

ROPME MUSSEL WATCH PROGRAMME 2011



Technical Report: No.3

ORGANOTIN COMPOUNDS SCREENING

Prepared by:

MESL/IAEA
Monaco, January 2013

For:



REGIONAL ORGANIZATION FOR THE PROTECTION OF THE MARINE ENVIRONMENT



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1. INTRODUCTION

Organic tin compounds are used worldwide as antifouling agents in ship's hull and in other submerged parts of coastal constructions (walls, cooling pipelines, etc.). Since about five decades, the potentially toxic Tributyltin (TBT) has been used in paints as an effective biocide chemical against fouling phenomena in the marine environment.

The primary source of TBT release is leaching from ship's hull paints and from related activities such as docking, dumping of dredged materials, etc. In addition, other sources include industrial discharges from production/ formulation of organic tin compounds and atmospheric deposition of organic tin compounds. Although some sources of TBT could be identified, no quantitative estimate regarding TBT release are available in RSA.

The surveys of TBTs in the marine environment of the RSA have been conducted within the framework of the ROPME-IAEA Contaminant Screening Project (1994-2005) in which the levels of organotin compounds have been analyzed in nearshore sediments and biota from four Member States of Bahrain, Qatar, UAE and Oman during 2000-2001. The obtained data show the presence of these compounds in noticeable amounts in the marine sediments of certain locations, especially near Jebel Ali Port Complex in UAE, Umm Said and Dukhan in Qatar, and off BAPCO in Bahrain. The concentrations of these compounds in most fish samples were generally very low with the presence of organotin derivatives in some fish species from Badaiya (Bahrain), Umm Said, Al Khawr and Doha (Qatar) and Quriyat (Oman). The levels were much higher in bivalves with the dominance of TBT derivatives in oysters from Abu Dhabi and off BAPCO in Bahrain, indicating the possibility of fresh input of TBT near these locations.

Although the usage of TBT has been banned since about three decades ago, the risk of its introduction to the marine environment of RSA from different sources is still of particular concern. To this effect, ROPME has extended the monitoring of organotin compounds in the entire ROPME Sea Area within the framework of Mussel Watch Programme.

The present report summarizes the results of the detected levels of TBT and its derivatives in the offshore sediment samples collected during the ROPME Oceanographic Cruise – Winter 2006 and in sediment and biota samples collected nearshore in early 2011.

2. SAMPLING METHODOLOGY

This report concerns the analyses of organotin compounds in offshore sediment samples collected during the ROPME Oceanographic Cruise in February - March 2006 and in sediment and biota samples collected in February and March 2011 as part of the ROPME Mussel Watch Programme, along the coasts of Bahrain, I.R. Iran, Kuwait, Oman, Qatar, Saudi Arabia and United Arab Emirates (UAE). The sampling stations, locations and the types of samples collected are given in Tables 1, 2 and 3, and presented in Maps 1 and 2.

Table 1. Offshore Sediment sampling sites in the ROPME Sea Area (February-March 2006)

Station	Date	Depth (m)	Latitude	Longitude
ST-01	9/3/2006	13	29° 21.000'	48° 29.000'
ST-25	3/3/2006	67	27° 18.290'	50° 58.400'
ST-51	22/2/2006	60	25° 48.625'	53° 05.650'
ST-58	21/2/2006	75	25° 53.289'	53° 52.585'
ST-07	08/3/2006	13	29°52.106'	49°52.049'
ST-05a	6/3/2006	21	28° 08.501'	49° 05.508'
ST-09a	6/3/2006	48	28° 51.200'	50° 24.200'
ST-10a	2/3/2006	26	26° 59.800'	50° 23.700'
ST-33	01/3/2006	14	26°21.800'	50°45.500'
ST-27	01/3/2006	54	27° 29.200'	51° 57.000'
ST-34	28/2/2006	14	26° 02.500'	51° 31.200'
ST-49	22/2/2006	42	25° 26.090'	52° 54.000'
ST-66	15/2/2006	42	25° 31.090'	54° 37.156'
ST-70	14/2/2006	44	26° 32.104'	54° 57.957'
ST-16a	9/2/2006	30	27° 01.400'	56° 39.300'
ST-93	5/2/2006	67	24° 33.147'	56° 50.739'
ST-98	3/2/2006	50	25° 26.801'	58° 36.914'
ST-26a	2/2/2006	53	23° 31.000'	58° 46.100'

Table 2. Sediment sampling sites in the ROPME Sea Area (February-March 2011)

