ABSTRACT

In this research, the levels of polychlorinated biphenyls (PCBs) were investigated in the marine sediments of Asaluyeh harbor, in the Persian Gulf. The samples were taken from industrial, semi-industrial and urban regions. The mean concentration levels of total (Σ) 18 detected PCBs were 514.32, 144.67 and 31.6 pg/g dw for the industrial, semi-industrial and urban sampling stations, respectively. Based on a multivariate statistical analysis, it was found that high contamination levels of PCBs in sediments collected along the Persian Gulf were associated with releases from local industries. Total organic carbon (TOC) content was significantly and positively correlated with the concentrations of PCB congeners. World Health Organization toxic equivalents (TEQs) for PCBs ranged from 0.04 to 2.66 pg TEQ/g dry weight (dw) in the coastal sediments. The TEQ values in this study were higher than many reported worldwide in the literature for sediments. This suggests that there are high levels of contamination in the area due to industrial and other human activities.

Key words | Asaluyeh, PCBs, Persian Gulf, sediments

INTRODUCTION

Polychlorinated biphenyls (PCBs) are a type of persistent organic pollutants, and are extensively spread in environment matrixes. Due to their persistence, long-range atmospheric transport, high bioaccumulation potential, toxicity and nonbiodegradability, and disruption of endocrine systems, they pose serious threats to ecosystems and human health, and so they have recently attracted much attention (Hamlin & Guillette 2011; Jiang et al. 2011; Sobek et al. 2014). PCBs can be released into the environment from various sources including scrap metal recycling, auto salvage yards, auto crushing, repair activities, used oil, tar paper, tar roofing materials, plasticizers, hydraulic fluids and lubricants, miscellaneous uses, industrial and municipal wastewater discharge, leaching from landfills,

In the environment, the main route for the transport and deposition of PCBs to aquatic systems is atmospheric. After being transferred to a water body, due to their low solubility in water, these contaminants tend to adsorb and accumulate on particles and in sediments for a long time and undergo partitioning, degradation and transportation processes. As a result, the sediments can act as a natural sink for the contaminants that re-suspend at the interface of water and sediment, particularly during water body mixing and also in flood events. These phenomena may increase the accumulation and bio-availability of these pollutants and other toxic materials in the food chain (Ssebugere et al. 2013; Zhang et al. 2014) as they may be taken up by microorganisms, and finally biomagnified in top predators such as humans (Kelly et al. 2007). The main probable pathways of exposure to such contaminants in humans are ingestion, dermal contact and inhalation (Dirtu & Covaci 2010; Chan & Wong 2013). In living organisms, these hazardous pollutants cause various toxic and biochemical responses including lesions, immunosuppression and immunotoxicity, disruption of the endocrine system, reproductive impairment, induction of gene expression, and weight loss (Sormo et al. 2009). Thus, the use and disposal of PCBs are now considered to be major environmental issues worldwide and, as a consequence, information about PCBs and concentration levels in sediments is necessary to gain awareness of the present level of pollution, evaluate the risks, and plan remediation actions.

Asaluyeh harbor (26°30’ –27°50’N, 51°01’ –52°81’N) is located along the northern margin of the Persian Gulf and Oman sea, in Bushehr Province, Iran. Asaluyeh industrial area, 100 square kilometers in size, is well known for the numerous petroleum, petrochemical and natural gas refining industries. Therefore, many environmentally challenging problems occur in the coastal areas of the Asaluyeh harbor, with sediment contamination being one of the most serious concerns in this industrialized area (Arfaeinia et al. 2016; Raeisi et al. 2016). Regarding increased discharge of contaminants, marine sediment may be exposed to hazardous pollutants accumulated in the sediment (Karbasdehi et al. 2016, 2017).

To the best of our knowledge, there is no comprehensive report yet on PCBs concentration levels, sources, spatial distribution and their composition in the region of the Persian Gulf. So the objectives of this study can be summarized as follows: (1) to illustrate the spatial distribution and congener composition of PCBs in the sediments of Asaluyeh harbor in urban, semi-industrial and industrial areas along the Persian Gulf; (2) to trace the sources of PCBs and evaluate the correlation between PCB concentration levels and environmental factors such as total organic carbon (TOC) content in the research areas; (3) to compare the findings with those reported in research elsewhere; and (4) to compare concentration levels of PCBs obtained in this work with available criteria, standards and guidelines for ecotoxicological and human health assessment.

