

## ROPME MUSSEL WATCH PROGRAMME 2011



Technical Report: No.1

### *TRACE METAL SCREENING*

Prepared by:

MESL/IAEA  
Monaco, January 2013

For:



REGIONAL ORGANIZATION FOR THE PROTECTION OF THE MARINE ENVIRONMENT





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## **1. INTRODUCTION**

Under the ROPME Contaminant Screening Project, surveys of heavy metal and organic contaminants have taken place in Kuwait, Bahrain and UAE (June 1994), in I. R. Iran, Oman and Qatar (1997), in Saudi Arabia and Kuwait (October 1998), in Qatar and UAE (March 2000), in Bahrain (November 2000) and in Oman (August 2001). The results of these surveys have been published by ROPME (1996, 1998, 2001 and 2005). The aim of the survey as undertaken within ROPME Mussel Watch Programme in February-March 2011 was to screen for trace inorganic and organic contaminants in key coastal areas in Bahrain, I.R. Iran, Kuwait, Oman, Qatar, Saudi Arabia and the United Arab Emirates (UAE) and to compare the results with those from earlier surveys in the same areas. This report summarizes the results of trace metals in the sediments and biota in the Inner RSA. This report should therefore be considered as a companion document to ROPME publications of 1996, 1998, 2001 and 2005. The reader is referred to these latter documents for ease in following comparisons made with the previous surveys.

## **2. SAMPLING METHODOLOGY**

In February and March 2011, selected locations along the coasts of Bahrain, I.R. Iran, Kuwait, Oman, Qatar, Saudi Arabia and the United Arab Emirates (UAE) were sampled for sediment and biota within the framework of ROPME Mussel Watch Programme. The sampling stations, locations and types of samples collected are given in Map 1 and Table 1.

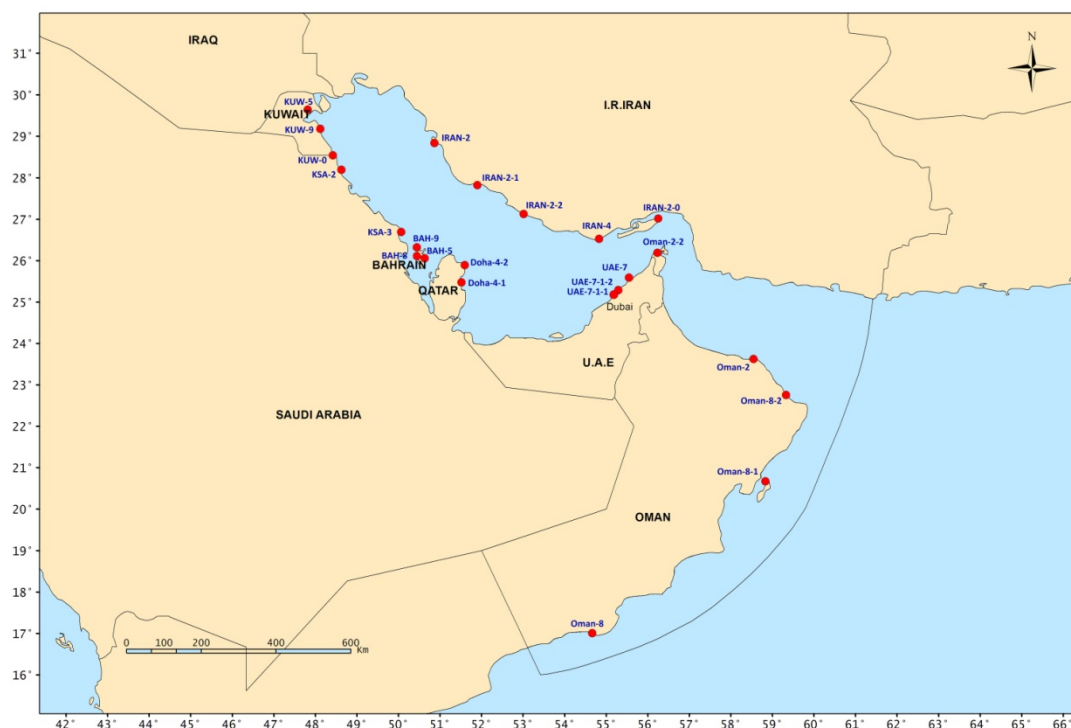
## **3. ANALYTICAL PROCEDURES**

The analytical protocol for measuring trace metal and grain size is detailed in the following:

### **3.1 SEDIMENT SAMPLES**

#### **3.1.1. Sample pre-treatment**

The sediment samples were received already freeze-dried and were sieved at 1mm.



**Map 1.** Mussel Watch Sampling Stations in the RSA

**Table 1.** Sediment and Biota Sampling Sites in the ROPME Sea Area

Country	Sample Code	Site Name	Coordinates		sample	
			N	E	Sed	Biota
Bahrain	BAH-5	Askar #	26° 03'	50° 38'	√	Pearl oyster
I.R.Iran	IRAN-2	Bushehr	28°50'	50°52'	√	Rock oyster
	IRAN-4	Lengeh #	26°32'	54°51'	√	Rock oyster
Kuwait	KUW-5	Doha #	29 39	47 49	√	x
Oman	Oman - 2	Mina Al-Fahal#	23°37'	58°33'	√	Rock oyster
	Oman -8	Mirbat#	17°00'	54°40'	√	Rock oyster
Qatar	Doha-4-2	Ras Laffan	25°53'	51°36'	√	Pearl oyster
SA	KSA-3	Ras Tanura	26 41'	50 04'	√	Asiatic clam
	KSA-2	Ras Mishab	28° 11'	48°37'	√	Asiatic clam
UAE	UAE-7	Umm Al-Quwain	25°35'	55°33'	√	Rock oyster
	UAE-7-1	Dubai	25 17'	55 16'	√	Rock oyster
	UAE-7-2	Dubai	25 17'	55 18'	√	Pearl oyster

# To follow up the temporal trend of results: similar samples have been collected during the Contaminant Screening of 2005

### **3.1.2 Microwave digestion**

All the samples were digested using a CEM MARS Xpress pressure microwave digestion system. A quantity of  $250\pm 50$  mg of freeze-dried sediment material was weighed for digestion. Samples were digested in acid-cleaned Teflon microwave vessels with 5 ml of ultrapure nitric acid, 2 ml ultrapure concentrated hydrofluoric acid and 2ml of hydrogen peroxide. Each digestion batch included at least 2 reagent blanks and an appropriate natural matrix certified reference material (CRM): IAEA-158, marine sediment (IAEA) in this case.

The digestion procedure involves gradually increasing the temperature to  $190^{\circ}\text{C}$  over a 15 minute period, then maintaining that temperature for an additional 15 minutes. After cooling, the reactors are opened, 10 ml of 4% boric acid solution is added, and another microwave run (increasing to  $170^{\circ}\text{C}$  in 10 minutes and holding  $170^{\circ}\text{C}$  for 15 minutes) is done to dissolve the fluoride precipitates. The digested sample is then transferred onto 50ml plastic tubes containing an extra 10ml of 4% boric acid solution, and made up to volume with ultrapure water.

### **3.1.3 Flame atomic absorption measurements**

The digested samples were analyzed for Al, Fe, Ca, Mg, Mn and Zn by flame atomic absorption spectrophotometry (AAS) (Varian, 120FS) using external calibration. Calibration curves were prepared daily using CRM standard solutions; a second source standard solution was used as independent calibration verification at the beginning and at the end, and generally throughout the run.

The matrix effects were checked using post digestion matrix spike, if the recovery were outside the limits, standard addition was used as calibration mode, no matrix effect were detected during the measurements of the samples.

The method blanks and CRMs prepared with each batch of samples were measured at the beginning and at the end of each measurement sequence to validate samples measurements.

Quantification limits were calculated using method blanks or the lowest calibration standard if blanks were negligible.

### 3.1.4 Inductively Coupled Plasma–Mass Spectrometry

Inductively Coupled Plasma–Mass Spectrometry (ICP-MS) was the method used for the determination of Ag, As, Ba, Cd, Co, Cr, Cu, Li, Ni, Pb, Sb, Se, Sn, U and V in sediment samples, and for the determination of Ag, Al, As, Ba, Cd, Co, Cr, Cu, Li, Ni, Pb, Sb, Se, Sn, U and V in biota samples.

ICP-MS incorporates high temperature (9000 K) argon inductively coupled plasma (ICP) together with a mass spectrometer (MS). Ions produced in the ICP are sorted on the basis of their mass to charge ratios in the MS device which provides both quantitative and isotopic information about the samples introduced to the instrument. One drawback of ICP-MS is that certain polyatomic ions may form due to the combination between argon and major matrix elements (e.g.  $^{40}\text{Ar}^{16}\text{O}$ ) which may degrade analytical performance on certain analytes which are detected at the same nominal mass.

All the measurements were carried out at the International Atomic Energy Agency in Monaco, using the quadrupole mass spectrometer 2 Q-ICP-MS (XSERIES, Thermo Fisher Scientific). The instrument was equipped with a micromist nebulizer (0.2 ml/min, Glass Expansion) and a cyclonic spray chamber cooled by Peltier cooling system ESI. 2 Q-ICP-MS (XSERIES, Thermo Fisher Scientific), the instrument is equipped also with collision/reaction cell for interference removal, consisting of a non-consumable hexapole and e ion deflector, which takes the ion beam off-axis and leads to low instrument backgrounds. This hexapole is inherently part of the Thermo lens system and is present in the ion path, regardless of the use of the collision cell. The collision gas used in our measurements was He with high purity at a flow rate of 3.75 ml/min. Polyatomic ions generated within the plasma have larger atomic radii than analyte ions of similar mass. Thus, when using a collisional/reactive gas, these larger species undergo more collisions/reactions in the cell, during which they lose increasingly more energy, and are then excluded from the quadrupole mass filter by the kinetic energy barrier. For the reasons mentioned above, the Collision/Reaction Cells (CRC) have been accepted as the preferred means of removing spectral interferences in quadrupole ICP-MS.

The XSERIES (Thermo Fisher Scientific) has the capability of operating at two different modes (normal settings and collision reaction cell).

Before the measurements, the method parameters in each of the modes used were optimized for maximum intensity and precision of each single isotope. The optimized parameters for Q-ICP-MS are listed in the Table 2 and Table 3.

**Table 2.** Optimised parameters for the Q-ICP-MS on Standard Mode (XSERIES 2, Thermo Fisher Scientific)

<b>Parameter</b>	<b>Unit</b>	<b>Value</b>
Plasma gas flow	lmin <sup>-1</sup>	13.5
Nebuliser gas flow	lmin <sup>-1</sup>	0.91
Auxiliary gas flow	lmin <sup>-1</sup>	
RF power	W	1200
Sensitivity for 1 ppb In	cps	>100000
Background on mass 220	cps	< 2
Dead time	ns	39
Number of sweeps/replicate		150
Number of replicates		3
Dwell time per amu	ms	75
Total analysis time per sample	sec	72
Sample uptake	ml/min	0.2

**Table 3.** Optimised parameters for Q-ICP-MS in the CCT Mode (Xseries 2, Thermo Fisher Scientific)

	<b>Unit</b>	<b>Value</b>
Plasma gas flow	lmin <sup>-1</sup>	13.5
Nebuliser gas flow	lmin <sup>-1</sup>	0.91
Auxiliary gas flow	lmin <sup>-1</sup>	
RF power	W	1200
Sensitivity for 1 ppb In	cps	>100000
Background on mass 220	cps	< 2
Dead time	ns	39
Number of sweeps/replicate		150
Number of replicates		3
Dwell time per amu	ms	75
Total analysis time per sample	sec	72
Sample uptake	ml/min	0.2

### **3.1.5 ICP–MS measurements**

The samples were analyzed for trace elements content using isotopic measurements for quantification. As, Se, Cr and V were measured in CRC mode, whereas the rest of trace elements determined in sediment samples (Ag, Ba, Cd, Co, Cu, Li, Ni, Pb, Sb and U ) were measured in normal mode (see 0). Each measurement sequence started by the monitoring of the instrumental background and followed by procedural blank analysis to avoid cross contamination problems. Every sample was introduced into the plasma at least 2 minutes prior to measurement to ensure that the isotopic signals were stable.

The concentration of elements in the sediment samples was determined via external calibration using appropriate working standards derived from mono elemental standards (1000 µg/ml). The standards were prepared in 2% HNO<sub>3</sub>. The analytical quality control was provided by the contemporaneous analysis of the certified reference material (IAEA-158, marine sediment, IAEA) prepared with each digestion batch.

The samples digested were diluted 50 times prior to analysis with 2% nitric acid.

The procedural blanks, which were prepared in the same way as the samples were measured on separate days and were determined by external calibration with 3 different concentrations of element standards prepared by dilution of adequate Merck standards.

