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Heavy metals and hazardous organic pollutants in sediment and mussels in the Gulf of Suez, 1999 and 2001

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Abstract

This paper presents the results of the EIMP monitoring of heavy metals and hazardous organic pollutants in sediment and mussels collected in the Gulf of Suez in 1999 and 2001.

The major findings were: The sediments were not polluted or only insignificantly polluted by heavy metals at the majority of the investigated sites in the Gulf of Suez. High levels of cadmium were found at Ras Gharib and Ras Shuker. The sediments on the northern most station in Suez bay had elevated concentrations of heavy metals. The concentrations of PCB in the sediments were low in the entire Gulf.

The study identified a number of pollution "hotspots" where the sediments were Suez Bay Which was polluted by Heavy metals (Copper, mercury, lead, zinc) on the northernmost site), PAH, Aliphatic hydrocarbons, Ain Sukhna was polluted by DDT, Aldrin, and aliphatic hydrocarbons, Ras Abu Darag was polluted by DDT, PAH, aliphatic hydrocarbons, Ras Gharib was polluted by Cadmium, DDT, HCH, Dieldrin, Aldrin, PAH, aliphatic hydrocarbons, Ras Shukeir was polluted by Cadmium, DDT, HCH, Dieldrin, Aldrin, PAH, aliphatic hydrocarbons, Ras El Sudr was polluted by HCH, PAH, Abu Rude by PAH, Abu Zenima by Dieldrin, aliphatic hydrocarbons and El: Tur was polluted by Dieldrin

Severely polluted by one or more pollutant. The worst affected areas are Ras Gharib and Ras Shukeir, where the sediments are severely polluted by cadmium, pesticides (DDT, HCH, Dieldrin, Aldrin) and petroleum hydrocarbons (PAH and aliphates) followed by Suez Bay that is polluted by heavy metals in the northern part and with PAH and aliphatic hydrocarbons. The sources of PAH and aliphatic

hydrocarbons on the sites are the oil production and transport activities in the areas. The sources of pesticides (DDT, HCH, Dieldrin and Aldrin) at Ras Gharib, Ras Shukeir and Ain Sukhna should be investigated, as there are no known agricultural activities, which normally are the sources of pesticides.

Introduction

The Coastal Water Monitoring Programme (CWMP) has established a marine monitoring system in the Egyptian coastal waters. The CWMP is part of the EIMP, which is directed by a Steering Committee with representatives from the EEAA and the Danish International Development Assistance (Danida). Now EIMP was directed by EEAA since June 2001. The EIMP Coastal Water Monitoring Programme comprises 1) Monitoring of water quality parameters (basic-, eutrophication and bacteriological parameters). 2) Monitoring of contaminants in sediments, mussels and corals and 3) Monitoring of benthos and coral reefs.

This paper presents the results of the EIMP monitoring of heavy metals and hazardous organic pollutants in sediment and mussels in the Gulf of Suez in 1999 and 2001.

The sampling sites for sediment and mussels (Brachiodontes sp.) are presented in Figure 1 and Table 1. In 1999 sampling took place during the period 8th - 22nd October. Sampling in 2001 was carried out from 4th to 12th February. The samples were analysed for the parameters indicated in Table 2. Sampling and analysing was carried out by NIOF Alexandria and papered in four volumes (Refs 1-4). This annual paper presents the major findings and the conclusions, which EIMP made based on the results from NIOF.

In this paper, the data have been compared to sets of international sediment quality standards i.e. "Ecological assessment criteria for trace metals and organic micro-contaminants in the North East Atlantic. Oslo and Paris Commission (OSPARCOM) 1994" (Table 1 in Appendix) and "Canadian Council of Ministers of the Environment (CCM) (1999). Canadian sediment quality guidelines for the protection of aquatic life".(Table 2 in Appendix)

NIOF expressed the results on organic pollutants in sediments on wet weight basis. Existing sediment quality standards are based on dry weight. In order to be able to compare the results with the existing standards the original data were converted to dry weight basis based on measurements of the dry matter content of the sediments, i.e.: Concentration on dry weight basis (Concentration on wet weight basis x 100) / (% Dry matter).