MATERIAL AND METHODS

Materials, reagents and standards

All of the extraction solvents (such as acetonitrile, n-hexane, dichloromethane, toluene, etc.), and the calibration check solution of PCB were obtained from AccuStandard, Inc. (New Haven, CT, USA). The purity of reagents, solvents and standards used was over 99.9%. Sulfuric acid, alumina, C18-modified silica gel, acetonitrile, anhydrous sodium sulfate and silica gel were of analytical grade. To eliminate the background levels of pollutants, the silica gel was heated overnight at 200°C before use. Eighteen PCB congeners (the four non-ortho PCBs 169, 126, 81, 77 as well as eight mono-ortho PCBs 189, 167, 157, 156, 123, 118, 114, 105 and six indicator PCBs 180, 153, 138, 101, 52 and 28) were quantified, as they are the most toxic compounds and have a common mode of action. Afterwards, all prepared stock solutions were stored in a fridge and maintained at 4°C until the analysis.

Study area and sediment sample collection

Sediment samples were collected in March 2015 from 21 sampling sites: eight sampling stations in the industrial area (S1 to S8), four sampling stations in the semi-industrial area (S9 to S12) and nine sampling stations in the urban area (S13 to S21) of Asaluyeh harbor (Table 1). Figure 1 shows the locations of the sampling stations. The sediments were collected using an Ekman steel grab sampler (25 × 25 × 25 cm³). All samples were immediately transferred to glass jars, which had been pre-washed and kept in an icebox, then brought back to the laboratory and kept at −20°C until the extraction and analysis process. In the laboratory, each sediment sample was air-dried, ground and passed through a sieve of <0.5 mm to eliminate fine debris, dead organisms
solution and non-ortho PCBs were eluted with toluene. PCBs from the non-ortho PCBs. Mono-ortho PCBs were
free-
fi-
e the sediment samples. Then, the extracts solution was
(Dionex Corporation, USA) was used for extraction of
Extraction and clean-up procedures have
2400 CHN) was used to measure the TOC content of samples.
All the devices used for sampling, transportation and prep-
aration were pre-washed with n-hexane and acetone to minimize the probability of cross contamination.

**Extraction and clean-up procedures**

The sample extraction and purification procedures have previously been described in detail by Ssebugere et al. (Ssebugere et al. 2013). In summary, 10 g of the sediment samples were spiked with 13C-labeled PCBs and converted to a free-flowing powder by being mixed with Hydromatix (Varian). ASE 200 accelerated solvent extraction system ( Dionex Corporation, USA) was used for extraction of the sediment samples. Then, the extracts solution was filtered via silicagel-type columns and eluted with 120 ml n-hexane. A reversible carbon column (Carboxen1016, Supelco) was used for the first primary separation of the mono-ortho PCBs from the non-ortho PCBs. Mono-ortho PCBs were extracted with a mixture of n-hexane/dichloromethane solution and non-ortho PCBs were eluted with toluene. After extraction, the resultant volume was reduced to 1 mL aliquots on a rotary evaporator and purified as described by Ssebugere et al. (Ssebugere et al. 2013). The resulting eluted extracts were reduced to <1 mL with a rotary evaporator, poured into a vial containing internal recovery standards and then stored for gas chromatographic analysis.

**Instrumental analysis**

The analysis of non-ortho PCBs was performed with a gas chromatography/high-resolution mass spectrometry (GC/HRMS) system (Agilent 6890N GC coupled to Waters Auto specUltima MS) equipped with a 60 m × 0.25 mm DB-5/DB-5ms column (J&W Scientific, Folsom, CA, USA), operating in selected ion monitoring (SIM) mode. The carrier gas was helium at a flow rate of 1.0 mL/min. The following temperature program was used for the GC oven: a starting temperature of 125 °C for 1.5 min, raised to 200 °C at a rate of 25 °C min⁻¹ and then 4 °C min⁻¹ to 310 °C, then held at 310 °C for 16 min. The injection, transfer-line, ion source, and quadrupole temperatures were set at 300, 300, 250, and 150 °C, respectively. The instrumental analysis of in PCBs and mono-ortho PCBs was carried out using an HP 6890 gas chromatograph (Hewlett-Packard, USA) equipped with a non-polar DB-5ms capillary column (Agilent, USA), operating in SIM mode. Helium was employed as the carrier gas at a steady flow rate of 1 mL min⁻¹. The oven temperature was held at 90 °C for 1.5 min, raised to 180 °C at 20 °C min⁻¹, held for 8 min, raised to 270 °C at 3 °C min⁻¹, then to 310 °C at 20 °C min⁻¹ and held at 310 °C for 10 min. Both of the injector and the transfer-line temperatures were adjusted at 285 °C. Quantification was done using the 13C isotopic dilution method.