### **3.1.6 Mercury**

The mercury was determined in the sediment samples directly, using a solid AAS analyzer (AMA 254, Altech), therefore no digestion was needed. A portion of about 100 mg of sediment was measured. The internal calibration of the AMA 254 instrument was checked every day using an external standard solution and a CRM (MESS-3, NRCC) sampled at different intake masses, in order to verify the linearity of the calibration from 5 to 30 ng of mercury. The instrument was recalibrated if any of the checks failed.

The replicate blanks and CRM were analyzed for quality control purposes throughout the run, as well as the replicate samples.

The quantification limits were calculated using method blanks.

### **3.1.7 Grain size**

#### *3.1.7.1 Preparation of samples*

The samples were sieved at 300  $\mu\text{m}$ . Most of the samples have very small material below 300  $\mu\text{m}$ ; the sample DOHA-4-1S could not be prepared as not enough material was available.

#### **Preparation prior particle size analysis:**

Approximately an aliquot of 1 g (or less when not enough material was available, for a large number of samples it was a lot less which implies more uncertainty in the measurements) of sediment was put in a 10ml tube. 5ml of Milli Q water was added and the tube was shaken in order to separate the silt particles properly. An equilibration period of about half an hour was used to insure that the sample was uniformly wet before analysis.

#### *3.1.7.2 Particle Size Analysis*

The particle size distribution was determined using a Malvern Instrument Mastersizer device. The principle of this device is that small particles cause incident light to be diffracted through a large angle whereas large particles will diffract incident light through a small angle. Particle size information is derived by deconvolution of the diffraction data obtained by the instrument.

#### *3.1.7.3 Apparatus used*

The MALVERN Mastersizer Micro v2.12 is designed to analyze particle size of silty sediments ( $<300 \mu\text{m}$ ), the particles need to stay in suspension during the measurement process (this device is not suited for the analysis of coarse sandy material).

#### *3.1.7.4 Protocol used*

The analysis of the particles is achieved by slurring a sediment sample into a beaker containing 500 ml of water. The mixture is pumped through a cell which is interrogated by the instrument's laser beam. The particle size distribution is determined from the resulting diffraction pattern.

## **3.2 BIOLOGICAL SAMPLES**

### **3.2.1 Sample pre-treatment**

The biota samples were received already freeze-dried and ground, so no pre-treatment was applied.

### **3.2.2 Microwave digestion (for trace metals other than mercury)**

All the samples were digested using a CEM MARS Xpress pressure microwave digestion system. A quantity of  $250\pm 50$  mg of freeze-dried biological material was weighed for digestion. The samples were digested in acid-cleaned Teflon microwave vessels with 5 ml of ultrapure nitric acid and 2ml of hydrogen peroxide. Each digestion batch included at least 2 reagent blanks, and an appropriate natural matrix CRM: SRM 2976, mussel tissue (NIST) in this instance.

The digestion procedure involved gradually increasing the temperature to  $190^{\circ}\text{C}$  over a 15 minute period, then maintaining that temperature for an additional 15 minutes. After cooling, the reactors are opened, and the digested samples are transferred onto 50ml plastic tubes and made up to volume with ultrapure water.

### **3.2.3 Flame atomic absorption measurements**

The digested samples were analyzed for Fe, Ca, Mg, Mn and Zn by flame atomic absorption spectrophotometry (Varian, 120FS) using external calibration. Calibration curves were prepared daily using CRM standard solutions; a second source standard solution was used as independent calibration verification at the beginning and at the end, and generally throughout the run.

The matrix effects were checked using post digestion matrix spike, if the recovery was outside the limits, standard addition was used as calibration mode, no matrix effect were detected during the measurements of the samples.

The method blanks and CRMs prepared with each batch of samples were measured at the beginning and at the end of each measurement sequence to validate samples measurements.



The quantification limits were calculated using method blanks or the lowest calibration standard if blanks were negligible.

#### **3.2.4 ICP–MS measurements**

The samples were analyzed for trace element contents using isotopic measurements for quantification. As, Se, Cr and V were measured in CRC mode, whereas the rest of trace elements determined in the biota samples were measured in normal mode. (See0). Each measurement sequence started by the monitoring of the instrumental background and followed by procedural blank analysis to avoid cross contamination problems. Every sample was introduced into the plasma at least 2 minutes prior to measurement to ensure that the isotopic signals were stable.

The concentration of elements in the biota samples was determined via external calibration using appropriate working standards derived from mono elemental standards ( $1000 \mu\text{gml}^{-1}$ ). The standards were prepared in 2%  $\text{HNO}_3$ . The analytical quality control was provided by the contemporaneous analysis of the certified reference material SRM 2976 (mussel tissue, NIST) prepared with each digestion batch.

The samples digested were diluted 20 times prior to analysis with 2% nitric acid.

The procedural blanks, which were prepared in the same way as the blends were measured on separate days and were determined by external calibration with 3 different concentrations of element standards prepared by dilution of adequate Merck standards.

#### **3.2.5 Mercury**

The mercury was determined in the sediment samples directly, using a solid AAS analyzer (AMA 254, Altech), therefore no digestion was needed. A portion of about 100 mg of sediment was measured. The internal calibration of the AMA 254 instrument was checked every day using an external standard solution and a certified reference material sampled at different intake masses (SRM 2976, mussel tissue, NIST), in order to verify the linearity of the calibration from 5 to 30 ng of mercury. The instrument was recalibrated if any of the checks failed.

The replicate blanks and CRM were analyzed for quality control purposes throughout the run as well as the replicate samples.

The quantification limits were calculated using method blanks.

## **4. RESULTS AND DISCUSSION**

### **4.1 SEDIMENT**

The results for trace elements' concentrations in sediment are shown in the Table 4 for Ag, Al, As, Ba, Ca, Cd, Co, Cr, Cu, Fe, Hg, Li, Mg, Mn, Ni, Pb, Sb, Se, Sn, U, V and Zn.

The Figures 1, 2, 3, 4, 5, 6, 7 and 8 represent selected measured element concentration (in blue) of the samples collected in 2011, measured element concentration (in green) of the samples from the same sampling sites in 2005, and sampling campaign and Ecological Risk Assessment Marine Sediment Screening Benchmarks (black line) from EPA. The station order follows the coast from east to west (i.e. I.R. Iran to Oman).

The results for grain size analysis are shown in the Table 5

The size distribution in percentage for each sample is reported as:

% Sand =  $\sum$  percentage of particulates between 300  $\mu\text{m}$  and 63  $\mu\text{m}$ ;

% Silts =  $\sum$  percentage of particulates between 63  $\mu\text{m}$  and 3.9  $\mu\text{m}$ ;

% Clay =  $\sum$  percentage of particulates below 3.9  $\mu\text{m}$ ;

% Mud =  $\sum$  % Clay and % Silt.

**Table 4.** Trace Metal Results in Sediment Samples

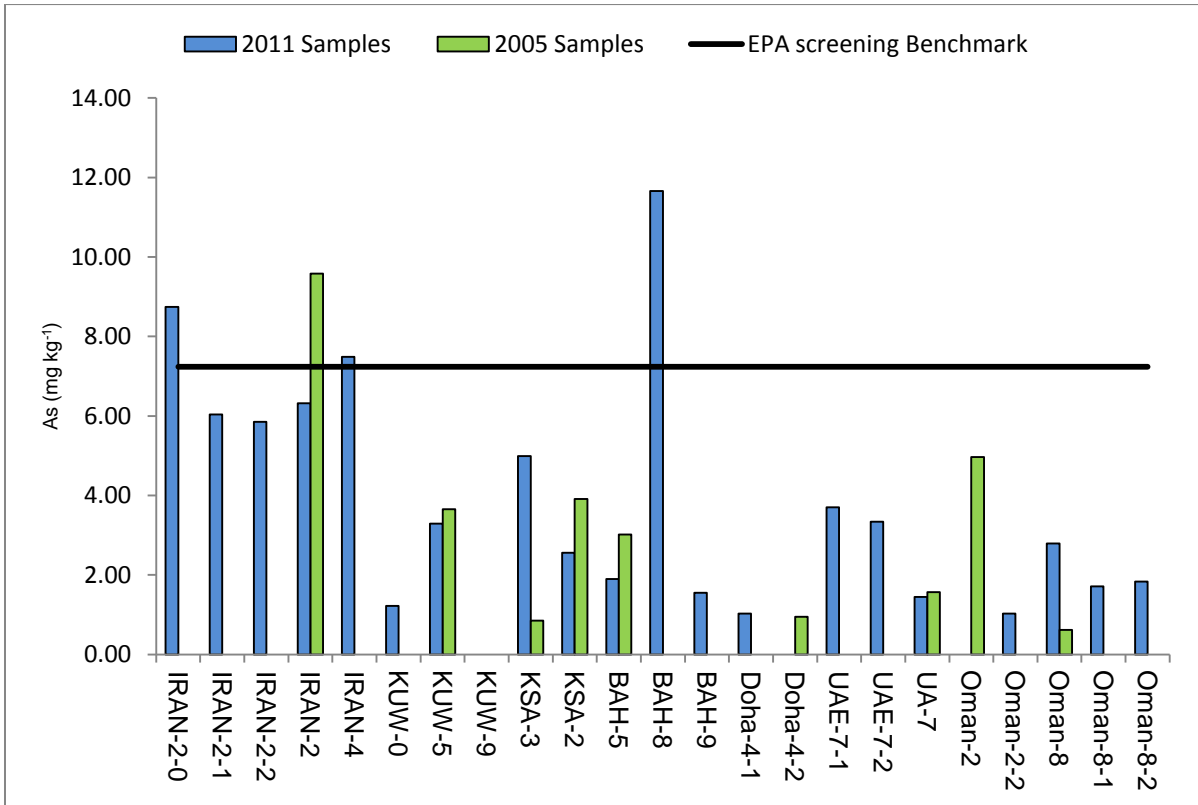
Sample name	Ag $\mu\text{g g}^{-1}$	Al $\text{mg g}^{-1}$	As $\mu\text{g g}^{-1}$	Ba $\mu\text{g g}^{-1}$	Ca $\text{mg g}^{-1}$	Cd $\mu\text{g g}^{-1}$	Co $\mu\text{g g}^{-1}$	Cr $\mu\text{g g}^{-1}$	Cu $\mu\text{g g}^{-1}$	Fe $\text{mg g}^{-1}$	Hg $\text{ng g}^{-1}$
BAH-5	<1.25	0.411	1.90	34.4	322	0.178	3.28	12.8	5.84	1.83	21.8
BAH-8	<1.25	0.631	11.66	120	164	0.159	1.89	7.81	2.07	0.87	2.52
BAH-9	<1.25	1.38	1.55	12.7	342	0.206	3.23	2.01	1.46	0.44	1.22
IRAN-4	<1.25	0.44	7.48	126	236	0.311	6.24	38.3	7.46	7.60	1.02
IRAN-2-0	<1.25	0.44	8.74	31.0	346	0.307	4.97	24.4	2.87	4.54	2.11
IRAN-2-2	<1.25	1.53	5.85	99.2	249	0.280	5.87	44.2	6.26	7.49	1.68
IRAN-2-1	<1.25	1.53	6.04	101	249	0.281	6.09	40.0	6.87	7.29	1.99
IRAN-2	<1.25	6.35	6.32	55.4	314	0.274	4.26	26.1	7.48	4.72	3.02
KUW-0	<1.25	0.415	1.22	75.3	114	<0.125	0.87	3.23	0.758	0.82	0.650
KUW-9	<1.25	0.637	<1	141	78.9	<0.125	0.76	2.89	3.00	0.81	0.810
KUW-5	<1.25	0.482	3.29	46.9	328	0.170	4.84	18.7	7.35	3.08	17.9
OMAN-8	<1.25	2.66	2.79	198	242	0.239	4.50	31.3	2.91	4.94	0.700
OMAN-8-1	<1.25	0.911	1.71	23.3	310	0.307	5.76	55.8	3.67	4.08	0.780
OMAN-8-2	<1.25	1.32	1.83	169	262	0.421	4.61	34.0	4.05	3.89	0.930
OMAN-2	<1.25	4.11	<1	297	193	0.176	4.99	19.8	3.02	8.83	<0.5
OMAN-2-2	<1.25	3.25	1.03	23.8	353	0.205	3.63	8.29	0.99	0.76	<0.5
DOHA-4-1	<1.25	0.496	1.03	11.0	363	0.207	3.72	<2.5	1.03	0.10	1.19
DOHA-4-2	<1.25	0.448	<1	10.2	363	0.244	2.92	<2.5	0.807	0.08	0.690
KSA-3	<1.25	0.269	4.99	33.9	313	0.202	3.11	7.96	4.86	1.30	15.5
KSA-2	<1.25	0.471	2.56	79.7	177	<0.125	2.03	8.88	2.59	1.61	2.19
UAE-7	<1.25	0.166	1.45	24.5	281	0.221	2.86	14.0	1.30	0.69	1.04
UAE-7-1	<1.25	1.57	3.70	42.7	280	0.275	5.35	48.7	14.8	3.13	5.49
UAE-7-2	<1.25	0.633	3.34	54.1	326	0.215	4.17	84.0	4.69	2.72	3.19