Table 1 Sampling stations and collected samples.

Station	Location	Number of sediment samples collected	Mussels
Su 1	Suez	Two samples	One sample
Su 2	Suez	Two samples	One sample
Su3	Suez	Two samples	One sample
Su3a	Suez	Two samples	One sample
Su 4	Ain Sukhna	Two samples	
Su 5	Ain Sukhna	Two samples	One sample
Su 6	Ain Sukhna	Two samples	One sample
Su 6 a	Ras Abu Darag	Two samples	One sample
Su 7	Ras Gharib	Two samples	One sample

Su 8	Ras Gharib	Two samples	One sample
Su 8a	Ras Gharib	Two samples	One sample
Su 8b	Ras Gharib	Two samples	One sample
Su 9	Ras Shukeir	Two samples	One sample
Su 9a	Ras Shukeir	Two samples	
Su 9b	Ras Shukeir	Two samples	
Su 10	Ras El Sudr	Two samples	One sample
Su 11	Abu Zenima	Two samples	One sample
Su 12	Ras Budran	Two samples	
Su 12a	Abu Rudeis	Two samples	
Su 12b	South of Abu Rudeis	Two samples	
Su 13	El Tur	Two samples	One sample
Su 13a	South of El Tur	Two samples	One sample

Table 2. Overview of analyses carried out on samples of sediments, mussels and corals in the Gulf of Suez/Red Sea in 1999 and 2001.

Parameter	Sediment		Mussels	
	1999	2001	1999	2001
Cadmium (Cd)	X	X	-	-
Copper (Cu)	X	X	-	X
Mercury (Hg)	-	X	-	X
Lead (Pb)	X	X	-	-
Zinc (Zn)	X	X	-	X
Total PCB	X	X	-	X
Total DDT	X	X	-	X
Total HCH	X	X	-	X
Cyclodienes	X	X	-	-
Total PAH	X	X	-	X
Total Aliphates	X	X	-	X

