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MERCURY POLLUTION IN ABU KIR BAY EAST OF ALEXANDRIA, EGYPT

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ميزانيـــة الزئبق في خليـــج أبو قير شرق الاسكندرية ـ مصـــــر

أســـامـة أبو الذهـــب

يتعرض خليج أبو قير شرق الاسكندرية للتلوث من مصادر الصرف البرية وخاصة محطة صرف الطابية وفتحة بحيرة إدكو . وقد تم في هذا البحث تعيين صور تواجد الزئبق المختلفة من ذائب فعال وذائب عضوي وعالق في مياه مصادر الصرف البرية وفي مياه الخليج الساحلية ، وكذلك تم تعيين الزئبق الكلي في رواسب القاع بمناطق الخليج المختلفة .

وأوضحت النتائج أن كمية الزئبق الكلي التي تدخل الخليج عبر محطة صرف الطابية تعادل ٣,١٣ كجم يومياً . وأظهر التوزيع المكاني للزئبق في مياه ورواسب قاع الخليج التأثير الواضح لمصادر الصرف البرية ، ويمكن تلخيص ميزانية الزئبق في خليج أبو قير باعتبار أن كميته الكلية التي تدخل الخليج يومياً تساوي ٤,٩٤ كجم يخرج منها إلى البحر المفتوح ما يعادل ٢٥٪ ويترسب منها إلى قاع الخليج حوالي ٥٥٪ .

Key Words: Egypt Coast, Fluxes, Mercury budget, Organic mercury, Particulate mercury, Reactive mercury.

ABSTRACT

Abu Kir Bay, east of Alexandria, is subjected to substantial pollution from two direct point sources which are Tabia Pumping Station (TPS) and Lake Edku Outlet (LEO). Mercury was speciated into dissolved reactive, dissolved organic and particulate in the Bay effluents and coastal waters. The Bay surficial sediments were also analysed for their mercury content. Total Hg concentrations and fluxes from TPS (1739 ngl^{-1} and 3.13 kg d^{-1}) to the Bay are considerably higher than those from LEO (516 ngl^{-1} and 1.81 kg d^{-1}). Average Hg levels in the Bay Waters were 6.6 ngl^{-1}, 1.2 ngl^{-1} and 28.5 ngl^{-1}, respectively, for reactive, organic and particulate phases. The Hg spatial distribution in the Bay waters and sediments showed a distinct impact from the two land-based sources of pollution. From the total mercury load to the Bay, 4.94 kgd^{-1}, flushing of the Bay to the open sea removes 25% and sedimentation within the Bay reaches 56%. (2.76 kgd^{-1} out of 4.94 kgd^{-1}).

INTRODUCTION

Abu Kir Bay, a shallow tideless semi-circular basin east of Alexandria, is simultaneously used as a marine habitat, source of food, site for recreation and disposal of industrial, agricultural and domestic wastes. The Bay is affected by heavy pollution from two direct point sources (Tabia Pumping Station, 1.8×10^6 m^3 d^{-1} and Lake Edku Outlet, 3.5×10^6 m^3 d^{-1}). Mercury is a trace metal with well documented toxic effects resulting from environmental contamination (Eisler, 1987). Anthropogenic mercury release through the Egyptian coastal waters are not well understood (El-Rayis *et al,* 1986 & Jorgensen *et al,* 1990). The scope of the present work is to speciate Hg forms in the Bay effluents and waters and to estimate the amounts of the element deposited in the Bay sediments and that leaving it by water exchange with the open sea.

MATERIAL AND METHODS

Water:

Tabia Pumping Station (TPS) and Lake Edku Outlet (LEO) were sampled 12 times on a monthly basis starting from January 1986. Two cruises were carried out covering 30 stations representing the whole Bay during winter and summer of 1986 (Fig. 1). Fig. 1 also shows sampling depths. Sample collection, treatment and analysis were carried out as described by (Kremling, 1983; Freimann & Schmidt, 1982).

Sediment:

Samples were collected by a coring device from the stations shown in Fig. 1. The surficial layer of sediment (about 2 cm) was analysed. Samples were digested with supra-pure aqua-regia

solution. Particulate mercury was treated in a way similar to that for sediments.

