Israel Oceanographic & Limnological Research Ltd. חקר ימים ואגמים לישראל בע"מ
Marine Chemistry Department המחלקה לכימיה ימית
Tel-Shikmona, P.O.B. 8030, Haifa 31080 תל-שקמונה, ת"ד 8030, חיפה
Tel: 972-4-8515202 : טלפון Fax: 972-4-8511911 : פקס
http://www.ocean.org.il

Preliminary screening for organic and metal pollutants in the northern Gulf of Eilat[1]

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Barak Herut (IOLR) and Ludwik Halicz (GSI)

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1. Objectives

The aim of this study was to examine the levels of toxic chemicals in the sediments and seawater at representative sites near potential pollution point sources and the coral reef along the Israeli coast of the northern Gulf of Eilat.

2. Methods

Sampling

Nine water and sediment samples were collected during a cruise of the R/V Surveyor on 25-26 June 2002. Four additional sediment samples were collected from shallow water on 18 July, 2002. The sediment samples were collected at/near the Eilat marina, Northern Beach channel, fish farms, coral reef nature reserve (Observatory) and Tur-Yam marina (Table 1, Fig. 1). In addition, this report includes samples from Eilat and Navy ports, collected in two monitoring surveys (September 2002 and 2003) for the Israeli Navy. ,

Sediment samples were collected with a stainless steel Van-Veen grab from which only the top 1 cm was taken. In two stations (Observatory and Northern Beach channel) the top sediment was collected by a spoon. Sediment samples were freezed on board (or cooled when sampling from the shore) in clean plastic vials or glass jars for heavy metals and organic pollutants analyses, respectively.

[1] Part of a comprehensive research program on the ecosystem of the Gulf of Eilat (IET Program)

Seawater was sampled from 2 m depth with a peristaltic pump. For dissolved heavy metals on-line filtration was performed on board with Whatman cellulose ntrate membrane filters (0.45μm) filters. The filtrate was stored in pre-clean acidified (suprapure HNO_3 1N) plastic bottles at pH<1. For total heavy metal (except Hg) seawater samples were stored in 125 ml pre-clean acidified (15 ml Backer Instra-Analyzed HNO_3 1N) plastic bottles. For total Hg concentrations 30 ml of seawater were stored in 50 ml pre-washed centrifuge tubes after addition of 7.5 ml of HCl 33% (suprapure), 1 ml 0.1N potassium bromate/potassium bromide and diluted with Milli-Q water to 50 ml.

Seawater samples for organic pollutants analyses were sampled following the protocols of the Israeli Ministry of Health and Zymax laboratory (USA). Samples were stored, cooled (4 °C) in glass bottles after the addition of 1.5 ml HCL (concentrated) per 1 L sample to preserve them at pH~2 until delivery. Volatile organic compounds were sampled into 40 ml vials to which 3 drops of HCl were added.

Analytical

Water: Trace metals (Cd, Pb, Zn, Cu, Ni, Co, Hg, U, Mn) were determined at GSI by pre-concentration on a small column of silica-immobilized-8-Hydroxyquinoline (Sturgeon et al., 1981), followed by their removal with a small volume of acid for introduction into the ICP-MS instrument (McLaren et al., 1985). The accuracy of the method was evaluated by analysis of natural seawater standard reference material NASS-1 or NASS-3 (NRC, Canada) and was found as satisfactory. The precision is estimated as about 12% dependent of the concentration. U was used to normalize the variations in yield of pre-concentration.

Organic compounds were measured by Zymax Envirotechnology (USA) as detailed in Table 2 (except for tributyltin (TBT) + degradation products (Dibutyltin-DBT; Monobutyltin-MBT) that were measured by Toxscan Laboratory -USA).

Sediment: The sediment samples were lyophilized at the laboratory (IOLR) for 48 hrs and sieved through 500 μm. The organic compounds screening was performed by ZymaX Envirotechnology, Inc. that is a certified laboratory by CA Department of Health Services (Laboratory #1717) using the procedures detailed in Table 2. Metals were determined at GSI and IOLR laboratories as detailed in Table 2.

Organic carbon was determined (IOLR) by the potassium dichromate method following the procedure of Gaudette et al. (1974) and Avnimelech (1989) with slight modifications.

Selected major elements (total) were determined by Perkin Elmer ICP-AES (Optima 3300) after Na_2O_2 sintering (GSI) and with Varian Spectra AA220 and AA880 after HF digestion (IOLR), following the procedure of ASTM (1983). Trace elements were determineded by ICP-MS Elan 6000 (Sciex-Perkin Elmer).

The accuracy and precision of the methods were estimated on the basis of analyses of International Standard Reference Materials: Estuarine Sediment 1646 (NIST) and MESS-2 (CNRC). Near complete recoveries were found for all certified metals (within ±10% of the certified values). To further validate the analyses, an inter-laboratory comparison of Al concentrations was carried out between IOLR and GSI. Applying a paired t-test no significant differences at the 99% confidence interval was found. The linear correlation between the two data sets gave a slope of 1.02 with a correlation coefficient of 0.99.