**Table 4** (Contd...)

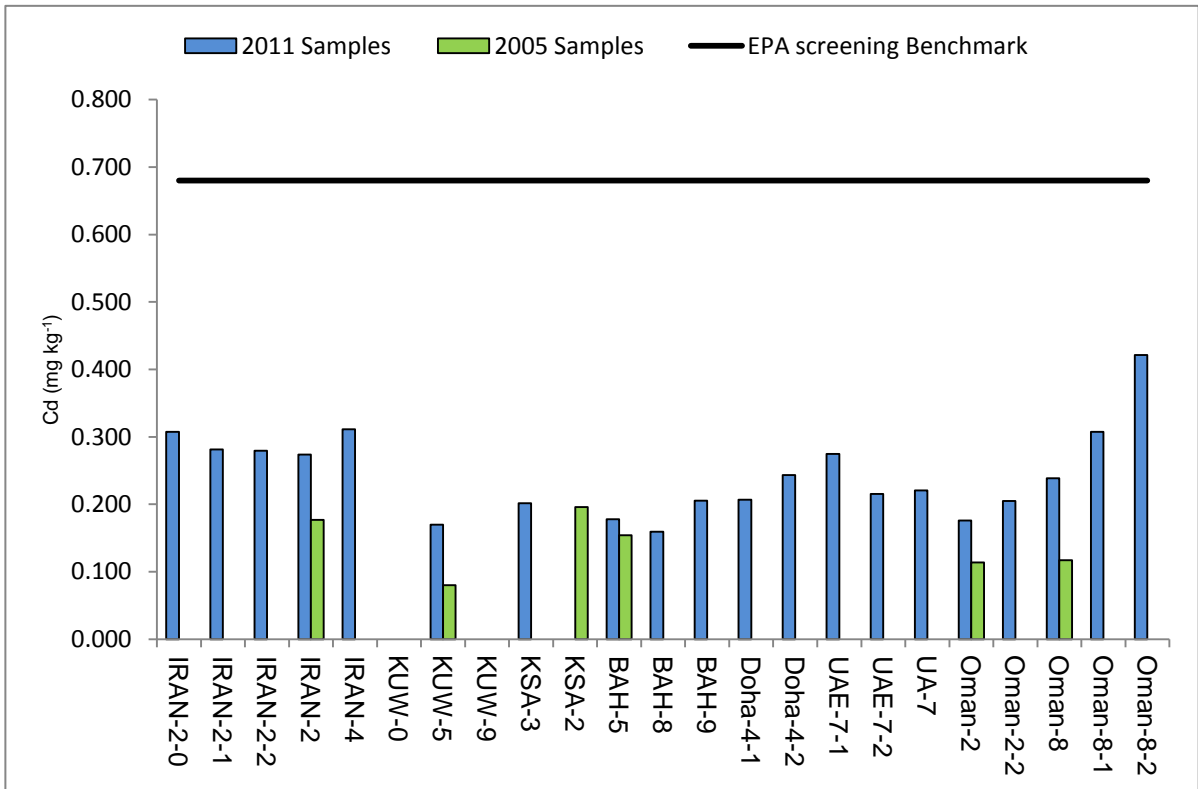
<b>Sample name</b>	<b>Li</b>	<b>Mg</b>	<b>Mn</b>	<b>Ni</b>	<b>Pb</b>	<b>Sb</b>	<b>Se</b>	<b>Sn</b>	<b>U</b>	<b>V</b>	<b>Zn</b>
	$\mu\text{g g}^{-1}$	$\text{mg g}^{-1}$	$\mu\text{g g}^{-1}$	$\mu\text{g g}^{-1}$	$\mu\text{g g}^{-1}$	$\mu\text{g g}^{-1}$	$\mu\text{g g}^{-1}$	$\mu\text{g g}^{-1}$	$\mu\text{g g}^{-1}$	$\mu\text{g g}^{-1}$	$\mu\text{g g}^{-1}$
BAH-5	2.45	12.6	34.2	8.75	8.06	<0.125	<1.25	<1.5	<1	8.75	13.1
BAH-8	2.58	5.43	24.5	6.55	1.91	<0.125	<1.25	<1.5	3.06	5.88	5.46
BAH-9	1.57	14.5	23.9	5.16	0.466	<0.125	<1.25	<1.5	<1	4.21	3.89
IRAN-4	12.3	18.6	192	28.2	5.85	0.266	<1.25	<1.5	2.63	32.2	14.3
IRAN-2-0	3.86	13.1	124	14.2	3.62	0.185	<1.25	<1.5	<1	16.0	5.41
IRAN-2-2	9.73	14.3	255	32.3	4.08	0.204	<1.25	<1.5	2.80	28.2	14.9
IRAN-2-1	9.52	14.9	278	30.7	3.94	0.203	<1.25	<1.5	2.92	28.4	14.5
IRAN-2	5.02	9.65	202	14.0	6.26	0.161	<1.25	<1.5	<1	16.2	12.8
KUW-0	2.83	1.22	16.9	4.60	1.78	<0.125	<1.25	<1.5	1.18	2.97	1.62
KUW-9	2.55	2.90	28.4	4.04	2.59	<0.125	<1.25	<1.5	<1	3.50	<1.4
KUW-5	3.73	4.51	59.2	16.6	3.08	<0.125	<1.25	<1.5	3.37	12.0	12.7
OMAN-8	2.47	13.6	128	21.2	3.26	<0.125	<1.25	<1.5	1.33	17.5	7.63
OMAN -8-1	2.82	16.1	77.7	40.2	0.465	<0.125	<1.25	<1.5	1.75	15.8	4.57
OMAN-8-2	4.31	24.5	150	30.8	2.93	0.141	<1.25	<1.5	2.54	21.6	6.51
OMAN-2	2.71	7.47	202	10.6	3.43	<0.125	<1.25	<1.5	1.48	30.1	14.9
OMAN-2-2	1.53	6.14	17.7	8.35	0.572	<0.125	<1.25	<1.5	<1	2.46	<1.4
DOHA-4-1	1.14	7.99	8.66	5.76	0.274	<0.125	<1.25	<1.5	<1	1.14	1.85
DOHA-4-2	0.931	6.21	7.38	4.22	0.226	<0.125	<1.25	<1.5	<1	0.96	1.44
KSA-3	2.17	4.33	17.1	7.41	7.66	0.161	<1.25	<1.5	<1	10.9	6.29
KSA-2	3.26	2.83	28.1	9.40	1.80	0.127	<1.25	<1.5	<1	7.65	2.77
UAE-7	1.87	7.60	24.8	7.28	0.647	<0.125	<1.25	<1.5	3.11	3.66	1.60
UAE-7-1	4.30	15.3	68.2	35.7	2.87	0.201	<1.25	<1.5	5.38	16.6	14.8
UAE-7-2	3.73	8.63	107	16.2	2.99	0.160	<1.25	<1.5	<1	16.1	10.3

**Table 5.** Grain Size Results

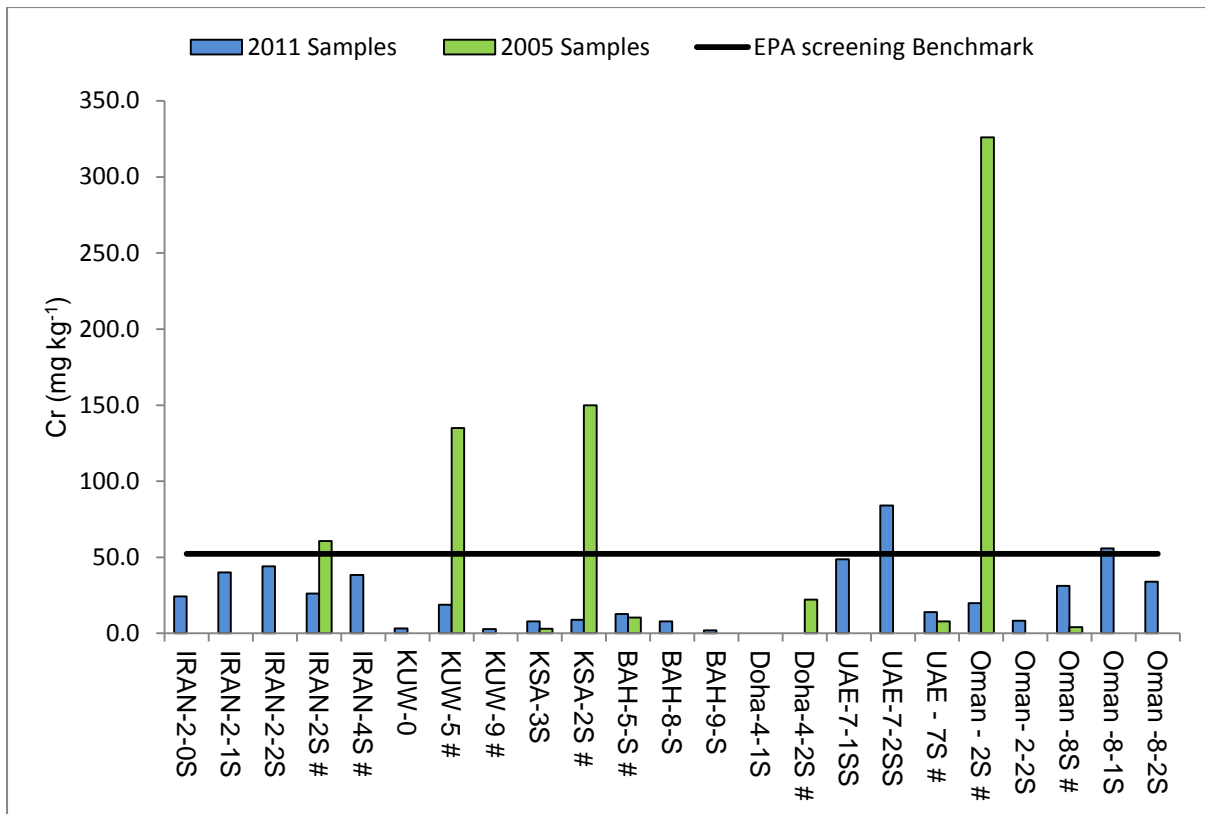
<b>Sample</b>	<b>Sand %</b>	<b>Silt %</b>	<b>Clay %</b>	<b>Mud %</b>
BAH-5	87.62	11.49	0.89	12.38
BAH-8	97.01	2.47	0.52	2.99
BAH-9	91.77	7.42	0.81	8.23
IRAN-4	89.16	9.90	0.94	10.84
IRAN-2-0	99.07	0.93	0.00	0.93
IRAN-2-2	91.22	7.65	1.13	8.78
IRAN-2-1	94.17	5.07	0.76	5.83
IRAN-2	99.05	0.53	0.42	0.95
KUW-0	98.72	0.64	0.65	1.28
KUW-9	98.07	1.33	0.60	1.93
KUW-5	70.31	22.49	7.19	29.69
OMAN-8	100.00	0.00	0.00	0.00
OMAN-8-1	98.74	0.87	0.40	1.26
OMAN-8-2	98.78	0.87	0.35	1.22
OMAN-2	100.00	0.00	0.00	0.00
OMAN-2-2	99.10	0.54	0.36	0.90
DOHA-4-2	91.94	7.52	0.54	8.06
KSA-3	76.53	21.40	2.08	23.47
KSA-2	74.32	24.30	1.38	25.68
UAE-7	98.62	0.99	0.39	1.38
UAE-7-1	66.91	29.64	3.45	33.09
UAE-7-2	98.62	1.03	0.35	1.38