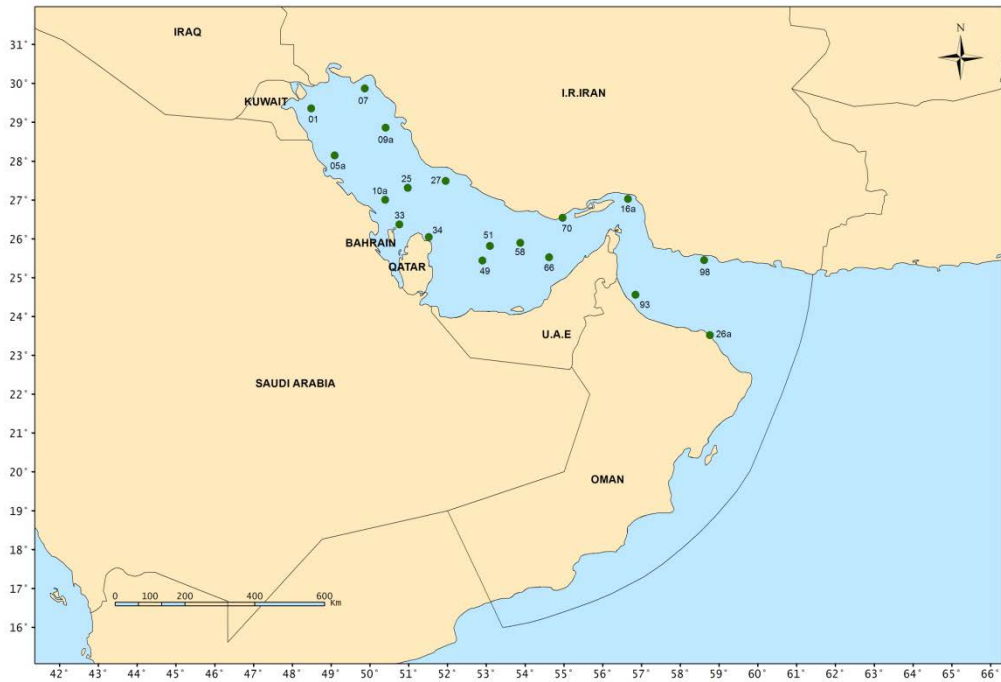
Code	Date	Location	Coordinates	
BAH-5	2/2011	Askar	26° 03.105'	50° 37.805'
IRAN-4	2/2011	Lenge Port	26 31'360N	54 49'742E
IRAN-2	2/2011	Bushehr (Rostami port)	28 50' 063N	50 52' 507E
KUW-5	3/2011	Doha	missed	
OMAN-8	3/2011	Mirbat	17°00'N	54°40'E
OMAN-2	3/2011	Mina Al-Fahal	23°37'N	58°33'E
DOHA-4-2	3/2011	Ras Laffan	25°53'N	51°36'E
KSA-3	3/2011	Ras Tanura	26 41' 092 N	50 04' 083E
KSA-2	3/2011	Ras Mishab	28° 11.269'N	48°37 .846'E
UAE-7-1-2	2/2011	Dubai	25 16 915	55 17 520
UAE-7-1-1	2/2011	Dubai	25 17 37.4	55 16 37.3

Table 3. Bivalve sampling sites in the ROPME Sea Area (February-March 2011)

Code	Date	Location	Sample description	Coordinates	
BAH-5	2/2011	Askar	Pearl oyster	26° 03.105'	50° 37.805'
IRAN-4	2/2011	Lenge Port	Rock oyster	26 31'360N	54 49'742E
IRAN-2	2/2011	Bushehr (Rostami port)	Rock oyster	28 50' 063N	50 52' 507E
OMAN-8	3/2011	Mirbat	Rock oyster	17°00'N	54°40'E
OMAN-2	3/2011	Mina Al-Fahal	Rock oyster	23°37'N	58°33'E
DOHA-4-2	3/2011	Ras Laffan	Pearl oyster	25°53'N	51°36'E
KSA-3	3/2011	Ras Tanura	Asiatic clam	26 41' 092 N	50 04' 083E
KSA-2	3/2011	Ras Mishab	Asiatic clam	28° 11.269'N	48°37 .846'E
UAE-7-1-2	2/2011	Dubai	Pearl oyster	25 16 915	55 17 520
UAE-7-1-1	2/2011	Dubai	Rock oyster	25 17 37.4	55 16 37.3



Map 1: Mussel Watch Sampling Stations in RSA



Map 2: Offshore Sediment Sampling Stations 2006

3. ANALYTICAL PROCEDURES

The analytical protocol for measuring organotin compounds are detailed in the following:

3.1 SEDIMENT SAMPLES

Deuterated surrogates (Mono-n-butyl trichloride-D9 and Tributyltin-chloride-D27) were added to 3 to 5 g of freeze-dried sediment samples. The slurry was leached by shaking with acetic acid, centrifuged and filtered. Using buffer and ammonia, the pH was stabilized between 5 and 6. The organotin compounds were simultaneously derivatized and extracted using sodium tetraethylborate (NaBEt₄) and n-hexane. Elemental Hg was used to eliminate sulfur, and Florisil cartridges were used to clean up the samples. The purified samples were concentrated to about 0.5 ml (prior a solvent change from n-hexane to isooctane) and injected into a gas chromatograph mass spectrometer (GC-MS). The samples were quantified using a calibration curve made out of ethyl derivatives target compounds and deuterated ethyl derivatives surrogates (Mono-n-butyl triethyltin-D9, Ethyltributyltin-D27). Tetra-n-propyltin-D7 was used as an internal standard to quantify recoveries of surrogates.