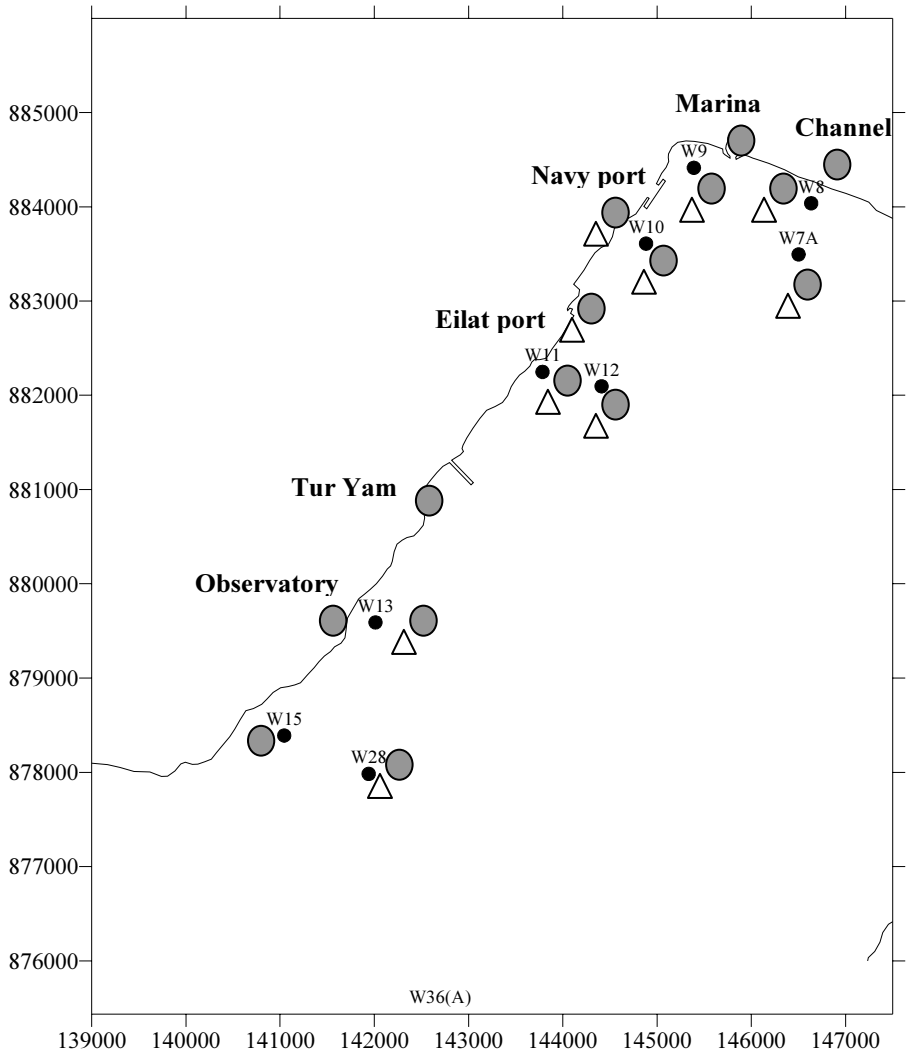


Fig. 1: Station locations. Circles and triangles denote sediment and water sampling, respectively.

Table 1: Station characteristics and measurements performed in this study.

Station	Date	Hour	Water depth	Sediment Type	Sediment Index color	Metals	Organic Pollutants	Water Dissolved Metals
W7A	25/06/02	9:00	**42**	sandy-silty	5Y 6/2	+	+	+
W8	25/06/02	9:40	**13**	sandy-silty/seagrass	5Y 5/2	+	+	+
W9	25/06/02	10:20	**16**	sandy-silty/seagrass	5Y 6/1	+	-	+
W10	25/06/02	10:45	**51**	carbonate sand	5Y 6/2	+	+	+
W11	25/06/02	11:30	**19**	carbonate sand	5Y 7/2	+	+	+
W12	25/06/02	12:05	**67**	mud/carbonate sand	5Y 6/3	+	-	+
W13	25/06/02	13:30	**68**	carbonate sand	5Y 7/2	+	-	+
W15	25/06/02	14:20	**60**	carbonate sand	5Y 7/3	+	-	+
W28	25/06/02	15:45	**280**	Yellow-brown mud	2.5Y 7/3	+	-	+
Marina	18/07/02	10:30	**~3**	nd	nd	+	+	-
Observatory	18/07/02	13:00	**0.6**	nd	nd	+	+	-
Tur Yam	18/07/02	11:40	**~2.5**	nd	nd	+	+	-
Channel	18/07/02	09:45	**0.4**	nd	nd	+	+	-

Table 2: Analytical methods and laboratories.

Parameter	Matrix	Method	Laboratory	Project
Semivolatile Organic Compounds (SIM) - PAHs	Sediment	EPA8270 Extrcted by EPA3550	Zymax	This study & Israeli Navy
Chlorinated Pesticides	Sediment	EPA8081 Extracted by EPA3550	Zymax	This study & Israeli Navy
PCB's	Sediment	EPA8082	Zymax	This study & Israeli Navy
Total Petroleum Hydrocarbons C8-C40	Sediment	GC/MS combination Extracted by EPA3880	Zymax	This study & Israeli Navy
Tributyltin (TBT)	Sediment	GC/FPD	Toxscan	This study & Israeli Navy
Metals	Sediment	ICP, ICP-MS, AAS after: HNO3 digestion; Total: Na2O2 Sintering or HF (Mn, Fe, Al)	GSI&IOLR	This study & Israeli Navy
Organic Carbon	Sediment	Potassium dichromate	IOLR	This study & Israeli Navy
VOCs - Volatile Organic Compound	Water	EPA8260	Zymax	Israeli Navy
PNA(SIM) - Polynuclear Aromatic Hydrocarbons	Water	EPA8270 (SIM) mode Extracted by EPA3510	Zymax	Israeli Navy
PCB's	Water	EPA8082	Zymax	Israeli Navy
TBT	Water	GC/FPD	Toxscan	Israeli Navy
Metals - dissolved	Water	ICP-MS after preconcentration	GSI	This study
Metals - dissolved & total	Water	Flow injection ICP-MS	GSI	Israeli Navy
Metals - total Hg	Water	Merlin Millenium - PSA PSA method for total Hg in water	IOLR	This study & Israeli Navy

3. Results

3.1 Water

Heavy metals: Dissolved trace metals in surface water were measured after pre-concentration at 9 stations, some relatively close to the shore and one c.a. 1.5 km offshore (W28). The concentrations of all metals were in the of ppt/sub-ppb range and depicted relatively small spatial variability (Table 3).

Table 3: Range of dissolved trace element concentrations (ppb) in surface water from Gulf of Eilat, June 2002.