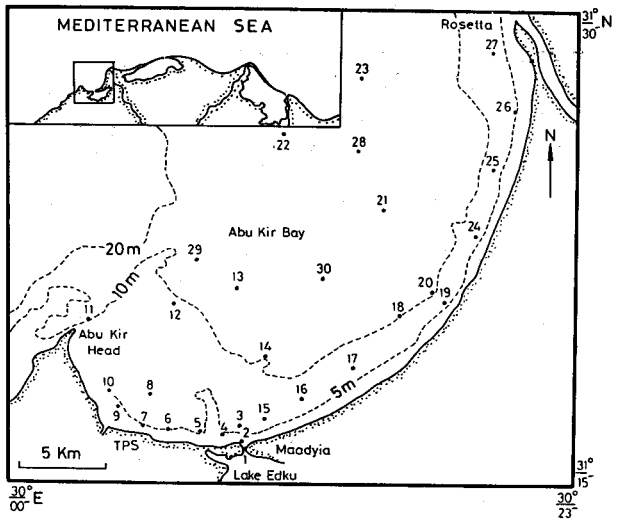

Fig. 1: Area of study. (Numbers 1-30 indicate sampling locations for sea water and sediments)

Cold Vapor atomic absorption spectrophotometry with argon aeration, tin chloride reduction, pre-enrichment and purification by amalgamation on finely dispersed gold was used for the measurement of mercury concentrations.

The detection limit of the used technique for mercury determinations in water samples was 0.5 ngl^{-1} and the coefficient of variation 7% for concentrations up to 100 ngl^{-1}.

For eight different recovery of a 10 µg spike varied between 89.2 and 97.6%, with a mean value of 93.1 ± 3.9%. Seven replicate analyses of standard references 1645 (45 National Bureau of Standards) "River sediment" containing 1.1 ± 0.5 µg g^{-1} Hg, yielded a mean value of 1.2 ± 0.3 µg.

RESULTS AND DISCUSSION

The spatial distribution of dissolved (reactive and organic) and particulate mercury concentrations in the Bay water during the two cruises, are shown in (Figs. 2-4). Table 1 gives the average concentration of the studied Hg species and their relative proportions to the total in the water of the Bay, TBS and LEO. The mercury concentrations in TPS and LEO water, are given in (Table 2). The daily average input of Hg to the Bay from the respective effluents is given in Table 3.

Total Hg concentration and load (waste water flow rate × Average Hg concentration) from TPS (1739 ± 207 ngl^{-1} and 3.13 kgd^{-1}) to the Bay are consistenly higher than those in LEO (517 ± 93 ngl^{-1} and 1.81 kgd^{-1}). Average Hg concentrations in the Bay waters during the period of study were 6.6 ± 1.8 ngl^{-1}, 1.2 ± 0.7 ngl^{-1} and 28.5 ± 24.5 ngl^{-1}, respectively, for dissolved reactive, dissolved organic, and particulate phase. The horizontal distribution of particulate Hg in the coastal waters reflected the impact of TPS on the Bay (Fig. 4). About 69 ± 14% of the total Hg in the Bay waters occurred in the particulate form. This high proportion is in agreement with the well-known affinity of Hg for suspended matter (UNEP, 1987). The dissolved organically bound Hg represented only 1.2 ± 0.7% of the total Hg and 13.7 ± 7.1% of the dissolved phase. In general, Hg concentrations in water and sediments decreased in a seaward direction