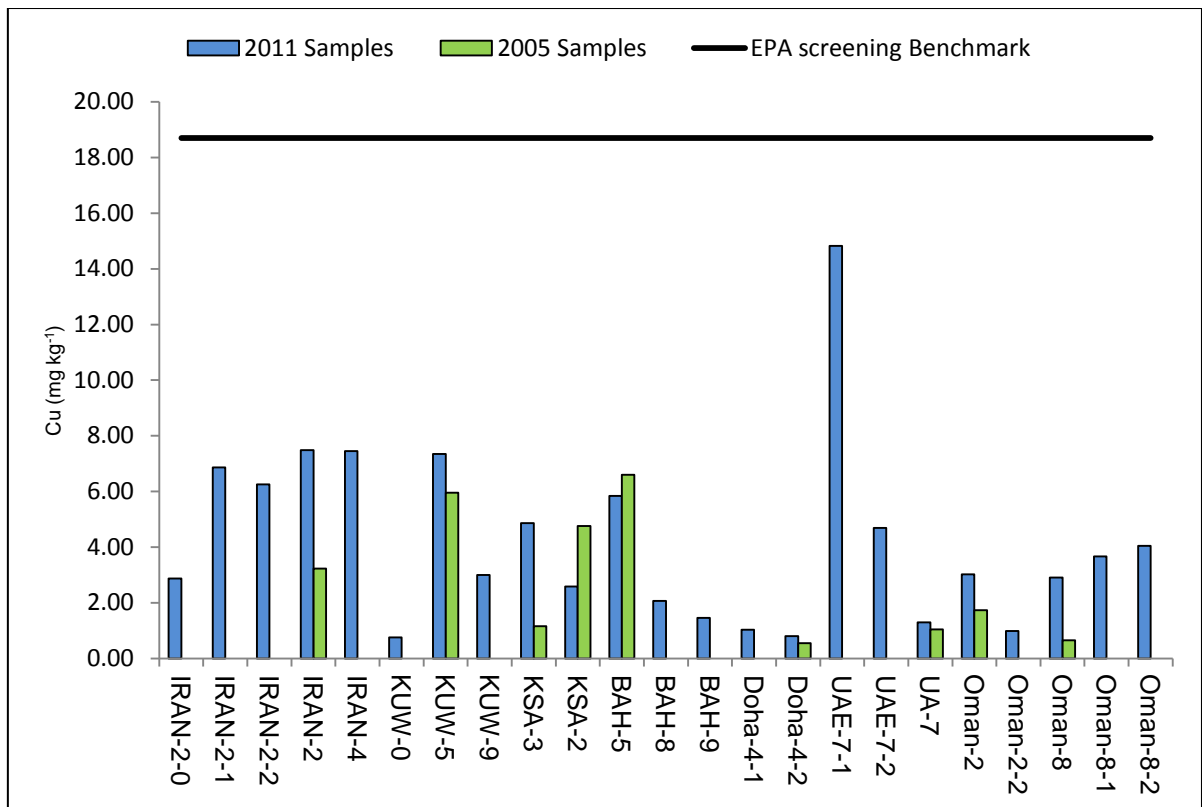
**Figure 1.** Arsenic concentrations in sediment samples



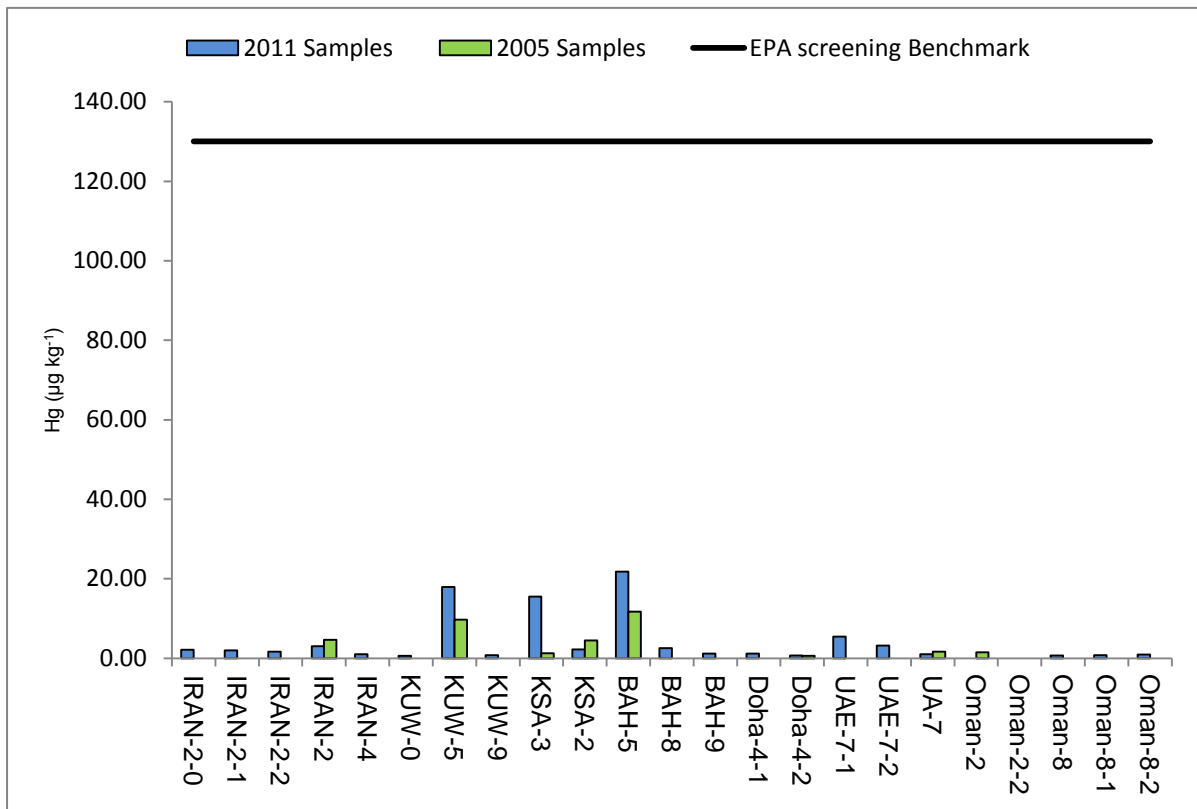
**Figure 2.** Cadmium concentrations in sediment samples



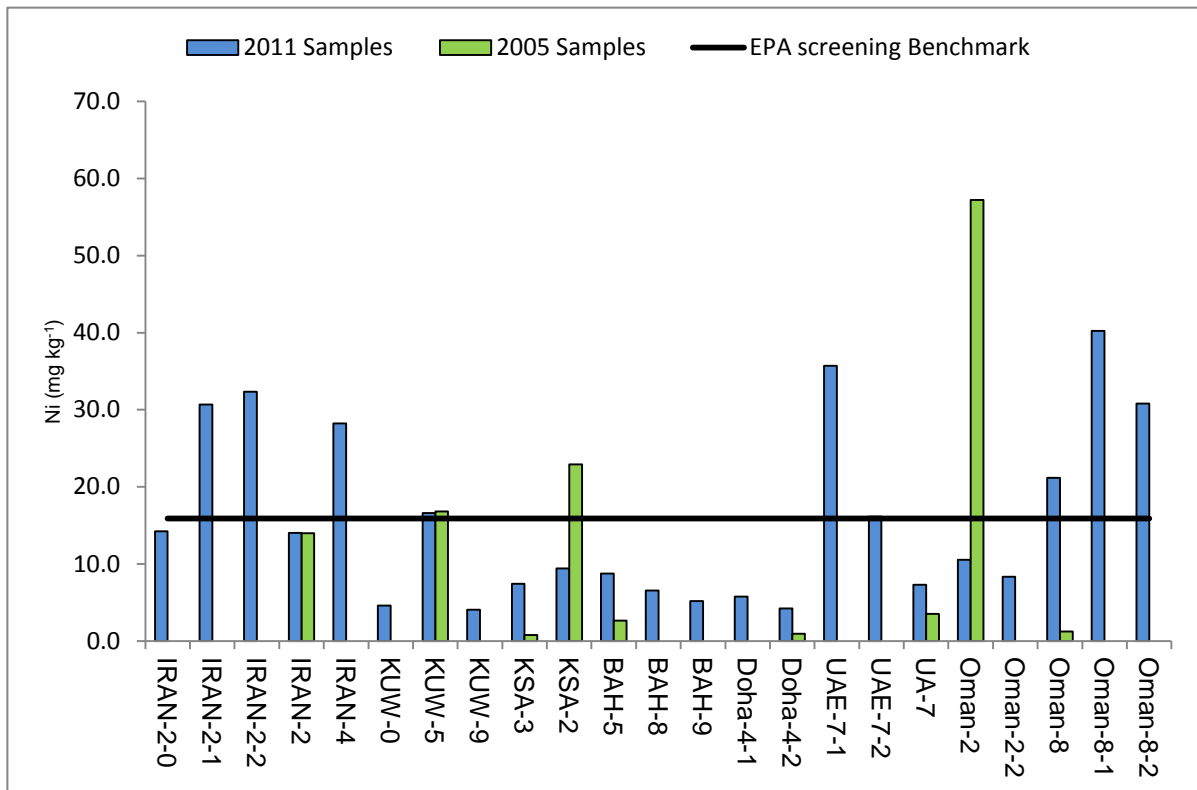
**Figure 3.** Chromium concentrations in sediment samples



**Figure 4.** Copper concentrations in sediment samples

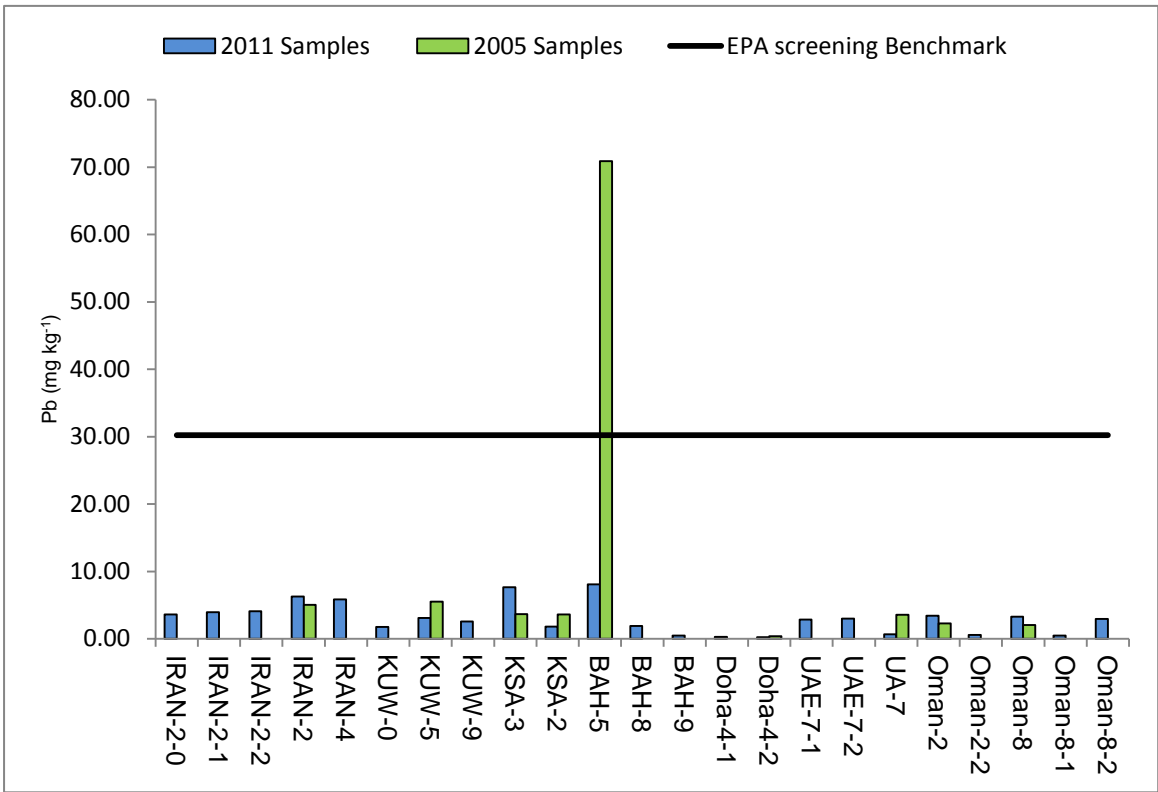


**Figure 5.** Mercury concentrations in sediment samples

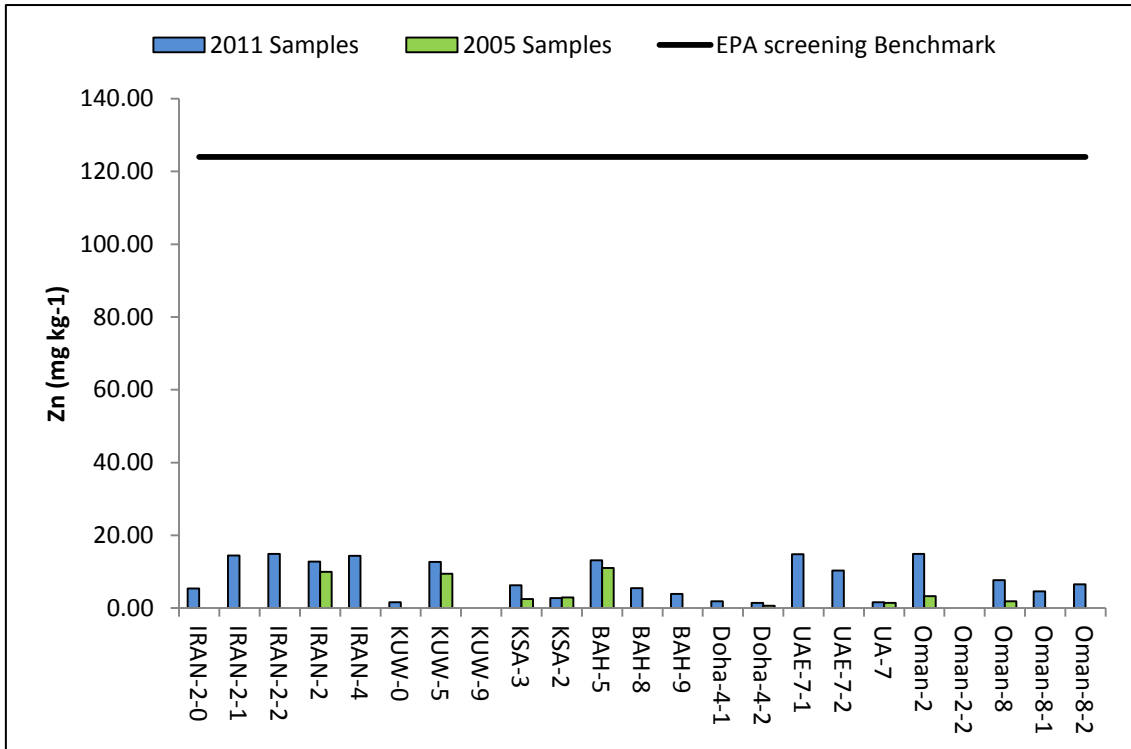


**Figure 6.** Nickel concentrations in sediment samples





**Figure 7.** Lead concentrations in sediment samples



**Figure 8.** Zinc concentrations in sediment samples

The levels observed, in general, were not exceptionally important and fell within the range reported previously (Basaham *et al.*, 1993; ROPME, 2001).