Element	Minimum (μg/L)	Maximum (μg/L)	Israeli Standard[@]
Mn	0.067	0.347	
Ni	0.072	0.169	10 (8.2)
Co	0.025	0.038	
Cu	0.138	0.399	5 (2.9)
Zn	0.505	1.590	40 (20)
Cd	0.008	0.013	0.5
Pb	0.018	0.055	5
Hg	<0.0004	0.003	0.16 (0.025)
U*	2.11	3.7	

* Variations represent changes in yield of pre-concentration.
@ Ministry of Environment - Marine and Coastal Environment Division, Mediterranean water quality criteria, August 2002. Parenthesis = other more strict standards

At the Navy and Eilat ports dissolve metals (except Hg) were measured by a less sensitive method of direct injection into the ICP-MS (without pre-concentration). Except for Zn at Eilat port in 2003 (10 μg L^{-1}), all results were below the analytical detection limit (μg L^{-1}): Ni<1; Co<0.5; Cu<1; Zn<2; Cd<0.05; Pb<0.1. Mercury concentrations were low, from below detection limit (<0.4) to 10 ng L^{-1}.

Organic pollutants: In 2002 and 2003, measurements were performed for the Israeli Navy (IN) in the context of diving safety. The results revealed low levels (below the analytical detection limits) of volatile organic compounds (<0.5 ug/L), PAHs (<0.1 ug/L), PCBs (<0.3 ug/L), and chlorinated pesticides (<0.03 ug/L, measured in 2002 only). However, significant concentrations of tributyltin (TBT) and its degradation products) were measured at both, the Navy and Eilat ports, as detailed in Table 4. The samples of Eilat port were more contaminated by organotin compounds than the Navy port by approximately an order of magnitude.

Table 4: Concentrations of TBT and its degradation products (ng/L) in seawater at the Navy and Eilat ports.

Site	Parameter	2002	2003
Navy port	Tributyltin	<20	6-11
	Dibutyltin	<20	<2-4
	Monobutyltin	<40	<2
	Total	**<20**	**6-15**
Eilat port	Tributyltin	50	70
	Dibutyltin	50	13
	Monobutyltin	<40	<2
	Total	**100**	**83**

3.2 Sediment

Heavy metals

Heavy metal concentrations in surficial sediments are presented in Table 5. In general, the metal concentrations show heterogenic spatial distribution attributed to variations in the sediment mineralogical composition and the level of anthropogenic enrichment at certain sites. Copper and mercury exhibited the largest differences between minimal and maximal concentrations, c.a 600-fold and 300-fold, respectively, followed by Pb (~150-fold), Cd (~50-fold) and Sn (~50-fold). The highest metal levels were found at the Eilat and Navy ports and at Eilat and Tur Yam marinas.

Table 5: Trace and minor element concentrations (ppm dry wt.) in surface sediments from the Gulf of Eilat.

Station	Date	Hg	As	Cd	Co	Cr	Cu	Mo	Ni	Pb	Sn	U	V	Zn	Fe
W7A	Jun-02	0.007	2.0	0.39	8.0	21.6	17.5	0.20	15.3	5.4	0.4	1.6	37	63	26020
W8	Jun-02	0.007	2.0	0.11	7.9	18.3	11.4	0.20	14.6	5.2	0.7	1.3	32	65	25516
W9	Jun-02	0.015	3.4	0.14	5.3	19.7	11.2	0.86	12.6	6.0	0.6	2.3	30	47	18061
W10	Jun-02	0.010	4.2	0.13	5.4	19.1	13.7	0.16	12.1	7.9	0.7	1.1	29	46	17283
W11	Jun-02	0.011	3.7	0.35	1.9	13.0	7.3	0.37	6.8	6.8	0.2	3.9	17	33	8560
W12	Jun-02	0.004	4.5	0.07	2.5	11.6	4.9	0.17	6.5	1.0	0.3	3.0	13	24	6663
W13	Jun-02	0.003	4.2	0.06	1.9	10.7	3.1	0.16	4.9	2.4	0.3	1.0	10	18	5636
W15	Jun-02	0.003	5.3	0.04	0.9	7.2	1.9	0.15	4.1	2.1	0.2	1.1	9	13	3336
W28	Jun-02	0.018	7.1	0.30	8.4	34.7	20.2	0.61	21.4	10.9	1.1	2.0	49	70	28209
Marina	Jul-02	0.029	4.4	0.21	7.1	19.7	52.7	0.30	13.0	12.9	2.9	1.9	32	130	22900
Observatory	Jul-02	0.007	1.8	0.09	4.6	19.4	8.5	0.17	9.4	4.8	0.7	0.8	22	47	17000
Tur Yam	Jul-02	0.222	3.7	0.47	3.3	27.6	46.8	3.17	9.4	61.6	9.1	2.5	23	114	11400
Channel	Jul-02	0.006	1.4	0.03	1.4	2.7	2.1	0.03	2.2	2.3	0.2	0.3	8	14	4500
IN Port-D 02	Sep-02	0.023	3.9	0.30	2.9	12.1	44.1	0.73	5.6	46.9	0.7	2.8	17	64	8253
IN Port-S 02	Sep-02	0.01	2.4	0.21	3.6	20.3	54.5	0.63	8.6	51.4	0.2	0.9	21	87	10625
Eilat Port 02	Sep-02	0.953	3.4	0.35	2.9	16.3	62.1	1.81	9.4	155.7	4.6	1.8	20	91	9388
N Beach 02	Sep-02	0.011	1.9	0.09	3.6	10.6	5.3	0.18	9.5	3.7	0.4	1.3	16	28	7737
IN Port-D 03	Sep-03	0.1935	5.1	0.30	4.0	34.9	180.1	1.31	16.5	164.3	0.7	1.9	33	257	13416
IN Port-S 03	Sep-03	0.067	10.2	1.11	2.8	27.1	1174.9	1.31	14.3	120.4	1.1	22.3	29	130	7732
Eilat Port 03	Sep-03	0.2831	3.0	1.60	2.1	13.1	28.0	0.52	9.3	46.7	1.1	1.5	17	99	6351

Organic pollutants

Several types of organic micro-pollutants (e.g. PAH's, PCB's, TBT, pesticides) were measured in the surficial shallow sediments at the northern Gulf of Eilat. The pollutant concentrations ranged from below the analytical detection limits to values higher by orders of magnitude as detailed hereafter.