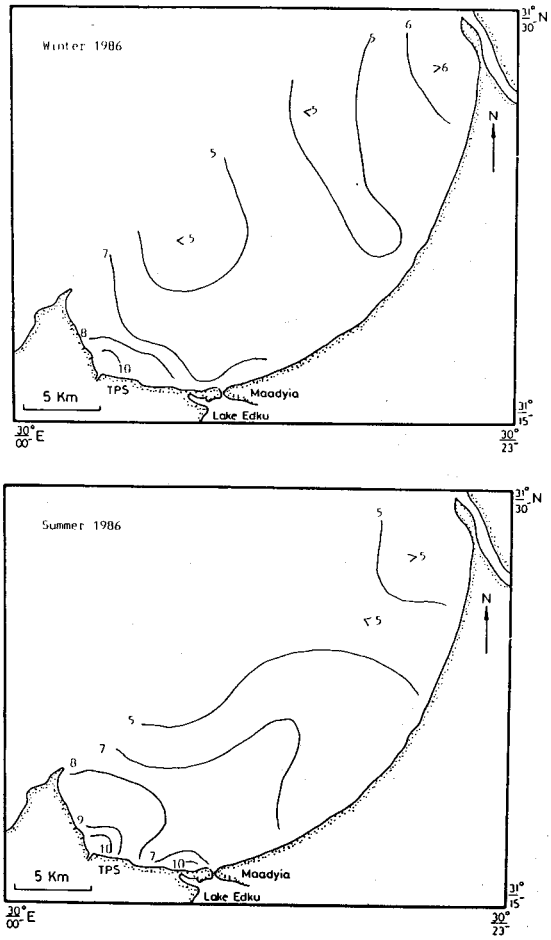

Fig. 2: Spatial distribution of dissolved reactive mercury in Abu Kir Bay water (ngl^{-1}).

Table 1

Average concentrations and relative proportions of mercury forms in Abu Kir Bay water and in the effluents.

Mercury species (ngl^{-1})	Relative proportion (%)	Sea water	LEO	TPS
TD		7.7 ± 2.3	69 ± 14	326 ± 64
P		28.5 ± 24.5	448 ± 86	1405 ± 168
T		36.1 ± 26.5	517 ± 93	1739 ± 207
	P/T	68.6 ± 16.4	87 ± 2	81 ± 3
DR		6.6 ± 1.8	51 ± 11	281 ± 54
	DR/T	27.5 ± 15.9	10 ± 2	16 ± 2
	DR/TD	86.3 ± 7.1	74 ± 5	87 ± 4
Dorg.		1.2 ± 0.7	18 ± 5	44 ± 15
	Dorg./T	3.7 ± 2.7	3 + 1	3 ± 2
	Dorg./TD	13.7 ± 7.1	26 ± 5	14 ± 4

(LEO = Lake Edku Outlet, TPS = Tabia Pumping Station, TD = Total Dissolved Hg, P = Particulate Hg, T = Total Hg, DR = Dissolved Reactive Hg, Dorg. = Dissolved Organic Hg).

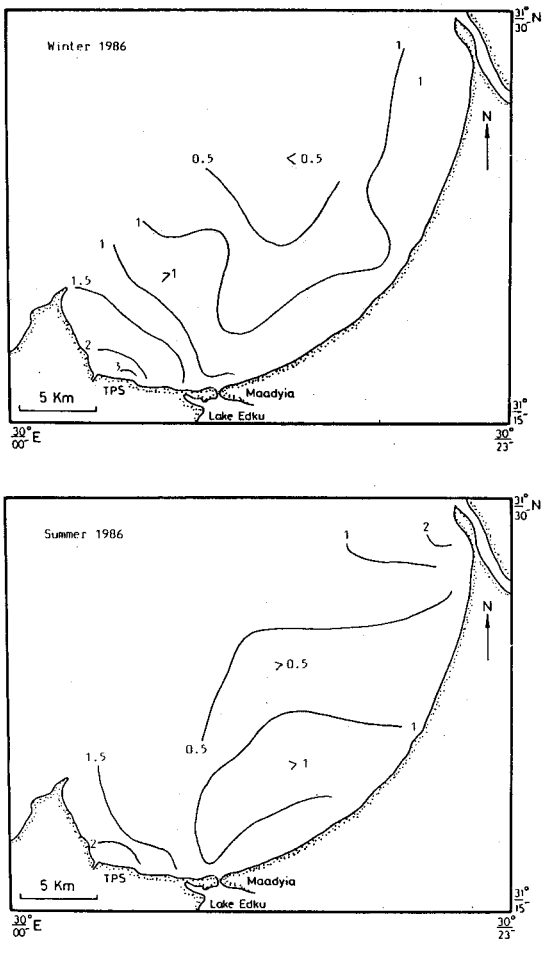

Fig. 3: Spatial distribution of dissolved organic mercury in Abu Kir Bay water (ngl^{-1}).