The batch sample collected may contain an important part of silica based (sand) and/or coarse material in addition to the finer sedimentary material. As silica generally does not contain any other trace elements, its presence in fact dilutes the sediment and generally the trace elements' concentrations are lower in comparison when only sedimentary fraction is analysed.

To account for this factor the common practice is to normalize the trace element concentrations to a reference element that is characteristic to terrestrial material. The elements commonly used for this purpose are Al, Fe or Li. The chosen element should be found at high and relatively reproducible concentration in the sediment, and behaves conservatively in the marine environment.

The concentrations found for Al and Fe were relatively low (0.16 to 6.3 mg g<sup>-1</sup> for Al and 0.1 to 8.8 mg g<sup>-1</sup> for Fe), in sandy sediments Al (or Fe) concentrations were below 5mg g<sup>-1</sup>. As shown in the Table 5, most of the analysed samples have more than 90% of sand, which is in good correlation with low Al and Fe results. Nevertheless, no clear correlation was found with any of the major elements and for this reason no further normalization was performed.

The levels observed in the sediment samples are compared with accepted action levels and limits shown in Table 6, the lowest limit (EPA) is also plotted on the Figures 1, 2, 3, 4, 5, 6, 7 and 8.

**Table 6 . Sediment Quality Guideline**

CAS#	Analyte	Screening value (mg/kg) <sup>a</sup>	ERL <sup>b,c</sup>	ERM <sup>b,d</sup>
7440-38-2	Arsenic	7.24	8.2	70
7440-43-9	Cadmium	0.68	1.2	9.6
7440-47-3	Chromium	52.3	81	370
7440-50-8	Copper	18.7	34	270
7439-92-1	Lead	30.2	46.7	218
7439-97-6	Mercury	0.13	0.15	0.71
7440-02-0	Nickel	15.9	20.9	51.6
7440-22-4	Silver	0.73	1.0	3.7
7440-66-6	Zinc	124	150	410

Note: <sup>a</sup> EPA Marine Sediment Screening Benchmarks  
[www.epa.gov/reg3hwmd/risk/eco/btag/sbv/marsed/screenbench.htm](http://www.epa.gov/reg3hwmd/risk/eco/btag/sbv/marsed/screenbench.htm) (Macdonald *et al.*, 1996);  
<sup>b</sup> (Long *et al.*, 1995);  
<sup>c</sup> ERL= Effects range low where effects are rarely observed (<10% of adverse effect reported if sediment <ERL);  
<sup>d</sup> ERM= Effects range Median (<50% of adverse effect reported if sediment are <ERM).

Some stations stood out in term of their relatively elevated levels of trace elements in sediment samples; they are analysed below **on a country by country basis**.

#### 4.1.1 Bahrain

Yazirat Ya'suf (BAH-8) showed the highest As concentration (11.7 mg kg<sup>-1</sup>) of the 2011 sampling campaign, exceeding the EPA screening benchmarks and the ERL level. This concentration is also higher than those already reported in the same area (ROPME, 2001) with values ranging from 3.16 to 6.88 mg kg<sup>-1</sup> for samples collected in 2000, and values from the 2005 campaign ranging between 2.60 and 4.66 mg kg<sup>-1</sup>.

All the other trace element concentrations found in the 3 sediment samples collected during this campaign are below above mentioned limits.

The relatively high Pb values observed previously in Askar (BAH-5), close to the BAPCO site (ROPME, 2001 and ROPME, 2006), were not observed during this campaign (70.9 mg kg<sup>-1</sup> in 2005 against 8.06 mg kg<sup>-1</sup> in this study), nevertheless the Pb concentration in Askar (BAH-5) is the highest of the 2011 sampling campaign

#### **4.1.2 I. R. Iran**

The two sediments collected in Lenge Port (IRAN-4) and Qeshm (IRAN-2-0) have higher concentrations for As, than the screening benchmark, but only IRAN-2-0 is higher than the ERL limit and none of them are above the ERM. Some relatively high arsenic concentrations have been already reported before (ROPME, 2006). In general, concentrations of As found in the Iranian samples collected in this study were higher than the other stations.

Ni concentrations in Lenge Port (IRAN-4), Qeshm (IRAN-2-2) and Daier (IRAN-2-1) are above screening limits, but none of them are above the ERM. High levels of Ni were already reported in the RSA (ROPME, 2001; ROPME, 2010). The levels measured in the 2005 campaign ranged from 14 to 105 mg kg<sup>-1</sup>, this is higher than levels observed in this campaign, where the highest value in the present study was 32.3 mg kg<sup>-1</sup> found in Parsian (IRAN-2-2). The levels observed along the Iranian coast are similar to the levels observed in the Sea of Oman.

#### **4.1.3 Kuwait**

With the exception of slightly over screening benchmarks from EPA (16.6 mg kg<sup>-1</sup>), the Ni concentration found in Doha (KUW-5) and all other elements measured in the 3 sediments samples are below this limit. In the 2005 campaign, Doha (KUW-5) had also slightly high Ni value, but the Cr concentration at that station was much higher (135 mg kg<sup>-1</sup> in 2005 against 18.7 mg kg<sup>-1</sup> in 2011). It should also be noted that the Al concentration in the 2005 sample for Doha (KUW-5) was higher (9.06 g kg<sup>-1</sup> in 2005 against 0.46 g kg<sup>-1</sup> in 2011).

#### **4.1.4 Oman**

Five sediment samples were collected along the coast of Oman, of which 3 sites exceeded the ERL value for Ni: Mirbat, Masirah and Qalhat (OMAN-8, OMAN-8-1 and OMAN-8-2). The level of Cr in Masirah (OMAN-8-1) was also slightly above the EPA's screening benchmarks. ROPME (2001) reported some elevated Ni concentration in the Oman and eastern UAE coast probably related to the presence of ophiolite rich in nickel sulfide.

Levels of Cr and Ni measured in the sample from Mina Al-Fahal (OMAN-2) were higher in 2005 than in 2011. In general, the levels reported for Cr and Ni along the coast of Oman were lower in this campaign, ROPME (2001) reported Cr values

ranging from 6 to 133 mg kg<sup>-1</sup> against values ranging from 8 to 55 mg kg<sup>-1</sup> in this study.

#### **4.1.5 Qatar**

A 2 sediment sample was collected along the coast of Qatar, Palm Island-Doha (DOHA-4-1) and Ras Laffan (DOHA-4-2). All measured concentrations of trace elements were low/very low to being often the lowest values observed in the 2011 campaign.

#### **4.1.6 Saudi Arabia**

All measured trace elements in the 2 collected samples were below limits. The high Ni and Cr values observed in the 2005 campaign at Ras Mishab (KSA-2) were not seen in the 2011 sample.

#### **4.1.7 UAE**

The sediment samples were collected from 3 sites. The Cr limit (as set by the EPA screening benchmarks) was exceeded in Dubai (UAE-7-2), and the Ni limit was exceeded in Dubai (UAE-7-1). These two sites (close to Dubai) near each other are potential sampling collection sites for the future production of a certified reference material in the RSA. The concentrations of the other elements are below the EPA screening benchmarks.

Levels found at Umm Al-Qaiwain (UAE-7) were all below the limits and very comparable with the levels found in 2005 at the same site.

### **4.2 BIOTA**

The results for trace metal in biota are shown in the Table 7 for Ag, Al, As, Ba, Ca, Cd, Co, Cr, Cu, Fe, Hg, Li, Mg, Mn, Ni, Pb, Sb, Se, Sn, U, V and Zn.

The Figures 9, 10, 11, 12, 13, 14, 15 and 16 represent selected elements concentrations (in blue) in the samples collected in 2011, in green the concentrations in the same sampling site during the 2005 sampling campaign. Samples are separated based on species.

**Table 7 . Trace Metal Results in Biota Samples**

Sample name	Matrix	Ag	Al	As	Ba	Ca	Cd	Co	Cr	Cu	Fe	Hg
		$\mu\text{g g}^{-1}$	$\mu\text{g g}^{-1}$	$\mu\text{g g}^{-1}$	$\mu\text{g g}^{-1}$	$\text{mg g}^{-1}$	$\mu\text{g g}^{-1}$	$\mu\text{g g}^{-1}$	$\mu\text{g g}^{-1}$	$\mu\text{g g}^{-1}$	$\text{mg g}^{-1}$	$\text{ng g}^{-1}$
BAH-5	Pearl oyster	<0.05	69.6	18.7	0.73	4.70	1.88	<0.05	2.18	5.64	0.147	52.3
BAH-8	Pearl oyster	<0.05	64.4	43.9	0.82	5.08	7.27	0.112	0.451	3.73	0.175	46.6
BAH-9	Pearl oyster	<0.05	58.2	48.8	0.63	5.62	7.29	0.119	0.621	4.02	0.121	42.2
IRAN-4	Rock oyster	6.76	96.5	13.8	0.53	26.8	7.29	<0.05	1.86	528	0.175	64.0
IRAN-2-0	Rock oyster	2.03	43.2	18.4	0.53	23.8	14.0	0.360	2.41	179	0.137	38.2
IRAN-2-2	Rock oyster	5.99	108	23.1	0.96	18.9	3.99	0.352	2.56	345	0.221	111
IRAN-2-1	Rock oyster	4.10	68.3	18.0	0.45	24.8	6.10	0.245	1.40	199	0.142	73.6
IRAN-2	Rock oyster	1.37	177	19.8	0.61	27.3	6.25	0.492	1.83	284	0.204	65.1
OMAN-8	Rock oyster	2.16	17.5	18.2	0.31	3.55	8.99	0.160	0.518	278	0.078	136
OMAN-8-1	Rock oyster	2.74	26.2	14.6	0.23	9.19	34.2	0.314	0.921	183	0.141	37.6
OMAN-8-2	Rock oyster	1.80	14.0	15.6	0.51	59.5	12.7	0.192	0.575	90.1	0.071	23.4
OMAN-2	Rock oyster	4.84	22.2	17.1	0.73	24.4	8.64	0.202	0.684	437	0.115	168
DOHA-4-1	Pearl oyster	<0.05	24.9	22.6	0.35	2.78	5.68	<0.05	0.269	3.68	0.081	26.1
DOHA-4-2	Pearl oyster	<0.05	23.6	22.6	0.36	3.58	4.55	0.319	0.351	3.98	0.072	30.0
KSA-3	Asiatic clam	2.75	131	27.3	2.67	15.6	0.06	3.08	0.801	8.83	0.403	243
KSA-2	Asiatic clam	6.43	241	47.0	15.2	36.1	5.80	6.25	3.68	333	0.118	279
UAE-7	Rock oyster	3.58	15.0	24.8	0.94	94.9	2.44	0.213	0.467	255	0.071	79.1
UAE-7-1	Rock oyster	0.07	43.5	25.0	3.07	6.65	5.11	1.02	1.32	22.72	0.205	34.3
UAE-7-2	Pearl oyster	7.69	16.0	20.8	40.8	57.6	1.29	0.268	0.696	1069	0.098	39.1