Relatively high concentrations of total petroleum hydrocarbons (TPH, C8-C40) were found in the ports and at Tur Yam marina (Fig. 2). But, in general, low PAH concentrations were detected (Table 6), except for acenaphthene (in 2002 and 2003) and fluorine (2003) in the Navy port.

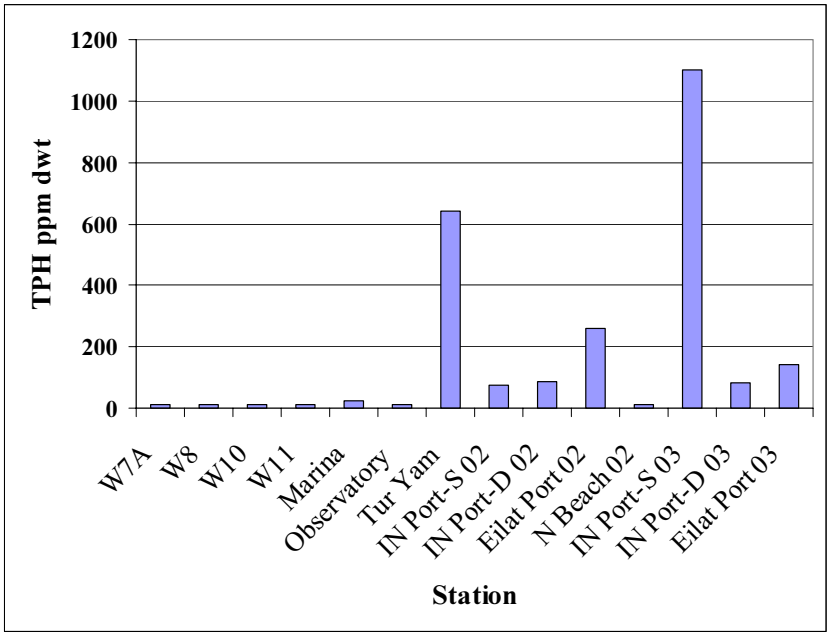


Fig. 2: Total petroleum hydrocarbons (TPH, C8-C40) concentrations in surficial shallow sediments from the Gulf of Eilat.

Both halogenated hydrocarbons, the pesticides and the polychlorinated biphenyls (PCBs), are known as persistent organic pollutants (POPs) belonging to the so called "dirty dozen". Relatively high concentrations of DDT pesticides were found near (W11) and at Eilat port, and near (W10) and at the Navy port (Fig. 3). High concentrations of PCB's were found at the Navy and Eilat ports and at Tur-Yam marina (Fig. 4).

Table 6: Polynuclear Aromatic Hydrocarbon concentrations in shallow surficial sediment samples from the Gulf of Eilat.

Constituent	PQL*	MDL**	Units	IN Port-D 03	IN Port-S 03	Eilat Port 03	IN Port-D 02	IN Port-S 02	Eilat Port 02	W7A	W8	W10	W11	Marina
Acenaphthene	0.005	0.001	mg/kg	0.06	0.007	0.006	ND (<0.005)	0.02	ND (<0.02)	ND	ND	ND	ND	ND
Acenaphthylene	0.005	0.001	mg/kg	ND (<0.02)	ND (<0.005)	ND (<0.005)	ND (<0.005)	ND (<0.02)	ND (<0.02)	ND	ND	ND	ND	ND
Anthracene	0.005	0.001	mg/kg	0.04	ND (<0.005)	0.007	ND (<0.005)	ND (<0.02)	ND (<0.02)	ND	ND	ND	ND	ND
Benz (a) anthracene	0.005	0.001	mg/kg	0.27	0.049	0.14	0.006	0.08	0.10	ND	ND	0.004 J	0.004 J	0.002 J
Benzo (b) fluoranthene	0.005	0.001	mg/kg	0.24	0.08	0.19	0.022	0.23	0.22	0.002 J	ND	0.009	0.006	0.003 J
Benzo (k) fluoranthene	0.005	0.001	mg/kg	0.14	0.034	0.091	0.013	0.20	0.13	0.001 J	ND	0.009	0.005 J	0.003 J
Benzo (a) pyrene	0.005	0.001	mg/kg	0.19	0.046	0.13	0.012	0.14	0.18	0.001 J	ND	0.008	0.005 J	0.003 J
Benzo (ghi) perylene	0.005	0.001	mg/kg	0.07	0.02	0.048	ND (<0.005)	0.03	0.12	0.001 J	ND	0.005 J	0.032	ND
Chrysene	0.005	0.001	mg/kg	0.2	0.047	0.11	0.006	0.13	0.11	ND	ND	0.006	0.005	0.003 J
Dibenzo (a,h) anthracene	0.005	0.001	mg/kg	ND (<0.02)	0.007	0.025	ND (<0.005)	ND (<0.02)	0.03	ND	ND	ND	ND	ND
Fluoranthene	0.005	0.001	mg/kg	0.28	0.057	0.11	0.008	0.21	0.18	0.002 J	ND	0.01	0.008	0.005 J
Fluorene	0.005	0.001	mg/kg	0.03	ND (<0.005)	ND (<0.005)	ND (<0.005)	ND (<0.02)	ND (<0.02)	ND	ND	ND	ND	ND
Indeno (1,2,3-cd) pyrene	0.005	0.001	mg/kg	0.08	0.023	0.058	0.006	0.06	0.12	ND	ND	0.005	0.003	ND
Naphthalene	0.005	0.001	mg/kg	ND (<0.02)	ND (<0.005)	ND (<0.005)	ND (<0.005)	ND (<0.02)	ND (<0.02)	ND	ND	ND	0.001 J	ND
Phenanthrene	0.005	0.001	mg/kg	0.19	0.029	0.038	ND (<0.005)	0.10	0.07	ND	ND	0.003 J	0.004 J	0.003 J
Pyrene	0.005	0.001	mg/kg	0.25	0.051	0.11	0.007	0.20	0.16	0.002 J	0.002 J	0.009	0.007	0.005 J
SUM			**ug/kg**	**2040**	**450**	**1063**	**80**	**1400**	**1420**	**9**	**2**	**68**	**80**	**27**

ZymaX envirotechnology, inc. is certified by CA Department of Health Services: Laboratory #1717
*PQL - Practical Quantitation Limit
**MDL - Method Detection Limit
***Results listed as ND would have been reported if present at or above the listed MDL. Constituents reported with a "J" qualifier are below the PQL but greater than the MDL and are estimated values.

