (ng/g, dry wt.)

Station No. / PAHs	1	2	3	4	5	6	7
Na	12.56	20.50	24.83	32.31	19.53	14.62	0
Acpy	57.42	89.64	130.56	109.73	67.37	25.06	11.86
Acp	3.27	17.05	34.74	68.82	4.15	10.09	0.00
Flu	26.33	104.13	138.89	580.34	51.57	8.22	27.59
Phen	153.36	520.50	1003.68	2820.60	220.83	95.24	27.48
Ant	76.55	131.28	237.47	668.39	121.25	50.25	35.56
Flur	77.06	113.90	228.59	2700.61	133.68	220.42	30.14
Py	92.32	151.26	317.94	1772.81	158.33	58.44	38.58
BaA	72.87	62.49	246.84	7079.15	181.15	46.23	15.69
Chr	53.8	73.14	235.24	5510.74	148.22	34.89	11.93
BbF	0.00	0.00	48.78	2898.68	91.36	6.30	0.00
BkF	5.11	2.14	34.16	1327.78	50.49	5.83	1.97
BaP	6.27	5.38	25.22	911.57	43.88	8.31	5.82
IP	3.91	20.93	0.00	83.42	61.35	21.75	6.78
DbahA	0.00	0.00	0.00	0.00	20.77	0.00	0.00
BghiP	5.54	0.00	6.32	94.05	36.46	7.39	3.13
Σ PAHs	647.37	1315.38	2718.33	26666.07	1419.46	624.12	228.56

Most values were exceptionally low, except for the sediments near the station 4, which is located near the aromatic outlet of Imam Khomeini petrochemical company and its concentration level approached the NOAA sediment quality guideline value (ERL) of 4000 (ng/g dry weight).

Therefore in this study PAH Benchmark was calculated for sediments of the selected sampling station according to U.S. EPA PAH ESB approach. According to the US. EPA definition, "benchmark is a chemical concentration in water or sediment, above which there is the possibility of harm or risk to the humans or animals in the environment". The acute toxicity (adverse effects resulting from a substance in a short term) and chronic toxicity (adverse effects resulting from a

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substance in a long term) were determined by U.S.EPA to calculate benchmarks. The potency divisors (Acute and Chronic Potency Divisor) were used in the calculations, which are indicated that the amount of individual chemical (such as pyrene / phenanterene and etc.), by itself can cause an adverse effect, (U.S.EPA, 2010b). Concentration of total organic carbon is the other factor which was measered in this study and PAHs benchmark was calculated for all 16 PAHs in each sampling station.

In order to calculate the differences in bioavailability of PAHs in the sampling sediments, the concentration of PAHs (dry weight) in each station are divided by the organic carbon concentration due to U.S EPA procedure (Table 7), (US.EPA,2010a).

Table 7: Benchmark calculation of the sampling sediments

Station	Acute Potency Ratio (ug/kg Organic Carbon) (For all 16 PAHs)	Chronic Potency Ratio (ug/kg Organic Carbon)(For all 16 PAHs)
1	0.043	0.01^
2	0.093	0.387
3	0.156	0.650
4	0.706	2.936
5	0.071	0.295
6	0.044	0.184
7	0.009	0.036

The sum of Chronic Potency Ratio showed that, the chronic benchmark was not more than the guideline at all the stations (it is exceeded when the sum exceeds 1.0) except in the vicinity of the Aromatic effluent outlet of BI-PC. Thus, the chronic benchmark at station 4 indicates that it has the potential to cause a chronic effect on sediment-residence organisms like crabs, clams and worms (US.EPA, 2010a).

Discussion

The results of the sampled wastewaters demonstrated that the average concentration of TPH was lower than the guideline value at most of the stations, except the effluent outlets of the Razi and Imam Khomeini petrochemical companies which are proximal to Khowr-e Musa Bay. Thus, they may have an adverse impact on the aquatic ecosystem of the bay. Although Razi petrochemical company had high concentration of TPH in its effluent outlet during the sampling time; the concentration of TPH in the sediments which are located in the vicinity of the R-PC effluent outlet, was lower than those other stations. The present result may be related to the high water depth at the site. But the concentration of TPH in sampling stations which are located in the vicinity of BI-PC effluent outlet (2, 3, and 4) was relatively moderate. The levels of TPH concentration in the study area relatively moderate compared to chronically oil-contaminated area in coastal and shorelines around the world such as, Gulf of Oman (0.05 -779 µg / g) and also highly oil-contaminated coastline of BAPCO oil

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refinery in Bahrain (779 µg / g), (Tolosa et al., 2005), oil-contaminated coastline of Saudi Arabia after the Gulf war (11-6900 µg / g) (Readman et al., 1996), highly oil-impacted sediments of Hong Kong's Victoria Harbour (60-646 µg / g)(Hong et al., 1995) and New York Bight (35–2900 µg / g), (Monazami Tehrani et al., 2013). In addition to TPH, the concentration of PAHs in sampling stations was monitored and the average concentrations of ∑PAHs group I and II showed that effluents of the selected petrochemical companies can be considered as unpolluted.

In addition, the levels of TPH concentration in the sediments of the study area relatively moderate compared to chronically oil-contaminated area in coastal and shorelines around the world. Also most PAHs values were exceptionally low, except for the sediments near the station 4, which is located near the aromatic outlet of Imam Khomeini petrochemical company and its concentration level approached the NOAA sediment quality guideline value (ERL) of 4000 (ng / g dry weight) (Long et al., 1995; Tehrani, 2013). Moreover, the result for Chronic Potency Ratio of 16PAHs showed that the chronic benchmark was not more than the guideline at all the stationsexcept in the vicinity of the Aromatic effluent outlet of BI-PC. Thus, the chronic benchmark at these stations indicates that it has the potential to cause a chronic effect on sediment-residence organisms such as crabs, clams and worms. Moreover, the source analysis results of the sampling sediments in the bay, showed that in addition to petrogenic input as a major source because of the vast amount of oil and gas in the Persian Gulf, pyrolytic input are also a source for PAHs. Also, another research in five creeks of the Musa Bay (Jafari, Ahmadi, Ardoleh, Ghazaleh and Merimos) showed that the main sources of PAHs in sediment in the studied region were mixed pyrolitic and petrogenicimputs, (Mirza et al., 2012).

In general, despite the high concentration of anthropogenic contaminates and other non-point source pollution, the results of the present study are unexpected in this semi-enclosed bay witha slow rate of water exchange. The unusual results may be related to the deposition of finer sediments along the Iranian eastern side and northwest area, which is associated with the counter-clockwise circulation from the Indian Ocean, deposition of eolian sediments and probably the effects of tidal currents (Massoud et al., 1996). According to the results of the current investigation, the health status of the benthic community should be determined, ecological Risk Assessment should be estimated and the concentration of other contaminants especially heavy metals in the sediments and also in the effluents of PETZONE should be evaluated and monitored.

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