Appropriate blanks were analyzed with each set of analyses and in addition, reference materials NRC PACS2 and SOPH-1 (marine sediments), containing certified concentrations of organotin compounds were analyzed simultaneously along with each analytical batch.

3.1.1 Total organic carbon and carbonates

The contents of total carbon (TC) and total organic carbon (TOC) were determined by using a CHN analyzer (Carlo Erba model 1602). Approximately 10–40 mg of dry sediment was encapsulated into a tin foil cup and introduced into a combustion furnace. Organic carbon was determined after treating the samples with concentrated H₃PO₄ to remove inorganic carbon. Concentration of total organic carbon is expressed as the percentage of the total dry weight. Carbonate content was calculated by subtracting the TOC from the TC content. The quality control was realized by measuring TC and TOC levels in a Certified Reference Material (SMR 1941b) providing information value for TC (3.3%) and reference value for TOC (2.99% ±0.24). The measured mean value obtained for TC was 3.18% ±0.02 (n=4) and 2.37% ±0.24 (n=10) for TOC.

3.1.2 Grain size

3.1.2.1 Preparation of samples

The samples were sieved at 300 μm . Most of the samples have very small material below 300 μm ; the sample DOHA-4-1 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 10 ml tube. 5 ml of MilliQ water was added and tube was shaken in order to separate the silt particles properly. An equilibration period of about half an hour was used to assure that the sample was uniformly wet before analysis.

3.1.2.2 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.

3.1.2.3 Apparatus used

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

3.1.2.4 Protocol used

The analysis of 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.

3.1.2.5 Results of grain size analysis

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

% Sand = \sum percentage of particulates between 300 μm and 63 μm

% Silts = \sum percentage of particulates between 63 μm and 3.9 μm

% Clay = \sum percentage of particulates below 3.9 μm

% Mud = \sum % Clay and % Silt

3.2 BIOTA SAMPLES

The deuterated surrogates (Mono-n-butyl trichloride-D9 and Tributyltin-chloride-D27) were added to 0.5 g of freeze-dried biological samples. The slurry was dissolved (alkaline digestion) by sonication in an ultrasonic bath with tetra methyl ammonium hydroxide, TMAH (25% solution in water). Using buffer and acetic acid, the pH was stabilized between 5 and 6. The organotin compounds were simultaneously derivatized and extracted using sodium tetraethylborate (NaBEt₄) and n-hexane. Florisil cartridges were used to clean up the samples. The purified samples were concentrated to about 0.5 ml (prior a solvent exchange from n-hexane to isooctane) and injected into a gas chromatograph mass spectrometer (GC-MS). Samples were quantified using a calibration curve made out of ethyl derivatives target compounds and deuterated ethyl derivatives surrogates (Mono-n-butyl triethyltin-D9 and Ethyltributyltin-D27). Tetra-n-propyltin-D7 was used as an internal standard to quantify recoveries of surrogates.

The appropriate blanks were analyzed with each set of analyses and in addition, the reference material ERM-CE477 (mussel tissue), containing certified concentrations of organotin compounds, was analyzed simultaneously along with each analytical batch.

GC-MS conditions used were as follows:

Gas Chromatograph	Agilent 6890 N
Detector	MSD 5975
Injection mode	Splitless
Carrier gas	Helium 2.7 ml min ⁻¹
Column	DB-XLBMSD 30 m x 0.25 mm i.d. x 0.25 μm film thickness
Injection specifications	inj. press.: 13 psi, Constant flow on 13 psi at 60°C, Temp. injector 270°C
Transfer line	280°C
Ion source	240°C
Analyser	100°C
Oven temperature program	60°C initial, 60°C to 120°C at 10°C min ⁻¹ , 120°C to 310°C at 4°C min ⁻¹

The organotin compounds were analyzed using selective ion monitoring (SIM) to enhance sensitivity. Details of the acquisition are provided in the Table 4.