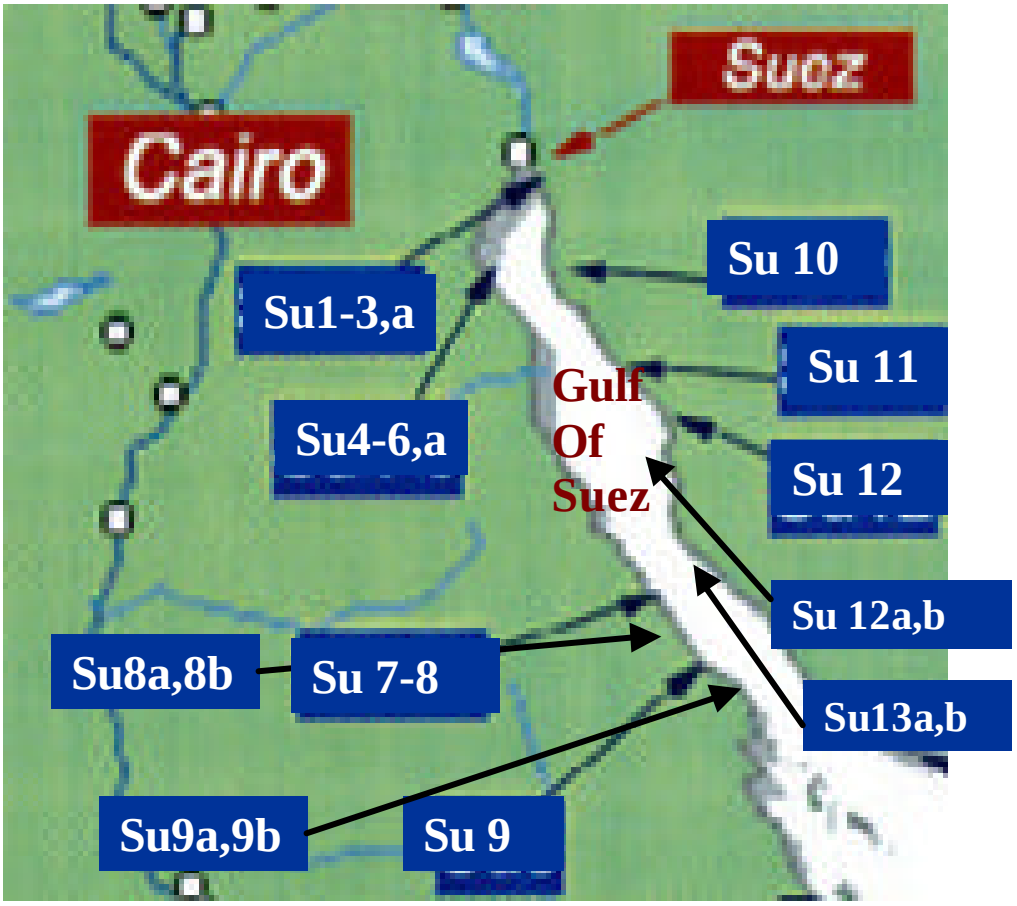

Figure 1. Sampling stations for sediments and mussels in the Gulf of Suez in 1999 and 2001.

Background

Heavy metals and hazardous organic pollutants, which are discharged to the sea, are generally adhered to fine-grained particles and settles with sediments on the seabed. Some of these contaminants can remain in the environment for a long time (such as DDT, PCB) and many of them cannot be degraded (heavy metals). They are ultimately accumulated in the sediments or in organisms. Heavy metals and persistent lipophilic organic compounds are absorbed and accumulated in organisms. This process is known as bioaccumulation. Bioaccumulated substances may be passed up the food chain to predator species. This process, which is known as biomagnification, is one of the ways that contaminants may become hazardous to people.

Heavy metals

Heavy metals in sediment

The measured concentrations of heavy metals in sediments on individual stations are depicted in Figs. 2-6. In table 3 the sediments are classified according to the criteria set by OSPARCOM 1994. Shading indicates the most polluted sites. Similar classifications do not exist for lead and zinc for which the CCM criteria have been used for comparison.

Except for cadmium, there is a decreasing trend in concentrations of heavy metals when moving from Suez Bay and southwards (Figs 2-6).

Generally, the sediment quality in terms of heavy metals can be classified as good and at some sites even very good and the concentrations encountered are well below toxic levels (Table 3)

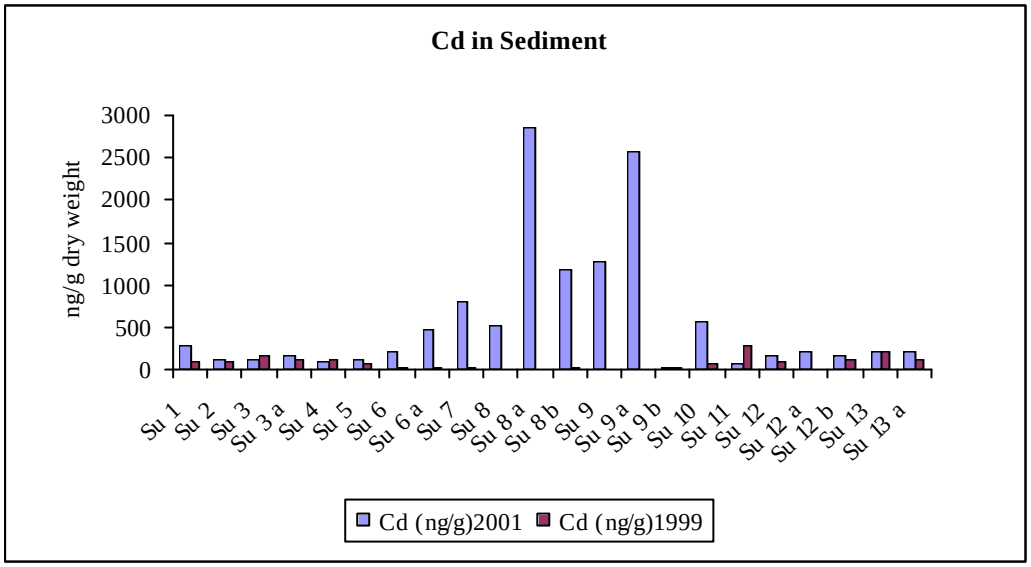

Figure.2. Concentration of Cadmium in Sediments in the Gulf of Suez 2001.