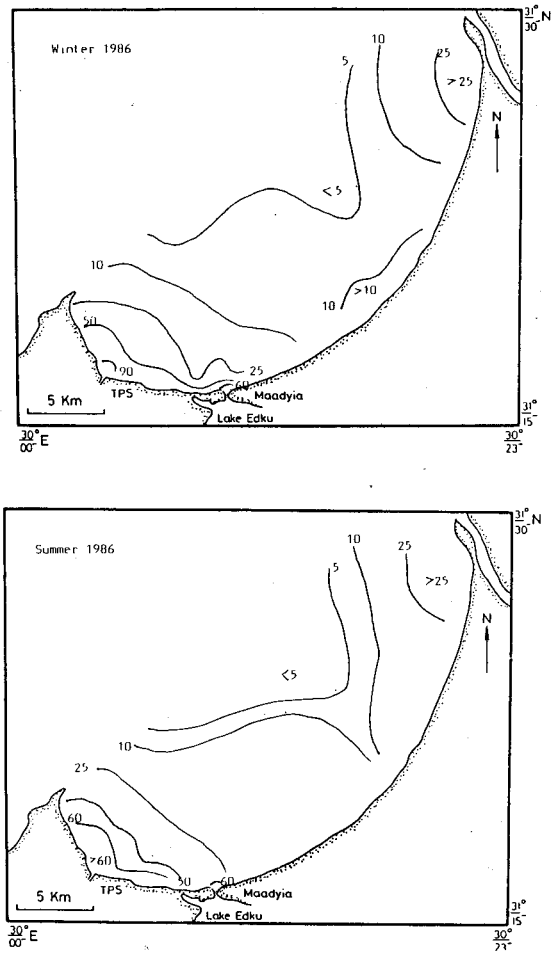

Fig. 4: Spatial distribution of particulate mercury in Abu Kir Bay water (ngl^{-1}).

(Figs. 2-5). The levels of Hg in Abu Kir Bay sediments fluctuated between 6.73 μg g^{-1} dw (station 9) and 0.09 μg g^{-1} dw (station 22), with an average of 1.72 ± 1.62 μg g^{-1} dw. The influence of TPS was unmistakable in rising Hg level in the sediments at stations 7, 9 and 10 (respectively, 4.23 μg g^{-1} dw, 6.73 μg g^{-1} dw and 5.12 μg g^{-1} dw). Also the effect of LEO was evident from the high Hg level in the sediments of stations 2, 3 and 4 (3 μg g^{-1} dw). The results showed that Hg released to Abu Kir Bay from the two point sources, is mainly retained in the nearby sediments.

Data of Hg concentrations in sea water from the Mediterranean are few, the validity of many of the older data is doubtful and even for recent data it is not clear which Hg species or groups of Hg species have been determined. Furthermore, several different analytical methods have been used and it is not clear which fraction of the Hg species present in sea water was determined. At present the fraction of the total Hg determined by each analytical procedure can only be operationally defined. This makes it impossible to compare results obtained by different authors and it is also not clear if the same analytical procedure will determine the same fraction of Hg species in different water masses. Hence, the results are not comparable and the data published can only give an idea of the order of magnitude of the mercury concentrations determined. Table 4 summarizes some published Hg concentrations in sea water from the Mediterranean and other regions.

The few data available today about Hg concentrations in the sediments show that 50 to 100 μg kg^{-1} dw may be considered a typical background value for the Mediterranean (UNEP, 1987). In comparing Hg levels among the different areas one has to bear in mind that the analytical procedures differ between authors and so the results obtained are not strictly comparable. Some published results about Hg concentrations in different Mediterranean sediments are given in Table 5.