Table 4. Selected masses for the Analysis of Ethylated Organotin in GC-MS-SIM

Group	Time (min)	Compounds (m/z monitored) ^a	Cycles (s ⁻¹)	Ions (m/z)
1	6-9	MBT-D9 (121, 179, 180, <u>244</u>) MBT (121, <u>179</u> , 235)	3.65	179, 235, 121, 180, 244
2	9-12	TePrT-D27 (207, 121, 214, <u>256</u>) DBT (121, <u>207</u> , 235, 263)	3.07	121, 235, 263, 207, 214, 256
3	12-15	TBT-D27 (121, 318, <u>217</u>) TBT (235, 121, <u>263</u> , 291)	1.72	121, 318, 217, 235, 263, 291

Note: ^a m/z used for quantification are underlined

4. RESULTS AND DISCUSSION

4.1 ORGANOTIN COMPOUNDS

4.1.1 Sediment samples

The concentrations of butyltins (BTs) compounds in sediments collected during the ROPME Oceanographic Cruise in February-March 2006 and sediments collected in the February-March 2011 period (as part of the Mussel Watch Programme, along the coasts of Bahrain, I.R. Iran, Kuwait, Oman, Qatar, Saudi Arabia and UAE) are reported in Table 5 and Table 6, respectively.

The concentration of butyltins were very low in most sediments collected along the ROPME Sea Area and in many cases can only be reported as <0.5 ng g⁻¹ as Sn.

Among 18 sediments analyzed from the ROPME Oceanographic Cruise – Winter 2006, only Station 51 presented measurable concentrations of butyltins (Σ BTs of 3.4ng g⁻¹ as Sn) (Figure 1).

Table 5. Total Organic Carbon, Carbonate Content, Percentage of Fine Particles (<63um) and Organotin Compounds concentrations in Sediment samples (ng g⁻¹ as Sn) collected in ROPME Oceanographic Cruise – Winter 2006

Station	TOC (%)	Carbonates (%)	<63um (%)	MBT	DBT	TBT	∑ Butyltins
ST-07	0.54	6	68	<0.2	<0.1	<0.2	<0.5
ST-05a	0.82	7.97	54	<0.2	<0.1	<0.2	<0.5
ST-09a	0.62	6.85	48	<0.2	<0.1	<0.2	<0.5
ST-10a	0.99	10.12	15	<0.2	<0.1	<0.2	<0.5
ST-33	0.86	9.64	21	<0.2	<0.1	<0.2	<0.5
ST-27	0.72	7.52	25	<0.2	<0.1	<0.2	<0.5
ST-34	0.83	10.5	6.4	<0.2	<0.1	<0.2	<0.5
ST-49	0.57	10.55	16	<0.2	<0.1	<0.2	<0.5
ST-66	1.17	9.74	32	<0.2	<0.1	<0.2	<0.5
ST-70	1.1	4.88	34	<0.2	<0.1	<0.2	<0.5
ST-16a	0.6	2.45	72	<0.2	<0.1	<0.2	<0.5
ST-93	0.44	9.27	29	<0.2	<0.1	<0.2	<0.5
ST-98	0.85	1.35	47	<0.2	<0.1	<0.2	<0.5
ST-26a	0.53	8.47	11	<0.2	<0.1	<0.2	<0.5
ST-01	0.51	5.12	66	<0.2	<0.1	<0.2	<0.5
ST-25	0.85	6.37	54	<0.2	<0.1	<0.2	<0.5
ST-51	1.27	7.54	34	2	0.7	0.7	3.4
ST-58	1.38	7.27	30	<0.2	<0.2	<0.3	<0.7

Table 6. Total Organic Carbon, Carbonate Content, Percentage of Fine Particles (<63um) and Organotin Compounds concentrations in Sediment samples (ng g⁻¹ as Sn) collected in 2011 (Mussel Watch Project)

Station	TOC (%)	Carbonates (%)	<63um (%)	MBT	DBT	TBT	∑ Butyltins
BAH-5	1.50	9.70	12	<0.2	<0.2	<0.3	<0.7
IRAN-4	0.50	7.40	11	<0.2	<0.2	<0.3	<0.7
IRAN-2	0.37	9.63	1.0	16	5.7	2.5	24
KUW-5	0.54	8.06	30	<0.2	<0.2	<0.3	<0.7
OMAN-8	0.15	8.55	0.0	<0.2	<0.2	<0.3	<0.7
OMAN-2	0.16	6.14	0.0	<0.2	<0.2	<0.3	<0.7
DOHA-4-2	0.18	11.52	8.1	<0.2	<0.2	<0.3	<0.7
KSA-3	1.18	9.32	23	<0.2	<0.2	<0.3	<0.7
KSA-2	1.13	6.87	26	<0.2	<0.2	<0.3	<0.7
UAE-7-1	1.10	7.20	33	10	4.3	2.2	17
UAE-7-2	1.30	9.00	1.4	3.7	0.4	0.4	4.5