Significantly elevated concentrations of cadmium was found in the sediments in the areas around Ras Gharib and Ras Shukeir. Here, the sediment quality can be classified as poor to very poor. However, according to the CCM standards the concentrations are well below the level for which there is a significant risk of toxic effects (PEL=probable effects concentration). Concentrations at the most polluted sites range between 1.2 -2.8 µg/kg, but the PEL for cadmium is 4.2µg/kg.

The sediment quality on station 1 in Suez bay is also poor, but the levels are well below PEL so the risk of toxic effects due to heavy metals is small.

The concentrations of cadmium measured in the Gulf of Suez were in the range 11.5 - 2857 ng/g dry weight. The upper range corresponds to levels found in the Mediterranean Sea (114-2350 ng/g dry weight) (Ref 6 and Ref 7).

Concentrations of copper ranged between 1.6 and 42.5 µg/g dry weight. The highest value found in the Gulf of Suez was higher compared to levels encountered in the Mediterranean Sea (Ref 6) (range: 5.5 -26.4 µg/g dry weight.)

Excluding the highest value of lead concentration of 60 µg/g dry weight in the Suez Bay the range was 3.7- 31 µg/g dry weight. This corresponds to levels of 6.56-27.03 found in the Mediterranean (Ref 6)

Table 3. Characterisation of sediment quality in 1999 and 2001 according to concentrations of cadmium, copper and mercury according to OSPARCOM 1994. Criteria for the characterisation are presented in Table 1 in Appendix). Lead and Zinc have been compared to CCM standards (TEL= Threshold Effect Level, below which there is no risk of toxic effects. PEL= Probable effects level. For concentrations above PEL there is a significant risk of toxic effects.

Station	Location	Cadmium	Copper	Mercury	Lead	Zinc
Su 1	Suez	Good	Fair - Poor	Poor	< TEL/<PEL 2)	< TEL/<PEL 2)
Su 2	Suez	Good	Good	Good	< TEL	< TEL
Su3	Suez	Good	Very good	Good	< TEL/<PEL 2)	< TEL
Su3a	Suez	Good	Very good	Good	< TEL	< TEL
Su 4	Ain Sukhna	Good	Very good	Good	< TEL	< TEL
Su 5	Ain Sukhna	Good	Good	Good	< TEL	< TEL
Su 6	Ain Sukhna	Good	Very good	Very good	< TEL	< TEL
Su 6 a	Ras Abu Darag	Good-Fair1)	Very good	Very good	< TEL	< TEL
Su 7	Ras Gharib	Good -Poor1)	Very good	Very good	< TEL	< TEL
Su 8	Ras Gharib	Fair	Very good	Very good	< TEL	< TEL
Su 8a	Ras Gharib	Good-very poor1)	Very good	Good	< TEL	< TEL
Su 8b	Ras Gharib	Good-Poor1)	Very good	Good	< TEL	< TEL
Su 9	Ras Shukeir	Poor	Very good	Good	< TEL	< TEL
Su 9a	Ras Shukeir	Poor	Very good	Good	< TEL	< TEL
Su 9b	Ras Shukeir	Very good	Fair	Good	< TEL	< TEL
Su 10	Ras El Sudr	Good-Fair1)	Good	Good	< TEL	< TEL
Su 11	Abu Zenima	Good	Very good	Good	< TEL	< TEL
Su 12	Ras Budran	Good	Very good	Good	< TEL	< TEL
Su 12a	Abu Rudeis	Good	Very good	Good	< TEL	< TEL
Su 12b	Abu Rudeis	Good	Very good	Good	< TEL	< TEL
Su 13	El Tur	Good	Good	Good	< TEL	< TEL
Su 13a	South of El	Good	Very	Good	< TEL	< TEL