**Quality assurance and quality control**

For quality assurance and quality control, blank and spiked samples were analyzed along with the real samples which were extracted for determining the PCBs of the sediments. Recovery and internal standards were employed for analytical control. Recovery efficiencies were determined as the averages of extractions of recovery standards ranging from 48% to 103%. Limits of detection (LOD) were adjusted to be three times as large as the standard deviation (SD) of the blank values. The mean of blank values was then deducted from all concentrations over the LOD values. The LOD was a function of the extracted mass and ranged within 0.02–1.01 pg for the PCBs.
Data analysis

SPSS ver. 20 (IBM Corp., USA) was used for statistical processing of the data. To evaluate the possible sources of PCBs, principal component analysis (PCA) was used to conduct multivariate statistical analysis. Also, ArcMap 10.2 geographical information system (GIS) (Esri, Redlands, CA) was utilized for mapping and the Raster Calculator of the ArcGIS Spatial Analyst extension was used to estimate concentration levels of PCBs anywhere that all of the predictors can be measured in sediments of Asaluyeh harbor in the Persian Gulf.

RESULTS AND DISCUSSION

The concentration levels of PCBs in the sediments

The concentration of PCBs, TOC content, and moisture content (MC) of the sediments are summarized in Table 2. All concentration levels in Table 2 are based on dry weight (dw). The concentration of PCBs including non-ortho, mono-ortho and indicator PCBs was quantified in the sediment samples. The sum (∑) PCBs of each group in the coastal sediment samples were determined and the concentration levels were 2,706 (2.97%), 16,516 (18.16%), 71,715 (78.86%) pg/gdw for non-ortho, mono-ortho and indicator PCBs, respectively (Figure 2). These results are different from those obtained by Vives (Vives et al. 2007) who reported the concentration levels of 11,000 and 3,000 pg/gdw for indicator and PCBs, but they are consistent with Nunes et al. (Nunes et al. 2011) regarding the low contribution of non-ortho (0.35–7.90%). The concentration levels of the ∑indicator PCBs in this study varied widely from 18 to 1,890 pg/gdw. As seen in Table 2, PCB 52, PCB 77 and PCB 118 had the highest concentration levels of the ∑indicator PCBs, ∑non-ortho PCBs and ∑mono-ortho PCBs with concentration levels of 1890 (station S4), 93 (station S1) and 988 (station S8) pg/gdw, respectively. El-Kady et al. (El-Kady et al. 2007) reported a similar distribution of congeners in sediments gathered from River Nile in the region of Cairo. A possible explanation for the high concentration level of PCB 77 might be that it does not degrade easily. In most commercial PCB mixtures and environmental samples, mono-ortho PCB congeners are found at high concentrations, and are environmentally persistent (Hornbuckle et al. 2010; Vives et al. 2007).
Table 2 | Mean concentration levels, ranges (pg/gdw) of PCBs, TOC and MCs of sediments in the study stations