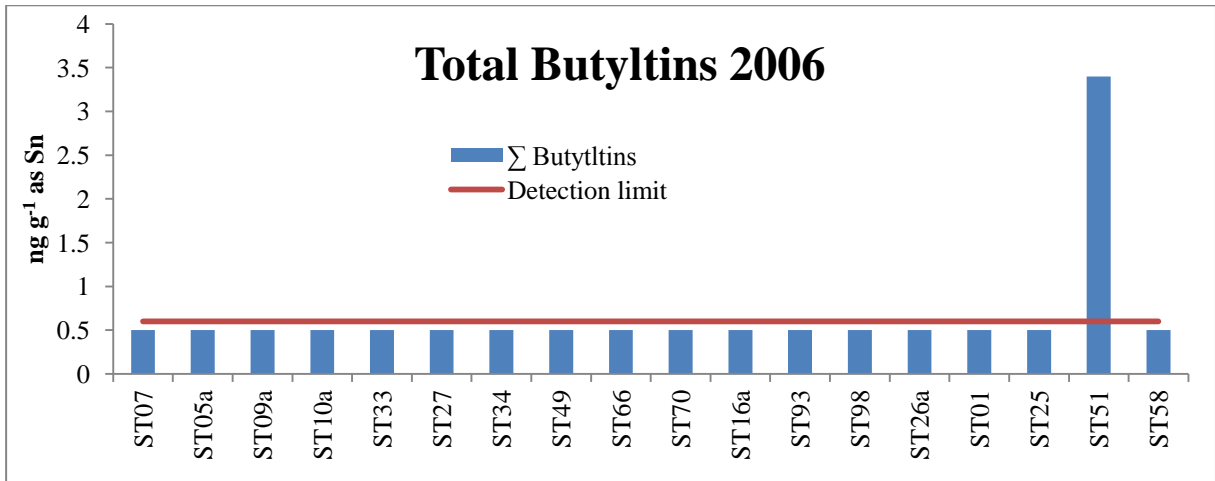


Figure 1. Total butyltins in sediments samples collected in ROPME Oceanographic Cruise – Winter 2006

As far as the 2011 Mussel Watch Project is concerned, Rostami port in I.R. Iran (IRAN-2) and samples collected in Dubai (UAE-7-1 and UAE-7-2) presented concentrations of butyltins of 24, 17, and 4.5 ng g⁻¹ as Sn, respectively (See Figure 2) while samples from the other locations were found to be below detection limit.

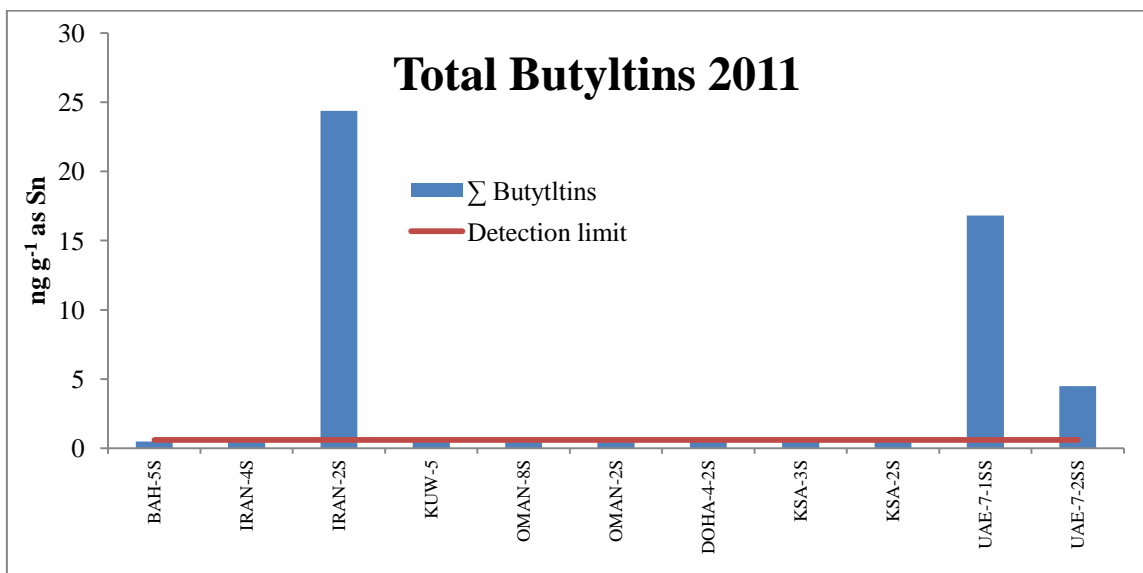


Figure 2. Total butyltins in sediments samples collected in 2011 (Mussel Watch Project)

The station 51, Rostami port (IRAN-2) and sample UAE-7-1 (Dubai) were the only sediments that could be considered contaminated with respect to TBT (i.e. TBT > 1.3

ng g⁻¹ as Sn) according to the classification scheme of Dowson *et al.* (1993). Taking in consideration the distribution of butyltin species within these samples (Figure 3) and the fact that TBT degrades only slowly in marine sediments (Stewart and de Mora, 1990) the high relative percentage of MBT in all sites indicates that there has been a little recent input of TBT into the marine environment of these locations.