High concentrations of TBT (and its degradation products) were found at the ports, Tur Yam marina and the Eilat marina. Only at the northern beach sites (W7A, W8 and N Beach02) the levels were below the analytical detection limit while at all other sites (ports, marinas, Observatory and sites nearby) they exceeded the detection limit. At most of the contaminated stations the TBT enrichment was also reflected by the higher levels of total tin (Sn) as presented in Table 5.

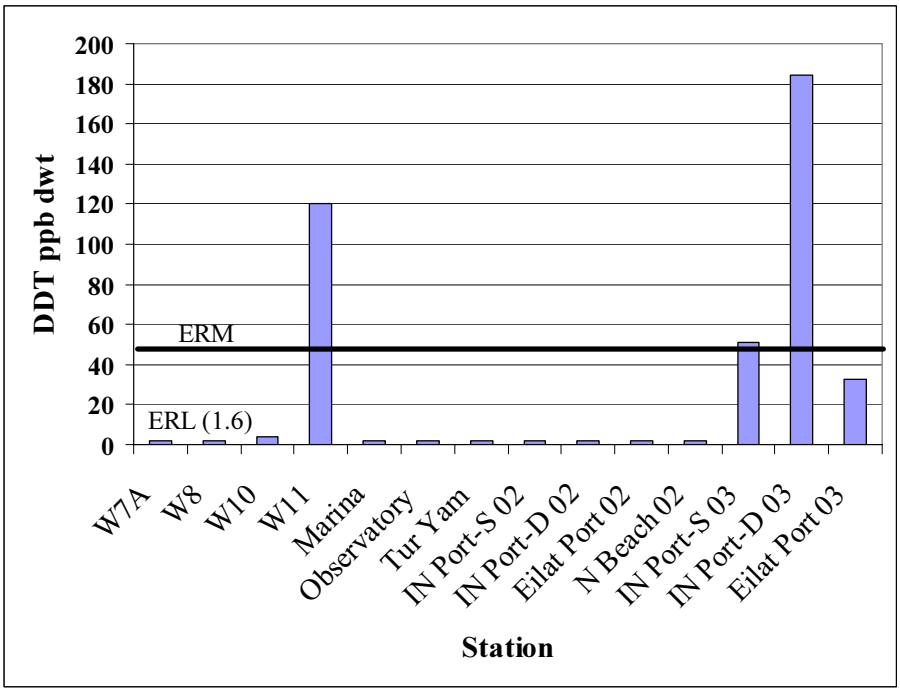


Fig. 3: DDT concentrations in surficial shallow sediments from the Gulf of Eilat.

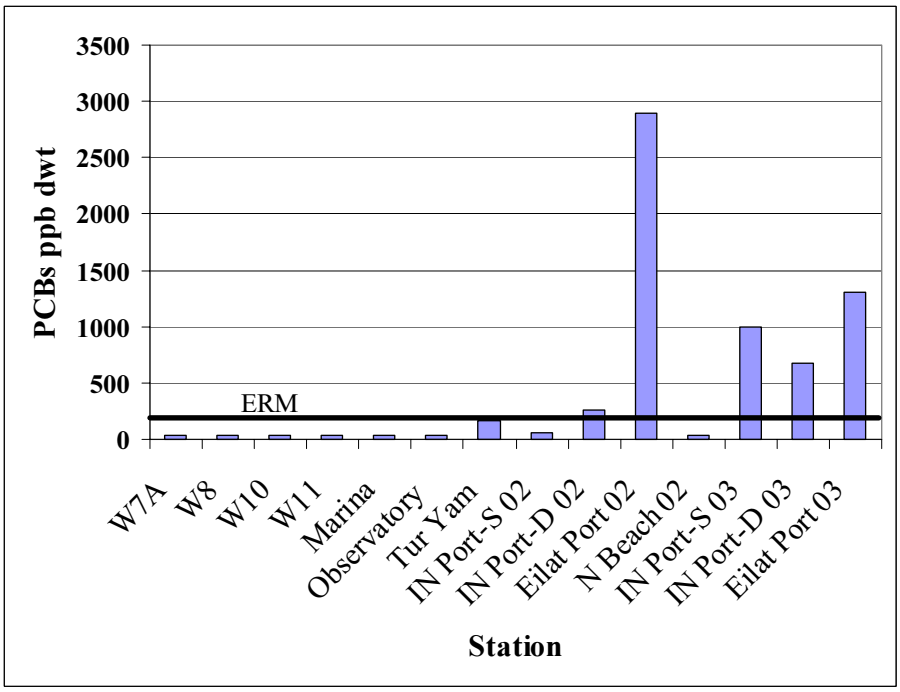


Fig. 4: Total PCBs concentrations in surficial shallow sediments from the Gulf of Eilat.