<table>
<thead>
<tr>
<th>Congeners</th>
<th>Alternate name</th>
<th>Industrial stations</th>
<th>Semi-industrial stations</th>
<th>Urban stations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indicator PCBs</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2,4,4'-Trichlorobiphenyl</td>
<td>PCB 28</td>
<td>892.87 (743–1,024)</td>
<td>298.5 (269–323)</td>
<td>51.67 (42–63)</td>
</tr>
<tr>
<td>2,2',5,5'-Tetrachlorobiphenyl</td>
<td>PCB 52</td>
<td>1,763.37 (1,627–1,890)</td>
<td>491.25 (433–554)</td>
<td>88.56 (73–112)</td>
</tr>
<tr>
<td>2,2',4,5,5'-Pentachlorobiphenyl</td>
<td>PCB 101</td>
<td>1,231 (1,098–1,352)</td>
<td>356.75 (339–370)</td>
<td>89.56 (74–109)</td>
</tr>
<tr>
<td>2,2',3,4,4',5'-Hexachlorobiphenyl</td>
<td>PCB 138</td>
<td>1,712.37 (1,589–1,833)</td>
<td>453 (398–518)</td>
<td>66.89 (33–97)</td>
</tr>
<tr>
<td>2,2',4,4',5,5'-Hexachlorobiphenyl</td>
<td>PCB 153</td>
<td>1,166 (987–1,316)</td>
<td>354.75 (213–476)</td>
<td>100.78 (76–128)</td>
</tr>
<tr>
<td>2,2',3,4,4',5,5'-Heptachlorobiphenyl</td>
<td>PCB 180</td>
<td>655 (598–716)</td>
<td>140.75 (127–154)</td>
<td>34.78 (18–42)</td>
</tr>
<tr>
<td>Non-ortho PCBs</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>3,3',4,4'-Tetrachlorobiphenyl</td>
<td>PCB 77</td>
<td>76.62 (65–93)</td>
<td>17.5 (13–21)</td>
<td>6.5 (3–11)</td>
</tr>
<tr>
<td>3,4,4',5-Tetrachlorobiphenyl</td>
<td>PCB 81</td>
<td>26.37 (19–33)</td>
<td>12.25 (10–14)</td>
<td>1.95 (N.D.-4.2)</td>
</tr>
<tr>
<td>3,3',4,4',5-Pentachlorobiphenyl</td>
<td>PCB 126</td>
<td>19.75 (17–23)</td>
<td>8.5 (7–10)</td>
<td>1.6 (N.D.-5.1)</td>
</tr>
<tr>
<td>3,3',4,4',5,5'-Hexachlorobiphenyl</td>
<td>PCB 169</td>
<td>11.25 (9–14)</td>
<td>6.75 (6–8)</td>
<td>1.05 (N.D.-1.9)</td>
</tr>
<tr>
<td>Mono-ortho PCBs</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2,3,3',4,4'-Pentachlorobiphenyl</td>
<td>PCB 105</td>
<td>380.75 (332–423)</td>
<td>93.75 (83–102)</td>
<td>23.55 (18–31)</td>
</tr>
<tr>
<td>2,3,4,4',5-Pentachlorobiphenyl</td>
<td>PCB 114</td>
<td>65 (59–73)</td>
<td>17 (16–19)</td>
<td>6.6 (3.6–9.7)</td>
</tr>
<tr>
<td>2,3',3',4,4'-Pentachlorobiphenyl</td>
<td>PCB 118</td>
<td>893 (839–988)</td>
<td>246.5 (198–334)</td>
<td>62.54 (34–78)</td>
</tr>
<tr>
<td>2,3,3',4,4',5,5'-Hexachlorobiphenyl</td>
<td>PCB 123</td>
<td>81.90 (63–94)</td>
<td>26 (23–29)</td>
<td>6.85 (4.3–11)</td>
</tr>
<tr>
<td>2,3,3',4,4',5,6-Hexachlorobiphenyl</td>
<td>PCB 156</td>
<td>136.62 (129–154)</td>
<td>34 (31–38)</td>
<td>10.34 (7–13)</td>
</tr>
<tr>
<td>2,3,3',4,4',5'-Hexachlorobiphenyl</td>
<td>PCB 157</td>
<td>49.25 (43–55)</td>
<td>13.75 (12–16)</td>
<td>3.84 (1.9–6.3)</td>
</tr>
<tr>
<td>2,3,3',4,4',5,5'-Heptachlorobiphenyl</td>
<td>PCB 167</td>
<td>59 (49–67)</td>
<td>18 (16–19)</td>
<td>6.55 (5–8)</td>
</tr>
<tr>
<td>Mono-ortho PCBs</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2,3,3',4,4'-Pentachlorobiphenyl</td>
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<td>59 (49–67)</td>
<td>18 (16–19)</td>
<td>6.55 (5–8)</td>
</tr>
</tbody>
</table>

Hence, it seems possible that the high levels of the mono-ortho PCBs are due to slow desorption kinetics. The concentrations of PCB 169 were quantified at low levels across all sampling stations (Table 2). A possible explanation for these results may be due to the limited mobility in molecular diffusion processes as well as greater susceptibility to the dissolution loss process (Li et al. 2009). Thus, the low levels of PCB 169 in the sediment samples in this study could be ascribed to the fact that it is more soluble in water (Ssebugere et al. 2013). The concentration levels of the mono-ortho PCBs varied from zero to 95 pg/gdw. The concentration levels of PCB 126 and 169 in stations S15, S16 and S17 were zero while PCB 153 was the main PCB in these stations. Also, the mono-ortho PCBs ranged from 1.4 to 988 pg/gdw and in all stations, the main mono-ortho PCB was PCB 118 and the minimum concentration level was for PCB 189 (Table 2). These findings further support the results of Vives et al. (Vives et al. 2007) and Loganathan et al. (Loganathan et al. 2008) studies.