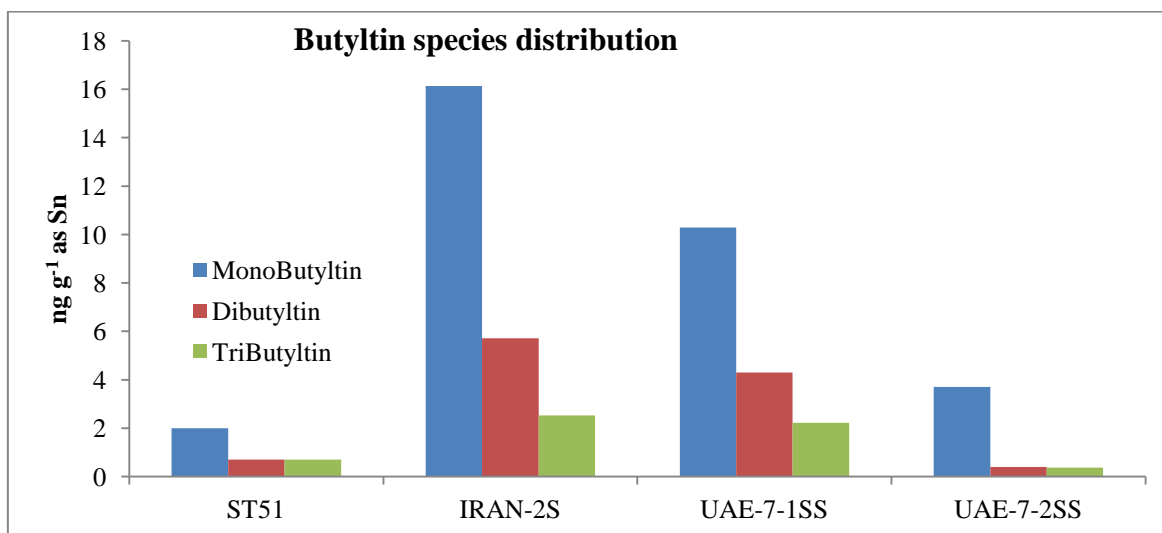


Figure 3. Butyltin species distribution in selected sediment samples

Previous studies (de Mora *et al.*, 2003) reported very similar concentrations of butyltins in sediments collected along the coasts of Oman, Bahrain and UAE in 2000 and 2001. Most of the samples presented concentrations of butyltins below detection limit with the exception of a few samples collected close to an industrial complex in Bahrain (BAPCO), and in Oman (Hilf) close to a ferry terminal for small vessels, with measured concentrations of total BTs of 80 and 72 ng g⁻¹ as Sn, respectively.

4.1.2 Biota

The concentrations of BTs in bivalves collected in February and March 2011 as part of the Mussel Watch Project along the coasts of Bahrain, Iran, Oman, Qatar, Saudi Arabia and UAE are reported in Table 7.

Table 7. Concentrations of Lipids (mg g^{-1}) and Organotin Compounds in Biota samples (ng g^{-1} as Sn)

Sample name	Lipids	MBT	DBT	TBT	Σ Butyltins
BAH-5	39	12	7.3	28	47
IRAN-4	67	<1.9	<1.9	<3.2	<7
IRAN-2	44	41	7.6	9.5	58
OMAN-8	74	<1.9	<1.9	<3.2	<7
OMAN-2	62	<1.9	<1.9	<3.2	<7
DOHA-4-2	32	<1.9	<1.9	<3.2	<7
KSA-3	45	<1.9	<1.9	<3.2	<7
KSA-2	32	36	<1.9	<3.2	36
UAE-7-1	63	150	44	152	346
UAE-7-2	36	59	19	68	146

Only half of the samples analyzed presented measurable concentrations of butyltins with Σ BTs of 36 ng g^{-1} as Sn in sample KSA-2; 47 ng g^{-1} as Sn in BAH-5; 58 ng g^{-1} as Sn in IRAN-2; 146 in UAE-7-2 and 346 ng g^{-1} as Sn in UAE-7-1, as represented in Figure 4.