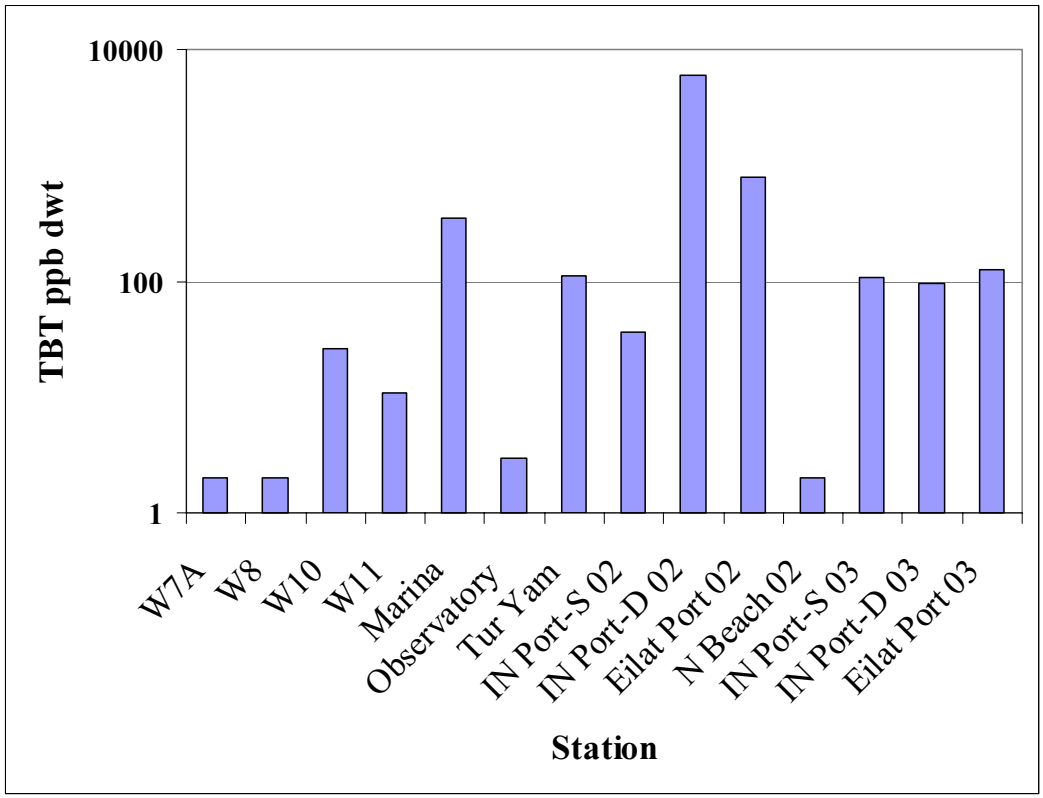


Fig. 5: TBT+ its degradation products (DBT&MBT) concentrations in surficial shallow sediments from the Gulf of Eilat (note the logarithmic scale).

3. Discussion

In many coastal areas, especially near sensitive ecosystems and nature reserves, pollution by potentially toxic trace metals and organic micro-pollutants is a concern. Several of these pollutants (e.g. Cd, Hg, Cr, Ni, Pb, As, PAHs, PCBs, TBT, pesticides) are most commonly found xenobiotics in the marine environment and are known by their potential carcinogenecity, mutagenecity and teratogenecity (for details see Hoffman et al., 2003; Kennish, 2001). Toxic compounds, non-degradable or degradable at low rates, may accumulate through the food web. The identification of conservative or bioaccumulative chemicals, including mercury, pesticides, polychlorinated biphenyls and other toxic substances reflects environmental pressures that may affect the sensitive ecosystem of the northern Gulf of Eilat. Indeed in ranking the threats on the coral reef in the National Park of American Samoa (Craig and Basch, 2001) the Pago Harbor toxicity was ranked as a high concern among all human-related impacts.

The measurements of dissolved pollutants in seawater were performed to assist the interpretation of the sediment data, especially with respect to heavy metals, considering the

magmatic characteristics of the basin area. Thus, the scarce measurements in such a dynamic matrix subjected to large variations in pollutant input should be considered as only preliminary.

Heavy metals

The concentrations of all **dissolved** metals are well below international environmental standard (Table 3) and were in similar level as uncontaminated seawater (NASS-1 and NASS-3). The maximal concentrations found are 10-fold lower than the most sensitive criteria, except for Cu (factor of ~7) and Hg (factor of ~8). However, the enrichment of heavy metals in sediments at certain sites (see hereafter) suggests events of contamination.

The anthropogenic enrichment of heavy metals in the **sediments** was evaluated by using Fe as a normalizing element for grain size effect (Fig. 6) or by using Ca to normalize the metal concentration to the variations in sedimentation rates attributed to biogenic carbonates. Heavy metal enrichments were observed at: Tur Yam (Cd, Cu, Mo, Pb, Sn, Hg); Eilat marina (Cu, Sn, Zn, Pb, Hg); near the fish cages (W7A: Cd) near Eilat port (W11: Cd, U) and at the Eilat and Navy ports (several metals) (Table 5, Fig. 6).

At the northeastern part of the Gulf of Eilat (shallow sediments along Aqaba shoreline) very high concentrations of Cd, Pb, Ni and Co were measured attributed to pollution from sewage discharge, phosphate loading and discharge of cooling water from an industrial complex (Abu-Hilal et al., 1988; Abu-Hilal and Badran, 1990; Abu-Hilal, 1993). The metal levels were significantly higher than the highest levels we found in Eilat

The shaded numbers in Table 5 are values exceeding the ERL[2] and ERM criteria (ERL - Effects Range Low and ERM - Effects Range Median). Deviation from these levels represent metal levels that can potentially induce toxic effects in marine organisms based on sediment quality guidelines suggested by Long et al. (1995) and adopted by the US National Oceanic and Atmospheric Administration (NOAA). The metals which exceeded ERL level were: Cu, Pb, Hg, Cd, As and Zn (see also Figs. 6 and 7).

[2] The ERL is calculated as the lower 10^{th} percentile concentration of the available sediment toxicity data which has been screened for only those samples which were identified as toxic by original investigators. It represents the value at which toxicity may begin to be observed in sensitive species. The ERM is the median concentration of the compilation of just toxic samples. It is not LC_{50}.