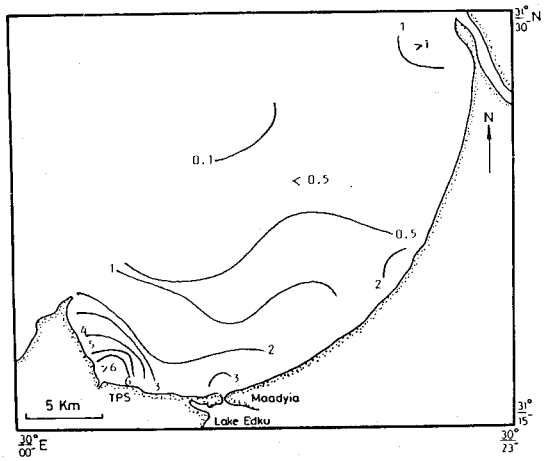

Fig. 5: Surficial distribution of mercury in Abu Kir Bay sediments (μg g^{-1} dw).

Table 2
Mercury concentrations in Abu Kir Bay main effluents (ngl^{-1})

Sampling date		Mercury species			
		Particulate	Dissolved		Total
			Reactive	Organic	
Lake Edku Outlet					
January	1986	372	35	15	422
February	1986	378	37	11	426
March	1986	381	53	19	453
April	1986	490	38	12	540
May	1986	668	52	28	748
June	1986	451	55	17	523
July	1986	522	59	19	600
August	1986	414	60	21	495
September	1986	499	59	24	582
October	1986	378	52	17	447
November	1986	418	44	15	477
December	1986	409	69	13	491
Average		448	51	18	517
Standard deviation	±	86	11	5	93
Lake Edku Outlet					
January	1986	1266	187	42	1495
February	1986	1209	269	24	1502
March	1986	1361	239	40	1640
April	1986	1315	208	33	1556
May	1986	1623	277	21	1921
June	1986	1749	365	64	2176
July	1986	1493	333	73	1899
August	1986	1234	308	48	1690
September	1986	1452	263	56	1773
October	1986	1539	354	45	1938
November	1986	1288	298	48	1634
December	1986	1325	276	35	1640
Average		1405	281	44	1739
Standard deviation	±	168	54	15	207

Table 3
Average daily discharge of mercury from Abu Kir effluents (kgd^{-1})

Mercury Species	Effluent	
	Tabia pumping station	Lake Edku outlet
Particulate (P)	2.54	1.57
Dissolved Reactive (DR)	0.51	0.18
Dissolved Organic (Dorg.)	0.08	0.06
Total Dissolved (TD)	0.59	0.24
Total	3.13	1.81

CONCLUSION

Mercury budget in Abu Kir Bay

— Amount of Hg exported from Abu Kir Bay to the open sea:

Fresh water input to the Bay from TPS and LEO = $1.8 \times 10^6 + 3.5 \times 10^6 = 5.3 \times 10^6$ m^3 d^{-1}
Average salinity of the Bay = 39.20%.
Abu Kir Bay contains 1.79% fresh water.
Abu Kir Bay surface area = 280×10^6 m^2.
Abu Kir Bay average depth = 10 m.
Abu Kir Bay volume = 2800×10^6 m^3.
Fresh water residence time in Abu Kir Bay = $\frac{\text{F. w. volume}}{\text{F. w. input}}$ = $50 \times 10^6 / 5.3 \times 10^6 = 9.4$ days.
The net export by water exchange (E) of a dissolved component from A to B can be approximately expressed as:

$$E = w(X_A - X_B)$$

Where, w is the water exchange rate due to mixing and X_A and X_B are concentrations of the conponent at A and B, respectively.

Therefore, $w = 2800 \times 10^6 / 9.4 = 298 \times 10^6$ m^3 d^{-1}
Taking $X_A = 10.18$ ngl^{-1} and
$X_B = 5.97$ ngl^{-1}

Therefore, $E = 298 \times 10^6 \times (10.18 - 5.97) = 1255$ gd^{-1} = 1.26 kgd^{-1}.

— *Mercury sedimentary flux for the whole Bay*

Bulk sedimentation rate = F = R(1 − p) d (Hamilton-Taylor, 1979).
where, R = Settling rate, P = Porosity of sediment and d = sediment dry density.