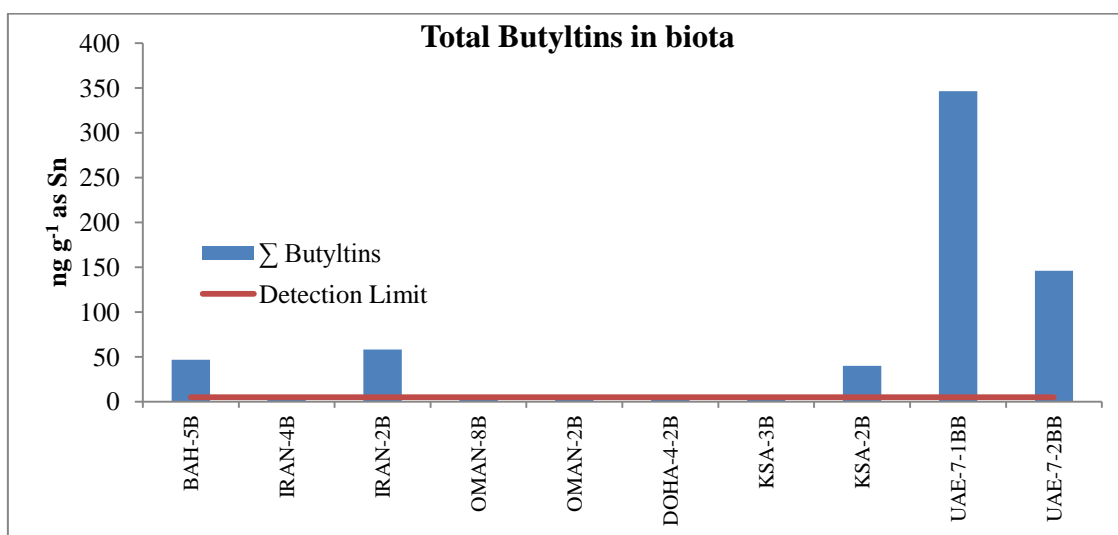


Figure 4. Total butyltins in biota samples

Figure 5 shows the distribution of the BTs species in samples that presented measurable concentrations.

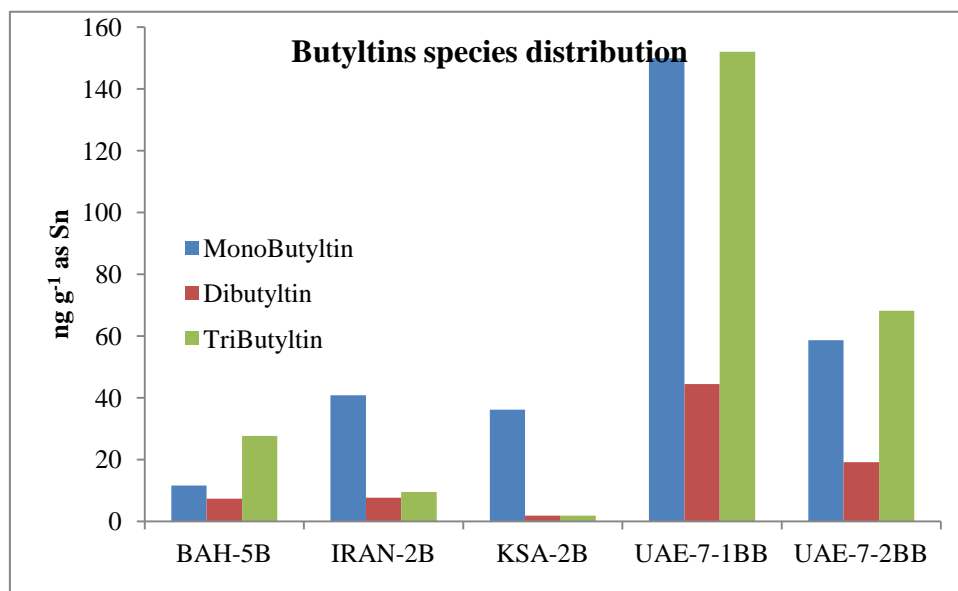


Figure 5. Butyltin species distribution in selected biota samples

Once released in the environment, butyltins are subjected to both biotic and photochemical debutylation from parent compounds (TBT) to their degradation products (DBT and MBT). Whereas in the water column microbial degradation and photolysis are the main debutylation processes, only anaerobic biodegradation can occur in sediments (Amouroux *et al.*, 2000). The degradation of TBT in water takes place within days to weeks (Stewart and de Mora, 1990), while the half-life was estimated to be about 2 years in the sediments underlying a seawater marina (de Mora *et al.*, 1989).

Mussels are filter feeders organisms exposed to pollutants coming from the water (either dissolved or adsorbed on fine particles) and pollutants re-suspended from the surrounding sediments. Looking at the ratio between TBT and its main metabolites DBT and MBT, it appears evident that for KSA-2 and IRAN-2 the source of pollution seems to be “old”, if only for the fact that most of the TBT had already been metabolized to MBT. Since the half-life of TBT in water is rather short, this could

indicate that the source of pollution could be re-suspension from the surrounding sediments.

On the contrary, for the sediment belonging to UAE-7-1, UAE-7-1 and BAH-5 the ratio between TBT and DBT+MBT strongly suggests an exposure to contaminated seawater and thus, a relatively fresh input of TBT in the environment.