A high concentration level of PCBs was also observed in sediment samples of the industrial stations of Asaluyeh with a concentration level of 74,062 pg/gdw, while the concentration levels of PCBs in semi-industrial and urban stations were 10,416 and 5,106 pg/gdw, respectively. The concentration level of PCBs in the industrial sediment samples was 7–14 times higher than in other areas including semi-industrial and urban areas. The greater industrialization in the Asaluyeh harbor may account for the higher
concentration levels of PCBs in the sediments, especially near gas sniper phases, which receive the greatest amount of transport and deposition to aquatic systems, industrial run-off and wastewater discharges from the big industries. The highest concentration levels of PCBs in the sampling stations of three areas related to PCB 52 in industrial as well as semi-industrial stations and PCB 153 in urban stations, all of which belong to the indicator group. Also, the maximum and minimum concentration levels of ΣPCB were observed in S4 and S17 in the industrial and urban areas, respectively. Figure 3 presents the spatial distribution of ΣPCB in the coastal sediment samples of Asaluyeh along the Persian Gulf.

Predominant pollutants and major contributors to the toxic equivalent (TEQ)

The contribution of ΣTEQ concentration levels for PCBs in sediments from different stations are presented in Figure 4. As seen in this figure, the highest concentration level of ΣTEQs in sediments was observed in sampling station S1 (16.26 pg TEQ/g dw), which is located in the industrial area.

The toxic equivalent factors were applied to calculate the TEQs set by the World Health Organization (WHO) in 2005. The WHO-TEQ values for sediment samples from three regions of Asaluyeh are shown in Table 2. As shown in Table 2, the TEQs values in the study were 1.58 for industrial stations (ranging from 0.006 to 15.8 pg/gdw), 0.35 for semi-industrial stations (ranging from 0.001 to 3.4 pg/gdw) and 0.15 pg/gdw for urban stations (ranging from 0.0006 to 1.48 pg/gdw). The TEQ concentration for ΣPCB in sediments ranged from 0.04 to 2.66 pg TEQ/g dw with an average value of 1.19 pg/gdw. Station S4 in the industrial area had the highest concentration level of PCBs with a value of 2.66 pg TEQ/g dw. The overall concentrations of TEQs in sediments decreased with the increase in the distance from the industrial to semi-industrial and urban areas (Figure 4). TEQ values in the present study were higher than those of sediments from Murchison Bay of Lake Victoria in Uganda (ranging from 0.04 to 0.64 pg TEQ/g) and Han river in Korea (ranging from 0.0118 to 0.626 ng TEQ/kg) (Kim et al. 2009; Ssebugere et al. 2014) and almost in the same range as those of the central South Africa (ranging from 0.02 to 4.4 ng/kgdw) (Nieuwoudt et al. 2009), but lower than the one in Krompachy in the Slovak Republic (ranging from 1.9 to 148 pg TEQ/gdw) (Conka et al. 2014).

The relationship between the PCBs and TOC contents of sediments

The TOC concentrations in the sediment are shown in Figure 5. They ranged from 8.93 to 11.10% with an average value of 10.05% in industrial area, 9.78 to 10.83% with an average value of 9.93% in semi-industrial area and 9.87 to 10.91% with an average value of 10.01% in urban area. The increase in the TOC content in sediment can increase bioactivity and bioaccumulation in the water system. Station S4 had the highest TOC concentration. The sediment collected from Station S4 (the estuary of the Khoor River) received large amounts of municipal wastewater which is rich in organic matter. Moreover, the average value of TOC content in the industrial stations was greater than the urban stations, in general. These findings showed that anthropogenic activities and the industrial zone represent the main sources of sediment TOC content and can exert a substantial influence on carbon cycling processes in coastal sediments. Effects on carbon cycling and the ecology of the marine ocean are also possible in that coastal productivity may be subsequently exported (Arfaeinia et al. 2016).