— *For Abu Kir Bay*

R = 0.35 cm yr^{-1}, P = 0.765 and d = 2.545 g cm^{-3} (Aboul Dahab, unpublished data).
Therefore, F for the whole Bay = $5.72 \times 280 \times 10^6 = 1601.6 \times 10^6$ gd^{-1}.
Hg sedimentary flux for the whole Bay = $1601.6 \times 10^6 \times 1.72\ 10^{-19} = 2.76$ kgd^{-1}.

The amount of rainfall over the Bay is negligible compared to the fluxes from the land based sources (Aboul Dahab, 1989). From the total Hg release to the Bay, 4.94 kgd^{-1}, flushing of the Bay to the open sea removes 25% and sedimentation within the Bay reaches 56% (2.76 kgd^{-1}). This budget is still preliminary but it provides estimations of the loads and the standing stock of Hg in the waters and biota of the Bay, which is about 0.92 kg.

Table 4
Mercury concentrations (ngl^{-1}) in sea water from the mediterranean and other regions

Hg species	Mean	Range	Location	Reference
Mediterranean:				
Open sea:				
T	92	62-110	Gibraltar	Roberson *et al*, 1972
TD	7	1-19	Tyrrhenian	Ferrara *et al*, 1986
R	2	1-10	Ligurian	Copin-Montegut *et al*, 1986
DR	3	1-6	Tyrrhenian	Ferrara *et al*, 1986
A	10	3-23	NW-Mediterranean	Aston *et al*, 1986
A	16	12-20	S-Levantine	Huynh-Ngoc & Fukai, 1979
P	2	0.3-8	Tyrrhenian	Ferrara *et al*, 1986
P	1	0.7-1.9	W-Ligurian	Buat-Menard *et al*, 1981
Coastal areas:				
T	70	12-280	Estuaries of Tuscan river	Breder *et al*, 1981
T	2	1-6	N-Tyrrhenian coast	Barghigiani *et al*, 1981
TD	6	1-8	Tyrrhenian coast	Ferrara *et al*, 1986
TD	93		Ionian sea	Alpha *et al*, 1982
R	2	1-3	Tyrrhenian coast	Ferrara *et al*, 1986
P	3	2-8	Tyrrhenian coast	Ferrara *et al*, 1986
TD	10		Mex Bay, Egypt	El-Rayis *et al*, 1986
P	39		Mex Bay, Egypt	El-Rayis *et al*, 1986
TD	7.7	3.9-12.6	Abu Kir Bay	Present study
P	28.5	2.1-91.4	Abu Kir Bay	Present study
Non-Mediterranean:				
Open Sea:				
T	2		N-Atlantic	Olafson, 1983
T	14	8-24	WN-Pacific	Miyake & Suzuki, 1983
R	2		N-Atlantic	Olafson, 1983
R	1		Hawai-Tahiti	Fitzgerald *et al*, 1983
P	1		WN-Pacific	Miyake & Suzuki, 1983
Coastal areas:				
T	12	6-16	Japan coast	Yamamoto *et al*, 1983
P	2	2-12	Suruga B. Japan	Fujita & Iwashima, 1981

(T = Total Hg, TD = Total Dissolved Hg, P = Particulate Hg, A = Hg determined by anodic stripping, R = Reactive Hg, DR = Dissolved Reactive Hg)

Table 5
Total mercury concentrations ($\mu g\ g^{-1}$ dw) in sediments from the mediterranean.

Mean	Range	Location	Reference
Open sea:			
0.24	0.07-0.38	NW-Mediterranean	Arnoux *et al*, 1983
0.13	0.16-0.57	SW-Mediterranean	Arnoux *et al*, 1983
	0.05-0.10	Adriatic sea	Selli *et al*, 1973
Coastal areas:			
8.50		Kastela Bay	Stegnar *et al*, 1981
	0.15-3.00	Gulf of Venice	Donazzolo *et al*, 1979
3.70	0.30-10.70	Mex Bay	El-Rayis *et al*, 1986
1.72	0.09-6.73	Abu Kir Bay	Present study

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