**Table 7** (Contd...)

Sample name	Matrix	Li	Mg	Mn	Ni	Pb	Sb	Se	Sn	U	V	Zn
		$\mu\text{g g}^{-1}$	$\text{mg g}^{-1}$	$\mu\text{g g}^{-1}$	$\mu\text{g g}^{-1}$	$\mu\text{g g}^{-1}$	$\mu\text{g g}^{-1}$	$\mu\text{g g}^{-1}$	$\mu\text{g g}^{-1}$	$\mu\text{g g}^{-1}$	$\mu\text{g g}^{-1}$	$\mu\text{g g}^{-1}$
BAH-5	Pearl oyster	0.545	4.63	11.1	0.440	1.79	<0.05	3.21	0.14	0.139	1.93	1493
BAH-8	Pearl oyster	0.877	6.50	13.2	0.618	0.209	<0.05	3.99	0.52	0.236	4.46	2685
BAH-9	Pearl oyster	0.951	7.10	21.0	1.32	0.172	<0.05	3.30	<0.1	0.183	1.89	2478
IRAN-4	Rock oyster	1.99	4.36	17.1	2.14	0.399	0.338	2.29	<0.1	0.301	0.577	1298
IRAN-2-0	Rock oyster	0.741	5.12	<6	1.46	0.227	0.260	1.83	<0.1	0.300	0.594	700
IRAN-2-2	Rock oyster	0.885	5.93	<6	1.72	0.271	0.146	3.17	0.12	0.245	0.958	3650
IRAN-2-1	Rock oyster	0.722	4.86	<6	1.29	0.500	0.085	2.44	0.19	0.180	0.647	1916
IRAN-2	Rock oyster	1.31	6.67	<6	2.18	0.374	0.29	1.26	0.13	0.068	0.542	1288
OMAN-8	Rock oyster	0.554	3.44	12.6	1.41	0.119	<0.05	1.90	<0.1	0.124	0.382	1393
OMAN-8-1	Rock oyster	0.646	4.61	<6	1.67	0.059	<0.05	1.60	<0.1	0.285	0.425	1005
OMAN-8-2	Rock oyster	0.802	3.09	18.7	2.00	0.235	<0.05	2.36	0.12	0.052	0.432	439
OMAN-2	Rock oyster	0.603	3.40	14.3	2.72	0.198	<0.05	1.71	<0.1	0.171	0.625	1975
DOHA-4-1	Pearl oyster	<0.05	3.82	27.1	<0.25	0.239	<0.05	3.39	<0.1	0.078	0.633	1310
DOHA-4-2	Pearl oyster	0.536	4.40	<6	2.37	0.140	<0.05	4.23	<0.1	0.059	1.01	1373
KSA-3	Asiatic clam	1.48	12.1	121	11.09	15.90	<0.05	3.57	<0.1	0.278	1.79	48.5
KSA-2	Asiatic clam	2.55	17.6	244	24.35	2.83	0.216	6.43	<0.1	0.690	3.36	45.5
UAE-7	Rock oyster	0.785	4.89	<6	1.95	0.146	<0.05	3.36	0.28	0.140	0.712	3484
UAE-7-1	Rock oyster	0.700	5.44	13.6	3.96	0.411	<0.05	4.45	0.37	0.264	4.36	1665
UAE-7-2	Pearl oyster	0.508	3.73	<6	2.05	0.129	<0.05	1.75	0.22	0.103	0.601	3810

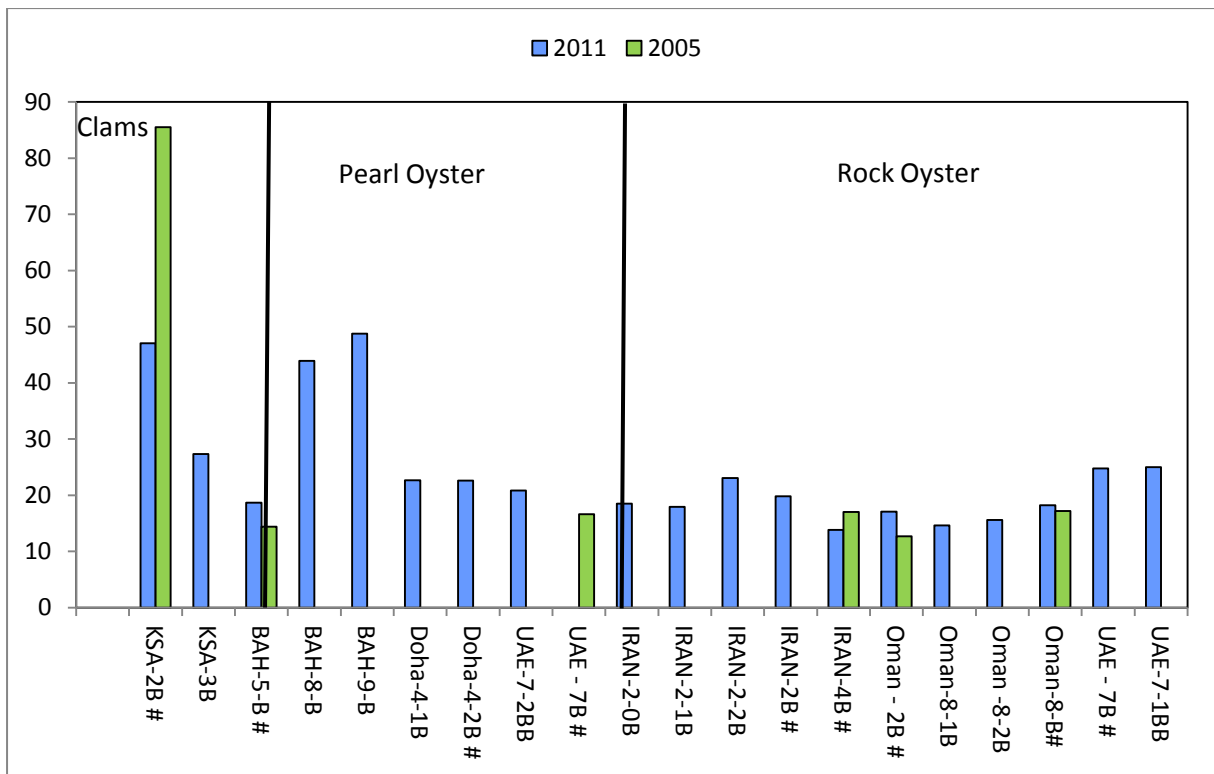


Figure 9. Arsenic concentrations in biological samples

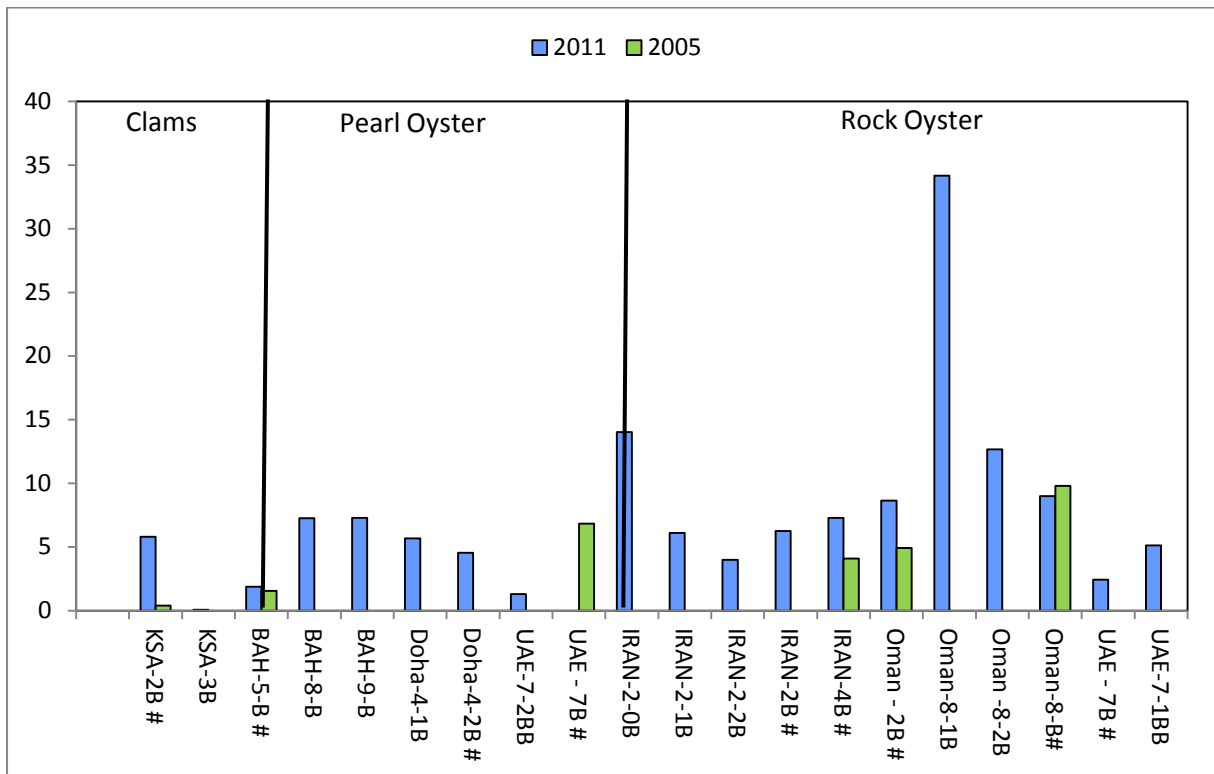
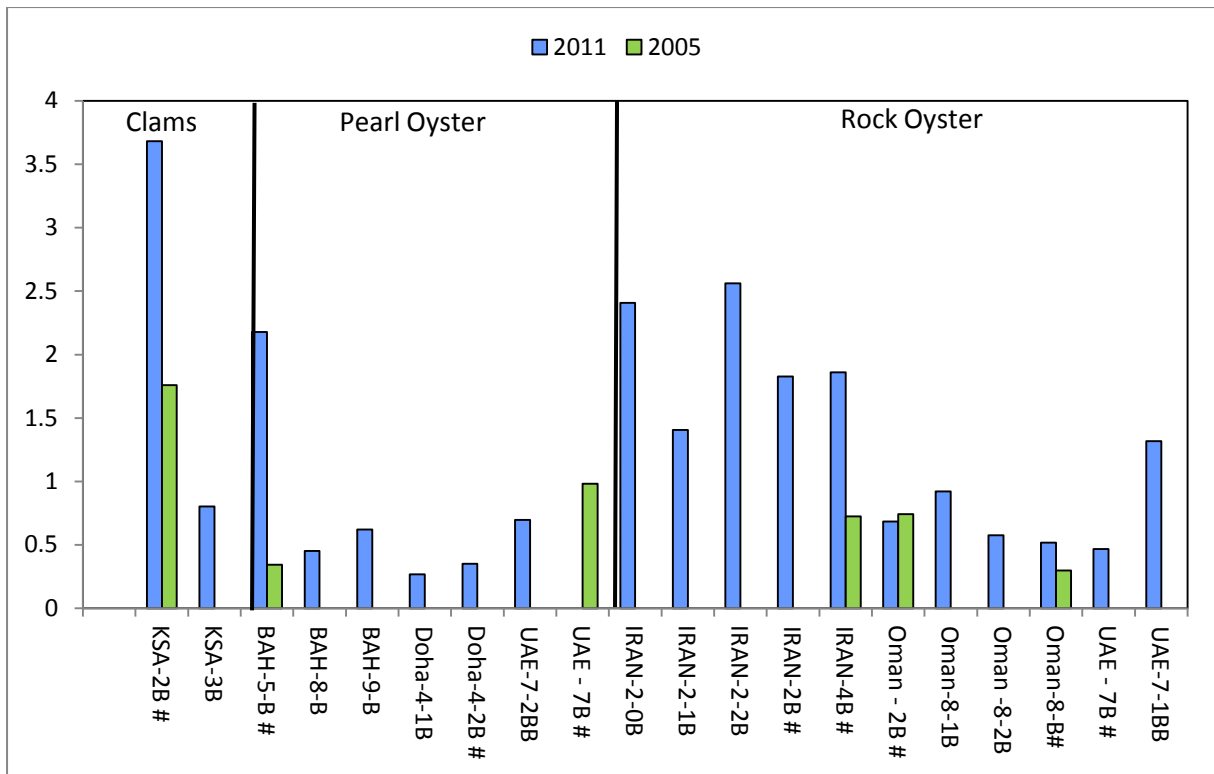
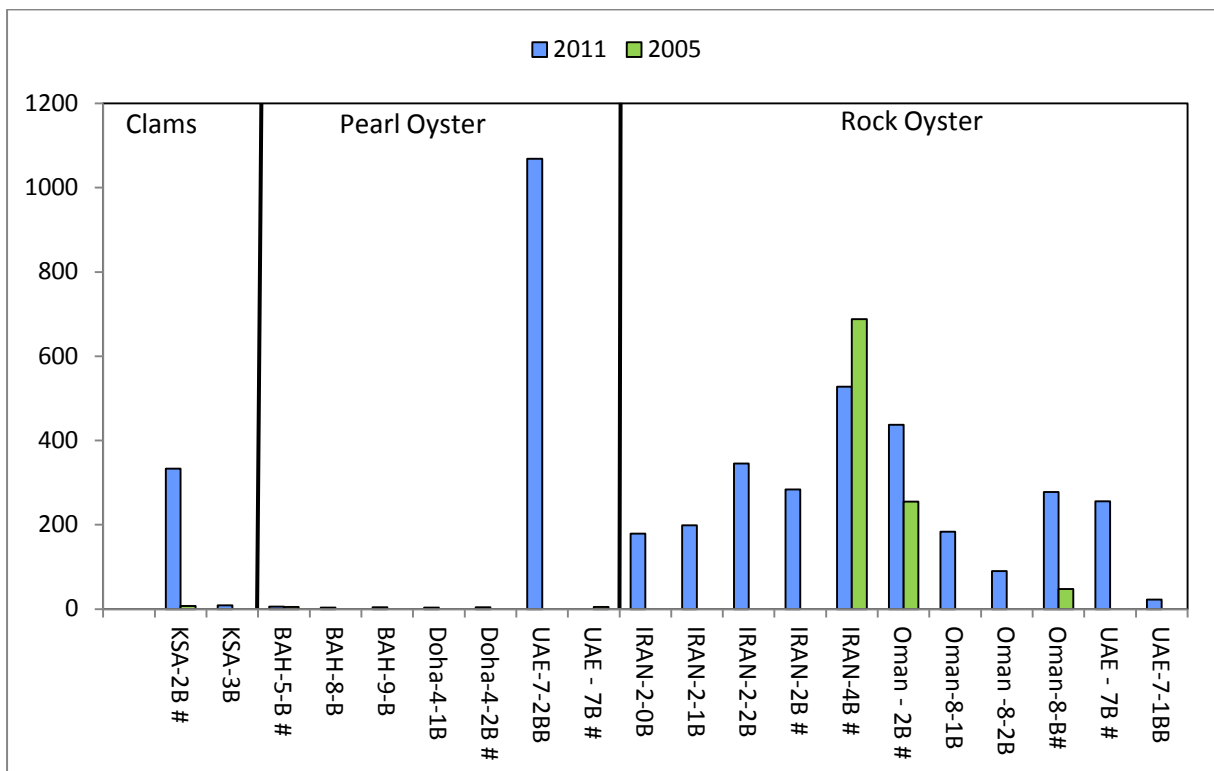