Tributyltin

Among the measured **dissolved** organic micro-pollutants only TBT and its degradation products were found in significant concentrations. TBT is a highly toxic compound used in antifouling paints and subsequently released to the marine environment especially in ports and marinas. It is harmful to benthic invertebrates (shell thickening, reduced growth rates, imposex and other undesirable effects) even at very low concentrations such as 1 ng L^{-1} (Kennish, 2001). Experiments by Negri and Heyward (2001) showed that TBT inhibits coral fertilization and larval metamorphosis (50% inhibition at 2 μg L^{-1}). The dissolved TBT concentrations found in the ports of Eilat (Table 4) exceed by 10 to 100-fold the Israeli seawater quality criteria suggested for the Mediterranean by the Ministry of Environment or the criteria adopted by the EPA (both, 1 ng L^{-1}). The ratio between TBT and its degradation products may serve as an indicator for the TBT supply or freshness. The relatively low ratio of DBT/TBT (<0.5) in the ports in 2003 suggests continuous supply of 'fresh' TBT to the water.

The sampled sediments exhibited a wide range of TBT concentrations, similar to levels found in ports and marinas worldwide (Fig. 8). No sediment quality criteria exist for TBT, and hence it is difficult to assess the level that can potentially induce toxic effects in marine organisms. However, all sites at which TBT concentration exceeded 100 μg/kg may be considered as significantly polluted by TBT. As for the water, the values of DBT/TBT were below 0.5 for samples of 2002 indicating for continuous supply of TBT, while in 2003 at the two ports, the ratio was approximately 1 indicating a decrease in the supply rate. The discrepancy in DBT/TBT ratios between the sediments (~1) and water (<0.5) in the ports in 2003 may indicate seaward transport that is faster than the removal into the port sediments.

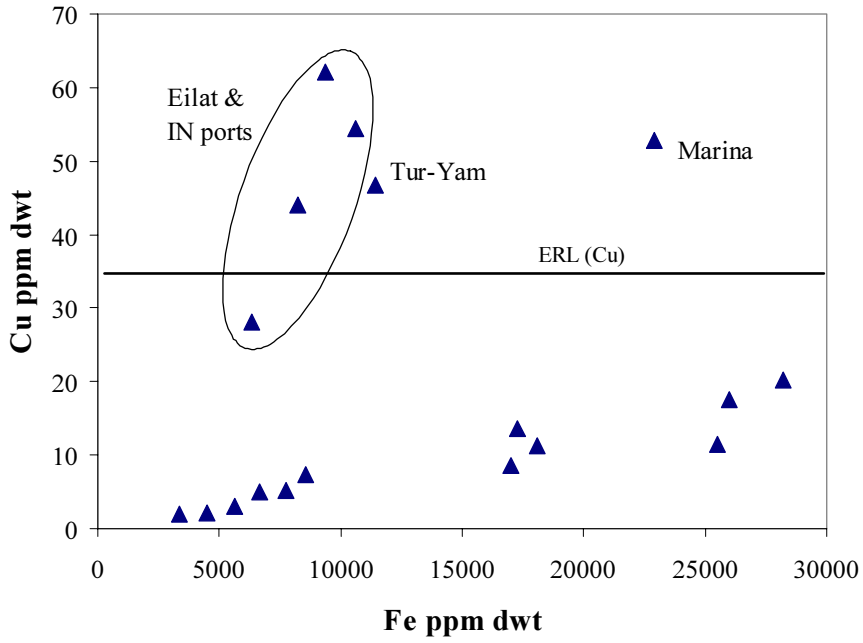
Ploicyclic Aromatic Hydrocarbons (PAHs)

While generally low PAH concentrations were detected (Table 6), acenaphthene (in 2002 and 2003) and fluorine (2003) at the Navy port exceeded ERL values.

Organochlorines (PCBs, Pesticides)

Concentrations above ERM for DDT pesticides were found at sea near Eilat port (W11) and the Navy port (in the 2003 survey), and above ERL at sea near the Navy port (W10) (Fig. 3). It is probable that such concentrations may induce toxic effects in marine organisms.

The sediments in both ports and at Tur Yam marina were polluted by PCBs at levels higher than ERM (Fig. 4). The concentrations in sediments at the 'open sea' stations were below the Practical Quantitation Limit (PQL[3]) of the method (30 ng/g) which is a bit larger than ERL level (23 ng/g).



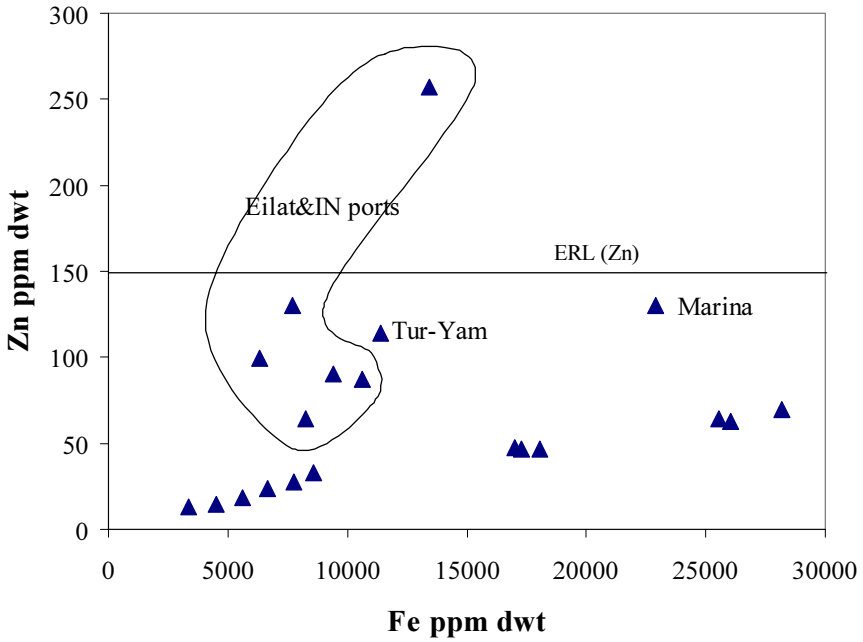


Fig. 6: Relationship between Cu, Zn and Fe concentrations in sediment at sites in Gulf of Eilat.

[3] PQL is based on the Method Detection Limit (MDL). The MDL is that minimum level at which an analyte can be detected with a 99% confidence level. It is statistically derived following the procedure from EPA 40 CFR Part 136, Appendix B. The PQL is set between 2.5 to 5 times the MDL (roughly 12 times the standard deviation resulting from the MDL procedure). The PQL is that minimum level at which an analyte can be detected and quantitated with a 99% confidence.