ROPME (2001) reported very similar concentrations of butyltins in bivalves collected along the coasts of Oman, Bahrain and UAE in 2000 and 2001 with concentrations of total BTs ranging from $<4 \text{ ng g}^{-1}$ as Sn to almost 500 ng g^{-1} as Sn for the most contaminated sites (Pearl oysters in Abu Dhabi). Considering the range of butyltin concentrations in oysters from a variety of coastal sites in various regions of the world (Alzieu, 1996), the levels of BTs in bivalves from the RSA generally fall in the lower end of the range of typical concentrations.

In 2004, the OSPAR commission (OSPAR, 2004, Furdek *et al.*, 2012) updated the Ecotoxicological Assessment Criteria (EAC) values for TBT in water, sediments and biota, according to the most recent knowledge on the TBT concentrations that could cause possible adverse effects in mollusk populations. The lower EAC value is the concentration needed for the protection of all marine species from chronic effects, including the most sensitive species, whereas the upper EAC value is defined as the highest concentration expected not to cause acute toxic effects. Between the lower and the upper EAC values, biological effects are possible (e.g. biomarker response, reproduction, impaired growth), whereas above the upper EAC value, long-term biological effects are likely, and acute biological effects on the survival of the population are possible. The OSPAR commission proposed for TBT in mussels a lower EAC value of 4.91 ng g^{-1} as Sn and an upper EAC value of 71.7 ng g^{-1} as Sn (OSPAR, 2004).

Half of the biological samples analyzed in this study were found to be below detection limit ($\text{TBT} < 3.2 \text{ ng g}^{-1}$ as Sn) and thus below EAC lower value. TBT concentrations found in bivalves from Bahrain and I.R. Iran relate to an intermediate EAC value meaning that biological effects are likely to take place. UAE-7-2 was close to the upper EAC level and UAE-7-1 exceeded the EAC upper level suggesting that for these two samples, long-term biological effects are likely and acute biological effects on the survival of the population are possible.

5. CONCLUSIONS

Based on the results of the organotin compounds screening project it is clear that there is no overall organotin contamination problem in the RSA region. However, the results indicate issues of concern needing further investigation.

In the sediment samples, concentrations of total butyltins ranging from below detection limits up to 24 ng g⁻¹ as Sn are relatively low when compared to European coastal sediments in which levels of 1000 to over 12000 ng g⁻¹ as Sn are commonly found especially in ports and marinas (Cassi *et al.*, 2008). Within the ROPME region, based on the samples analyzed, it seems that only the sediments near Dubai (UAE-7-1 and UAE-7-2) and IRAN-2S show evidence of an older TBT contamination, which is not very important. However these results indicate that these areas may require a more detailed investigation.

Only half of the biological samples analyzed presented measurable concentrations of butyltins, the other samples being below the detection limit of the analytical method used. Therefore no major TBT contamination was documented in the samples analyzed. The highest BT concentrations in biota were found close to Dubai (UAE), where relatively enhanced BT concentrations in the sediments were also found. The ratios between TBT and its main metabolites DBT and MBT suggest that while sediments samples seems to be affected by an “old” contamination, some bivalves seems to have been exposed to fresh inputs of TBT in the marine environment. Although the BT concentrations in the bivalves of the two Dubai stations appear not to pose immediate public health concerns according to available information (Benson, 1997; Penninks, 1993; World Health Organization, 1990), they exceed the OSPAR Environmental Assessment Criteria for long term biological effects. Although these criteria were developed for the North Atlantic region and consequently have to be used with caution in marine areas with different environmental conditions, this is an issue that needs further investigation.

6. RECOMMENDATIONS

The present organotin compounds screening in the RSA revealed very useful information on the state of organotin contamination in the RSA, as well as on the necessary priorities for the next steps.

In order to assess the extent of a potential environmental concern due to organotin compounds, it is necessary to continue the screening project by concentrating effort and resources on locations that showed relatively higher BT concentrations, as well as on additional possible hot spots (ports, marinas, coastal cities) as well as areas of public health concern (fish farms) along the coasts of the RSA. To implement such a targeted project, it is necessary to plan an extensive and comprehensive sampling campaign in order to collect adequate sediment and biota samples for analysis and statistical evaluation. The sampling scheme, in addition to the present-day survey, could include the collection of sediment cores from representative locations in order to reconstruct organotin pollution history in the region and selected hot spots, including peaks and past pollution trends. In all cases and in order to strengthen the usefulness of future data, samples should be collected following rigorous standard operating procedures to make sure samples are representative of the area of collection. For biota, samples should in addition be comparable with respect to species, size, gender, and spawning season. Replicate samples should be collected in both impact and control sites for both sediment and biota

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