Figure 10. Cadmium concentrations in biota samples

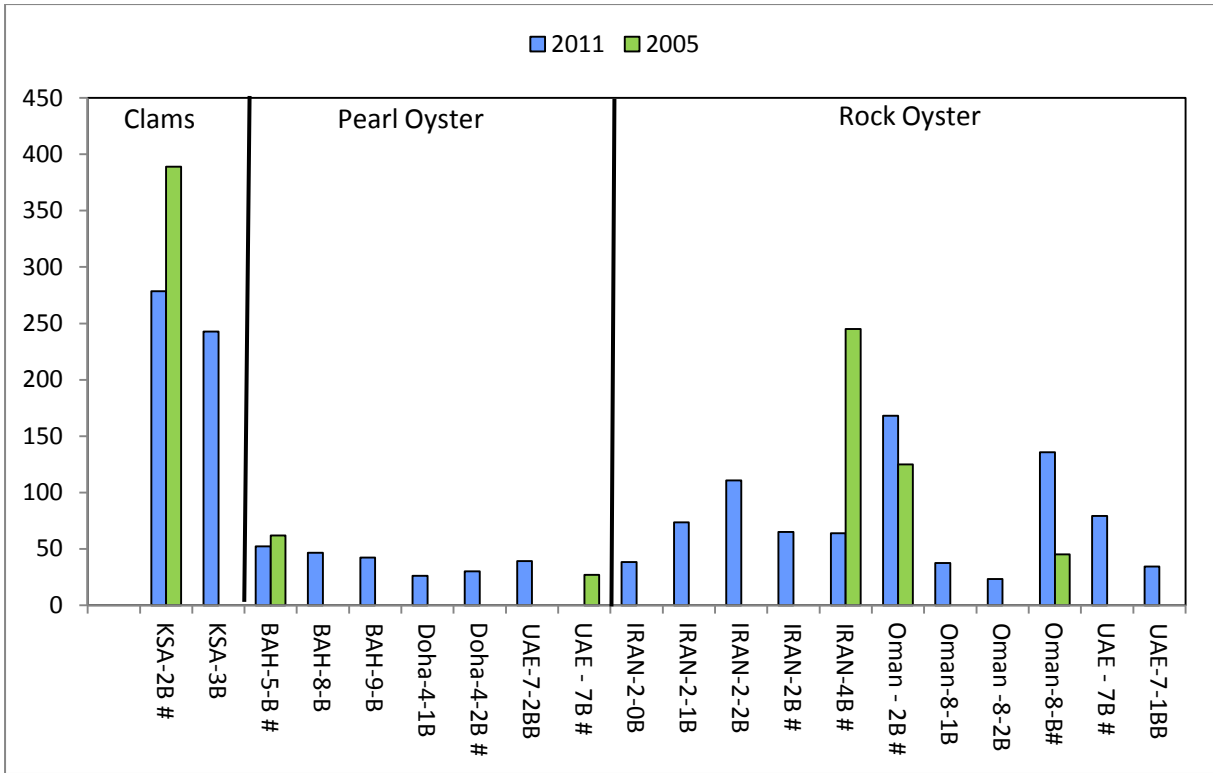




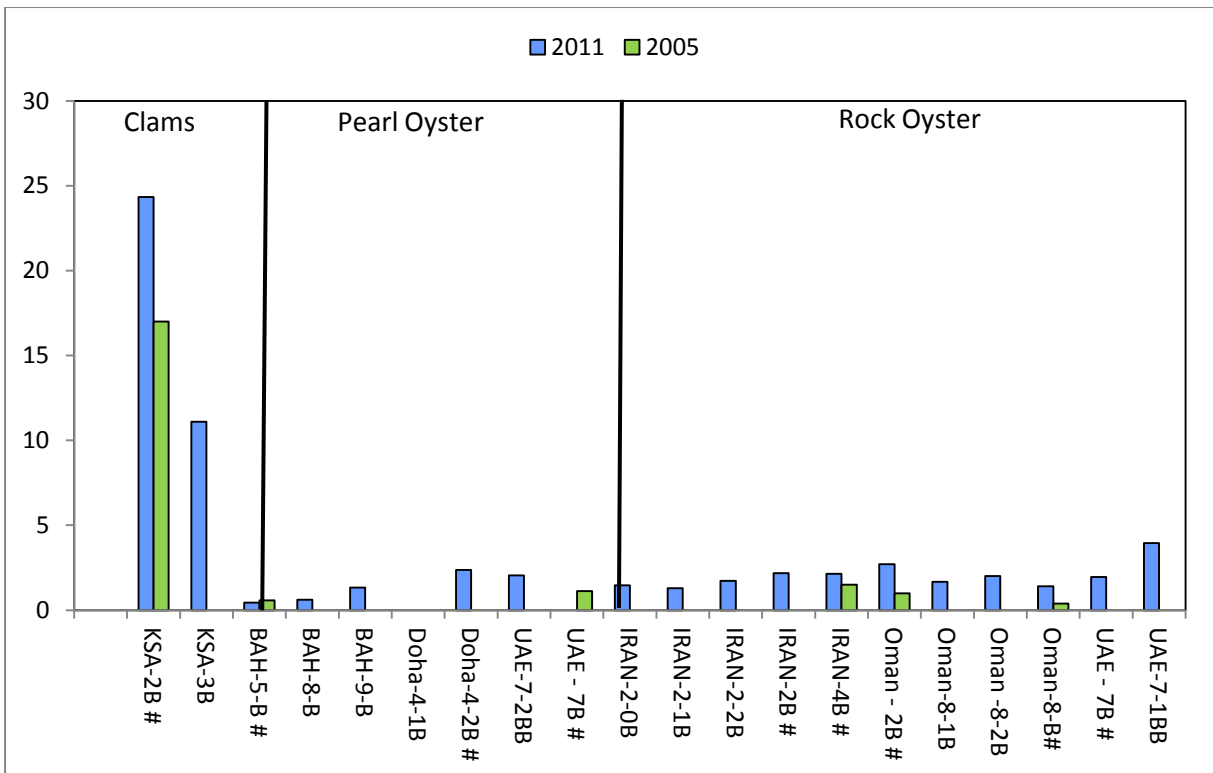
**Figure 11.** Chromium concentrations in biota samples



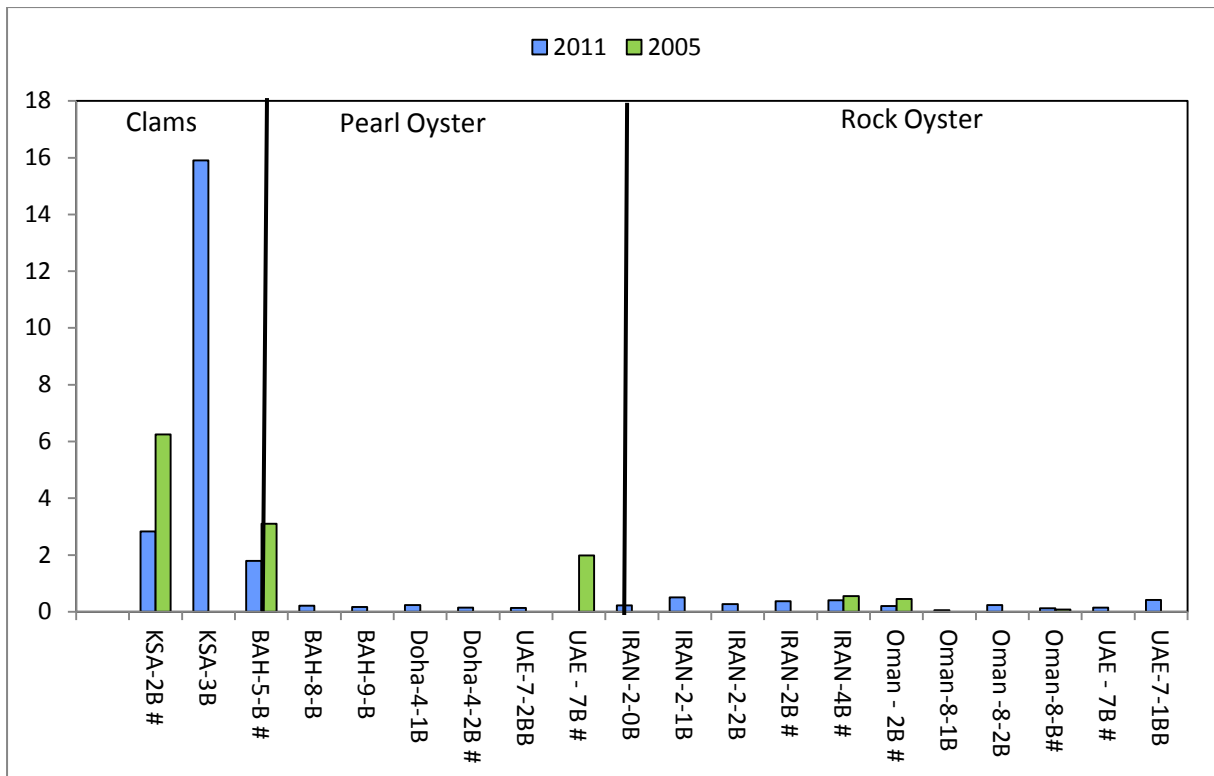
**Figure 12.** Copper concentrations in biota samples



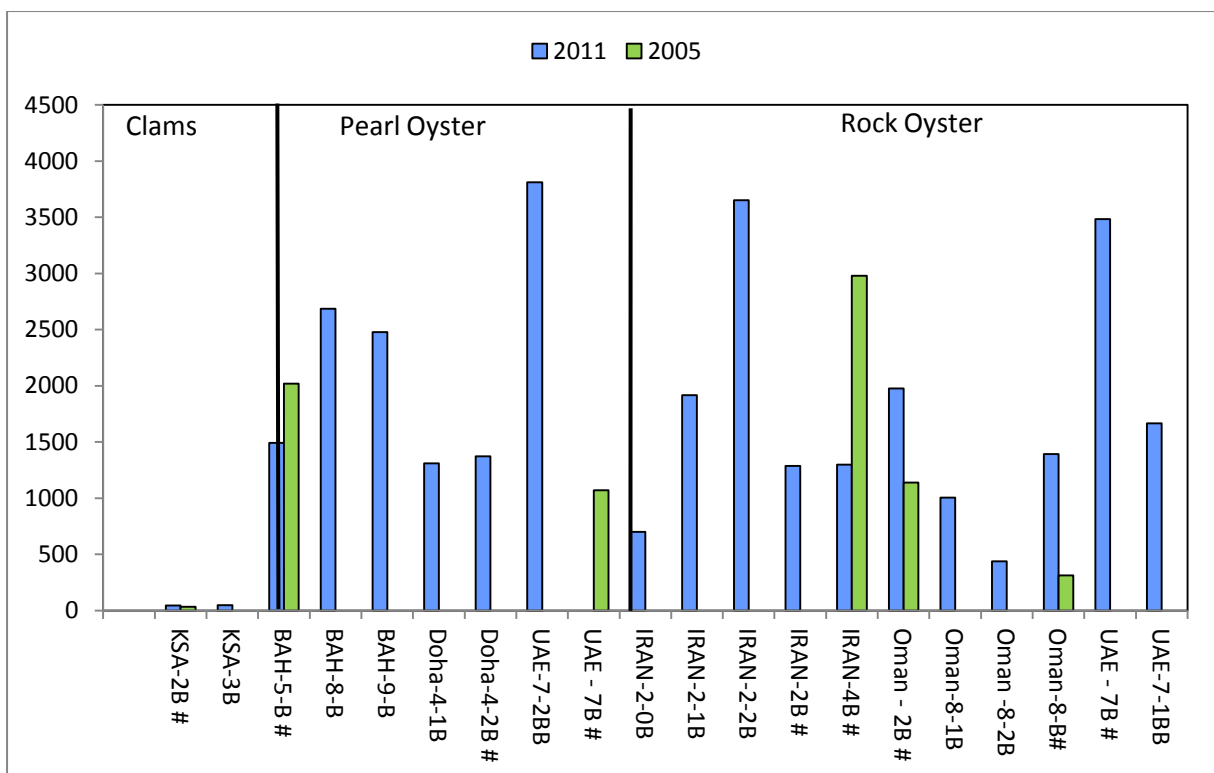
**Figure 13.** Mercury concentrations in biota samples



**Figure 14.** Nickel concentrations in biota samples



**Figure 15.** Lead concentrations in biota samples



**Figure 16.** Zinc concentrations in biota samples

In most of the cases, the interpretation of data must be treated with caution since only a small number of biota samples were analysed, and trace elements' concentrations exhibit natural variation from individual to individual in function of age, season of sampling and sex.