The relationship between the PCB and TOC content of sediments is shown in Figure 6. As seen in Figure 6, linear regression correlations were found between the concentrations levels of PCBs and TOC (with R² values of 0.748 and 0.739, respectively). These relationships imply that organic carbon could have an influence on the transport and distribution of these pollutants in the coastal area along the Persian Gulf. The correlation between the concentration levels of PCBs and TOC in surface sediments from Lake Maggiore in Italy and Switzerland, as well as the Han River in Korea (Vives et al. 2007; Kim et al. 2009) is comparable with those found in surface sediments along the Persian Gulf in Iran.
Source apportionment (PCA)

PCA was carried out to investigate the proportion of congener profiles with potential possible sources of PCBs contaminations in the coastal sediments of Asalouyeh harbor.

The PCA results for PCBs are shown in Figure 7. The first principal components (PC1) had 44.7% of the total variances and consisted of PCB 81, 105, 114, 156, 167, 169, 180 and 189. Among these, PCB 105 and 114 are penta-PCBs, PCB 156, 167 and 169 are hexa-PCBs and PCB 180 and 189 are hepta-PCB. Therefore, PC1 was characterized by penta-PCBs as well as hexa-PCBs. These congeners are used in equipment such as electrical transformers, gas transmission turbines, electrical capacitors and vacuum pumps. These pollutants are discharged into the environment from these sources in surface runoff, landfill and incineration of sludge (Konat & Kowalewska 2013). PCB 169 is one of the most abundant hexa-PCB congeners in PC1 which is released into the environment through emission gases of Al and Cu metallurgy (Ba et al. 2009).

In addition to penta- and hexa-PCBs, hepta-PCBs were also one of the dominant congeners in PC1. Higher concentration levels of higher chlorinated PCBs originate mostly from the discharge of anthropogenic pollution Dobaradaran et al. 2010. Thus, the hepta-PCBs of PC1 originate from local human-made sources. The other possible source for hepta-PCBs is combustion processes. In a study by Zhang et al.
(Zhang et al. 2010), it was confirmed that PCBs can be released into the environment by emission gases of iron ore sintering, hardwood burning and domestic coal. Moreover, Asaluyeh harbor lies on the northern margin of the Persian Gulf as one of the most important economic and industrial harbors in Iran. The petrochemical and natural gas refineries increase economic development in this region, but inevitably lead to many environmentally challenging problems in the coastal and marine environments. In addition, some other activities such as storage systems for petroleum products, shipping, mariculture and the fishing industry make it difficult to identify the precise origins of PCBs in the Asaluyeh region. Some environmental and geologic processes such as coastal transport or dechlorination and sediment resuspension cause modification in PCB structures from their source (Tyler & Millward 1996). Thus, PC1 indicates the input of PCBs from mix sources: leakages from landfill, emission gases, discharges of local sources and combustion processes.

The second principal components (PC2) had 23.2% of the total variances and consisted of PCB 28, 52, 77 and 138. Among these PCB congeners, PCB 28 is a tri-PCB, PCB 52 and 77 are tetra-PCBs. Thus, PC2 was dominated by tri-PCB and tetra-PCBs, which can be found predominately in the air. (Zhang et al. 2008) Some research (Gioia et al. 2006; Totten et al. 2006) has indicated that the
Volatilization of lower chlorinated congeners from the upper water layer can sustain the PCB concentration level in the lower atmosphere near the water. Therefore, PC2 represents atmospheric deposition.

CONCLUSION

This study indicated the findings of the first survey of PCBs in the sediments of the northern part of the Persian Gulf. The results showed that the concentration levels of PCBs varied widely from industrial to semi-industrial and urban areas. Industrial and urban areas had the higher and lower concentration levels, respectively. Significant correlations were observed between TOC content with the concentration levels of PCBs congeners. The high concentration levels of penta-PCBs and hexa-PCBs obtained in this study indicated that potential sources the PCBs can be the use some equipment such as electrical transformers, gas transmission turbines, electrical capacitors and vacuum pumps in industrial processes. TEQ values in this study were higher than many other values reported worldwide in the literature for sediments. This implies that there are high levels of contamination in the area due to the existence of the examined contaminants. Finally, continued monitoring and mitigation measures, particularly in the case of emerging pollutants, is highly recommended in marine and industrial areas.

DISCLOSURE STATEMENT

No potential conflict of interest was reported by the author.

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