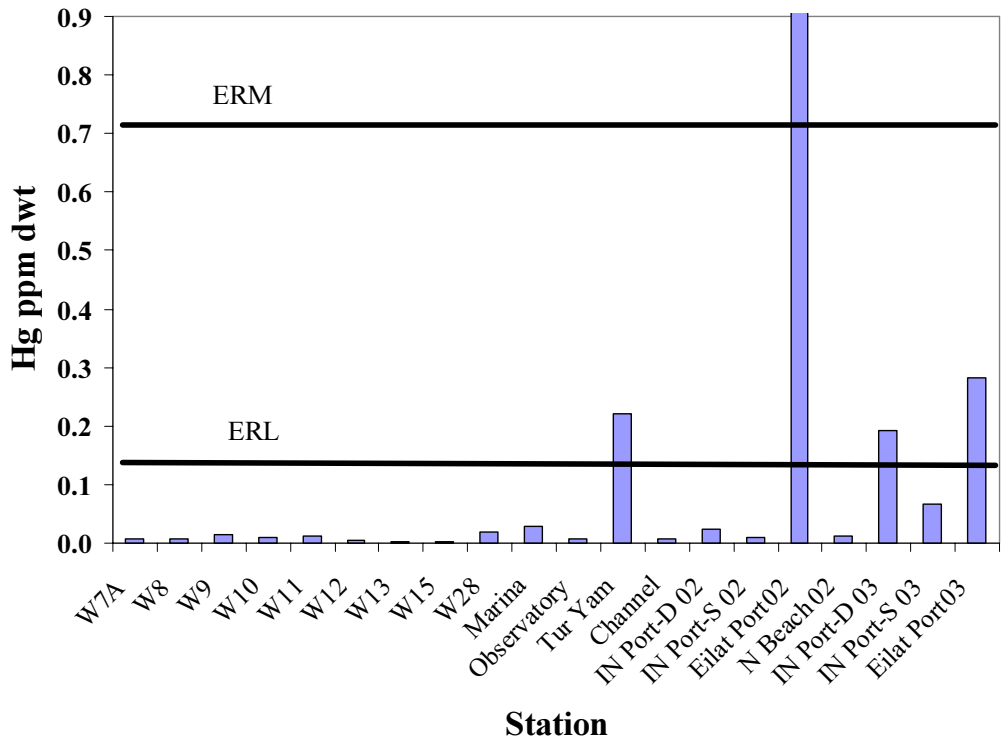


Fig. 7: Distribution of Hg concentrations in sediment at sites (see Fig. 1) in Gulf of Eilat.

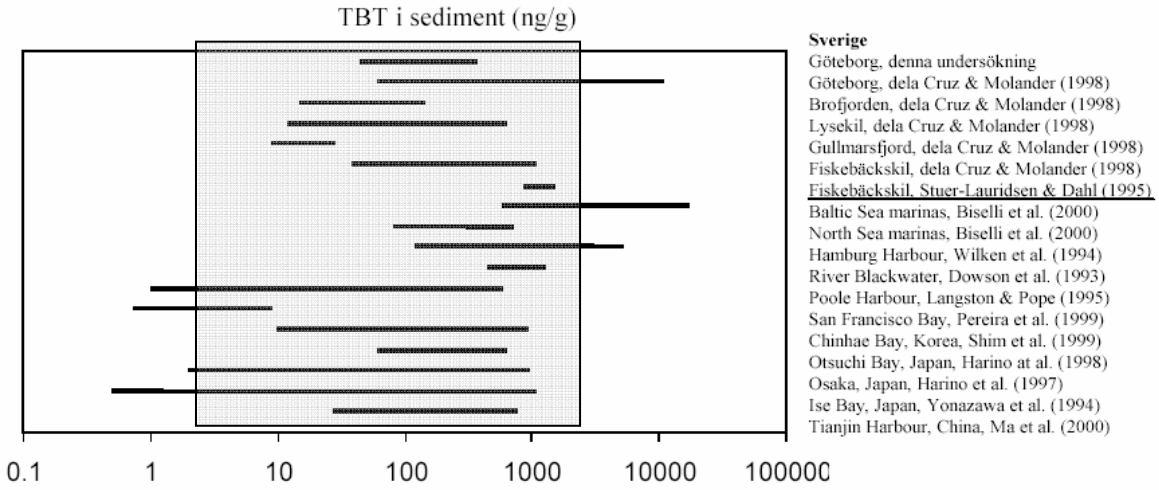


Fig. 8: TBT concentrations in sediment at harbors worldwide (source: Brack (2000), Report Geologi Geovetarcentrum, Goteburg Universitet). The shaded area represents the concentration range for samples of this study.

4. Conclusions

1. High levels of metal and organic contaminants were found in the sediments at several 'Hot spots' along the Israeli coast of the Gulf of Eilat mainly within marine structures. The sediments were significantly contaminated mainly by heavy metals (Hg, Cu, Pb, Cd, Zn), PCBs, TBT and its degradation products and DDT pesticides.

2. High concentrations of Tributyltin (TBT) (> 100 μg/Kg), probably originating from anti-fouling paints, were found in the sediments at the Eilat and Navy ports and at the Eilat and Tur Yam marinas. The concentration ratios of TBT and its degradation products in the sediments and in the water indicate continued TBT input. High concentrations of TBT were also measured in water samples from the ports.

3. The sediments did not contain significant amounts of polycyclic aromatic pollutants (PAH's), although significant contamination by acenaphthene (in 2002 and 2003) and fluorine (2003) was found in the Navy port.

4. The sites at which contaminant levels in sediment exceeded the levels that can potentially induce toxic effects in marine organisms (ERL/ERM criteria) are: Eilat & Navy ports; Tur Yam marina; Eilat marina; Station W11 (near Eilat port).

5. Many of the above substances are present along the Israeli coast of the Gulf of Eilat at concentrations well above levels at which toxicity may begin to be observed in sensitive species.

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