In total, 19 biota samples were analysed, most were Rock or Pearl oysters with the exception of two clams samples collected in Saudi Arabia. It should be noted that different species will naturally have different concentration levels of trace elements. Levels already observed in the Region (for the three species) are reported in Tables 8, 9 and 10, with the ranges observed in this study as well as with the median (except for clams as there were only 2 samples).

A number of the analysed trace elements (e.g. Fe, Cu, Zn and Mn) are considered to be in homeostasis within living systems (i.e. an organism will maintain these elements within an acceptable range, accumulating the metal when levels are depleted and excreting it when the concentration rises too high).

**Essential Trace Metals:** The average values (mg kg<sup>-1</sup>) for essential trace metals and their RSDs bivalves (oyster and clams) were as follows:

Mn: 46.7 (156%);

Fe: 150 (54%);

Cu: 222 (118%);

Zn: 1687 (66%).

**Table 8.** Selected Element Concentration in Pearl Oysters from ROPME Sea Area

Analyte	Reported range (2000) <sup>a</sup>	Reported range (2005) <sup>b</sup>	Reported range (2011) <sup>c</sup>	Median (2011) <sup>c</sup>
As	21.0-45.7	14.4-68	18.6-48.8	22.6
Cd	2.7-10.0	1.56-7.95	1.3-7.3	5.11
Cr	0.29-2.4	0.33-4.83	0.27-2.2	0.535
Cu	3.13-17.3	2.48-5.33	3.7-5.64 (1068)	3.99
Hg	0.009-0.112	0.009-0.085	0.026-0.052	0.04
Ni	0.54-7.02	0.58-6.28	0.44-2.4	1.32
Pb	0.15-3.92	0.275-23	0.128-1.8	0.19
Zn	159-4290	654-2280	1310-3810	1985

Note: <sup>a</sup> ROPME (2001);  
<sup>b</sup> ROPME (2006);  
<sup>c</sup> This study.  
( ) potential "artefact"

**Table 9.** Selected Element Concentration in Rock Oysters from ROPME Sea Area

Analyte	Reported range (2000) <sup>a</sup>	Reported range (2005) <sup>b</sup>	Reported range (2011) <sup>c</sup>	Median (2011) <sup>c</sup>
As	11.1-17.2	8.98-27.2	13.8-25.0	18.21
Cd	6.15-21.9	3.32-26.4	2.43-34.1	7.29
Cr	0.49-3.76	0.297-1.61	0.46-2.6	1.31
Cu	60.9-276	11-688	22.7-528	255
Hg	0.028-0.153	0.025-0.245	0.024-0.168	0.06
Ni	0.796-3.14	0.392-14.7	1.29-3.96	1.95
Pb	0.250-0.673	0.068-0.552	0.06-0.5	0.23
Zn	391-1614	308-2980	439-3650	1392

Note: <sup>a</sup> ROPME (2001);

<sup>b</sup> ROPME (2006);

<sup>c</sup> This study.

**Table 10.** Selected Element Concentration in “Clams” from ROPME Sea Area

Analyte	Reported (2000) <sup>a</sup>	Reported range (2005) <sup>b</sup>	Reported range (2011) <sup>c</sup>
As	156	19.1-119	27.3-47.0
Cd	1.17	0.38-1.72	0.1-5.8
Cr	0.97	0.88-1.76	1-3.7
Cu	8.35	6.98-13.00	8.8-(333)
Hg	0.315	0.11-0.49	0.242-0.278
Ni	23.9	12.8-38.5	11.1-24.4
Pb	1.45	0.81-6.25	3-15.9
Zn	69.1	33.6-76.9	45-48

Note: <sup>a</sup> ROPME(2001), only 1 sample;

<sup>b</sup> ROPME (2006);

<sup>c</sup> This study.

( ) potential “artefact”

Some stations stood out in terms of their relatively elevated levels of trace elements in biota sample; they are analysed below **on a country by country basis**.

#### **4.2.1 Bahrain**

Three samples of oysters were collected along the coast of Bahrain. The levels of As found in Jazirat Ya'suf (BAH-8) and Marwada (BAH-9) were the highest values reported in this study  $\sim 45 \text{ mg kg}^{-1}$ , but are consistent with values reported previously in the Region (ROPME, 2006; ROPME, 2001 and Fowler *et al.*, 1993). Jazirat Ya'suf (BAH-8) appears to have a source of As contamination as the sediment collected on this site also shows high concentration for As.

Askar (BAH-5) showed relatively high level of Pb and Cr. The level of Cr was 3 times higher than the median ( $0.696 \text{ mg kg}^{-1}$ ) and higher than the levels reported for this Region (ROPME, 2006; ROPME, 2001).

The high levels of Pb in biota and sediment were observed at this site already in 2005, (ROPME, 2006). The levels of Pb in oysters observed in 2011 at the station close to BAPCO ( $1.79 \text{ mg kg}^{-1}$ ) were lower than in 2005 ( $3.10 \text{ mg kg}^{-1}$ ), but stayed the highest Pb values for oyster and sediment reported in the present study.

#### **4.2.2 I. R. Iran**

Five rock oysters were collected along the coast of I.R. Iran, and for most measured elements, the values observed were comparable with other rock oysters collected in the RSA during the 2011 campaign. It can be noted that level of Cd in Qeshm (IRAN-2-0) was relatively high (twice the median). Chromium concentrations on all sites were slightly higher if compared to other sites (ranging from  $1.4$  to  $2.6 \text{ mg g}^{-1}$  while the median is  $1.31 \text{ mg kg}^{-1}$ ), which is comparable with results obtained in sediments (all higher than median).

#### **4.2.3 Oman**

Four oysters were collected along the coast of Oman during the 2011 campaign; most of the measured elements were comparable with the previous data observed in the Region. The Cd concentration found in Masirah (OMAN-8-1:  $34.2 \text{ mg kg}^{-1}$ ) was

about twice higher than in any other Oman's sites, and was the highest Cd concentration found in this study. Some high Cd concentrations were already reported in this species, especially in Rasia (OMAN-9) during the 2005 campaign (26.4 mg kg<sup>-1</sup>). It can also be noted that the two highest concentrations found of Hg in oysters were in Masirah and Mina Al-Fahal (OMAN-8 and OMAN-2), but the levels found are still comparable with previous mercury data in the Region (ROPME, 2001; ROPME, 2006).

#### 4.2.4 Qatar

Two pearl oysters were collected on the coast of Qatar in this study. All analyzed elements levels were low (i.e. at the level or lower than the median in this study). No previous data were available for oysters in this area.

#### 4.2.5 Saudi Arabia

Two Asiatic clams were collected along the coast of Saudi Arabia. The concentration observed in general were in good agreement with the previous results obtained for clams (ROPME, 2001; Fowler *et al.*, 1993 and ROPME, 2006). The concentration of Pb in Ras Tanura (KSA-3) (15.9 mg kg<sup>-1</sup>) is about 3 times higher than the concentration reported previously in 2005 for the same Region (6.25 and 3.11 mg kg<sup>-1</sup>). The concentration level for Cu in Ras Mishab (KSA-2) is almost 50 times higher in 2011 than it was in 2005 at the same sampling site (333 mg kg<sup>-1</sup> in 2011 against 7.08 mg kg<sup>-1</sup> in 2005). This result is most probably an artefact linked with sample preparation, as reported level of Cu in this species are in the range of 10 mg kg<sup>-1</sup> (ROPME, 2001; Fowler *et al.*, 1993 and ROPME, 2006).

#### 4.2.6 UAE

The concentration levels for analysed trace elements observed in the 3 oysters collected along the coast of UAE were generally good in comparison with levels observed in 2005 (ROPME, 2006) and earlier (ROPME, 2001; Fowler *et al.*, 1993). As for the clams sample KSA-2, the very high level of Cu observed in Pearl Oyster collected close to Dubai (UAE-7-2) appears to be an artefact; from previous study levels of Cu in pearl oysters are relatively low. This result is most probably an outlier linked with potential contamination during sampling process.

## **5. CONCLUSIONS**

The levels for most of the trace elements observed in oysters and clams are generally in agreement with levels reported in the previous study (ROPME 2001; Fowler *et al.*, 1993 and ROPME, 2006) for the same species. Some relatively high levels were observed for As, Cd and Pb in some stations.

As well, in general the levels observed in sediment compare well with previous study even if few differences could be underlined, particularly for Askar (BAH-5, site close to BAPCO). Sites close to the BAPCO refinery (BAH-4 and BAH-5) show very high level of Pb in sediment collected in 2005, while level for 2011 is below the ERL level. The usual high levels of Cr observed on certain sites (ROPME, 2001) were not present in 2011.

## **6. RECOMMENDATIONS**

Even if most results observed in this study are in good agreement with previous campaign, some more investigation can be done in some site where higher concentrations were found. In order to get a better appreciation of the situation, an extensive and comprehensive sampling campaign could be designed. Only few stations could be compared with previous study, it is important to get enough data to be able to apply some statistical treatment of dataset.

Biological samples should be collected following rigorous standard operating procedures to make sure samples are representative and comparable with respect to species, size, gender, and spawning season. In addition, sampling (of biota and sediment) should be carried out by competent and trained staff; sampling protocols should be followed consistently and rigorously for all the different steps involved including samples dissection, preparation, transport and storage.

Whenever possible sample should be collected in duplicates, in this study two results were considered as “artefact” due to the absence of duplicate confirmation.

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## 8. REFERENCES

- Basaham, A.S. and Al-Lihaibi, S.S., (1993). Trace element in sediment of the western Gulf. *Marine Pollution Bulletin*, **13**:240-247.
- Fowler S.W., Readman J.W., Oregioni B., Villeneuve J.P., McKay K. (1993). Petroleum hydrocarbons and trace metals in nearshore sediments and biota before and after the 1991 War: An assessment of temporal and spatial trends. *Marine Pollution Bulletin*, **27**, 171–182.
- Long, E.R., MacDonald, D.D., Smith, S. L. and Calder. F.D. (1995). Incidence of adverse biological effects within ranges of chemical concentrations in marine and estuarine sediments. *Environmental Management*, **19** (1):81-97.
- MacDonald, D.D., Carr, R.S., Calder, F.D., Long, E.R. and Ingersoll., C.G. (1996). Development and evaluation of sediment quality guidelines for Florida coastal waters. *Ecotoxicology*. **5**:253-278.
- ROPME (1996). ROPME 1994 Contaminant Screening Project. Mission Report by MEL/IAEA. ROPME/GC-8/001. 50 p.
- ROPME (1998). ROPME 1998 Contaminant Screening Project. Mission Report by MEL/IAEA. ROPME/GC-10/4. 53p.
- ROPME (2001). ROPME 2000-2001 Contaminant Screening Project. Mission Report by MEL/IAEA. ROPME/GC-11/001. 77p.
- ROPME (2006). 2005 Contaminant Screening Project. Final Report by MEL/IAEA. ROPME/GC-12/001. 198p.
- ROPME (2010). ROPME Oceanographic Cruise- Winter 2006. Technical Report Series. No.2; Contaminants in the Marine Sediments. ROPME/GC-14/7. 139 p.



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