	Tur		good			

1) Different classification in 1999 and 2001
2) Below TEL in 2001 in 1999 above TEL but below PEL

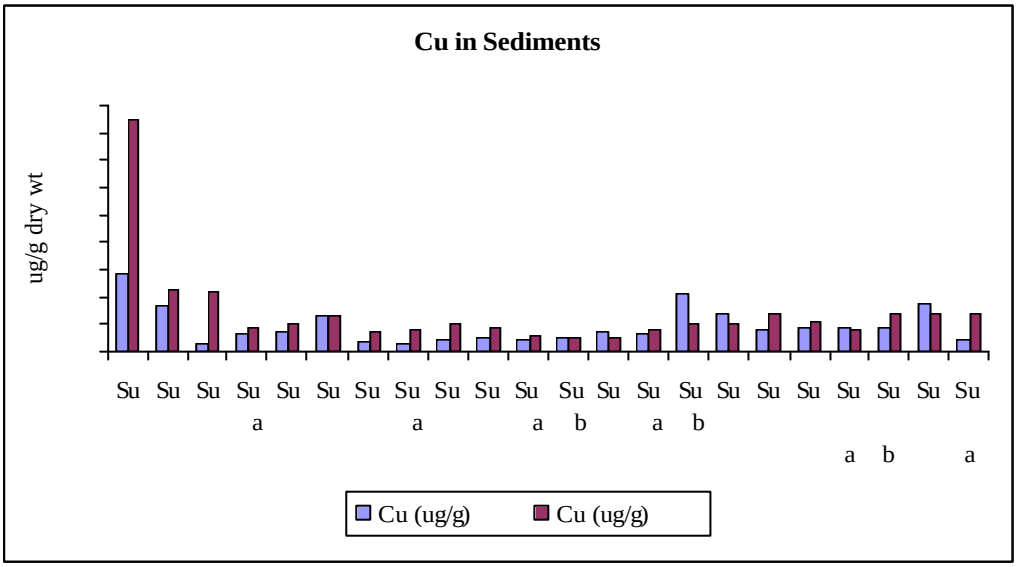

Figure 3. Concentrations of copper in Sediments in the Gulf of Suez 1999 and 2001

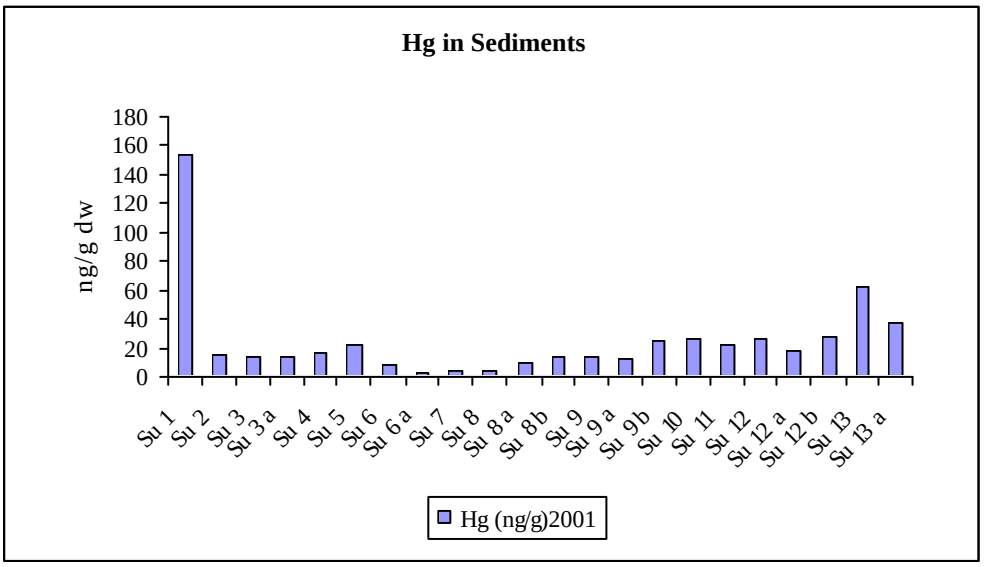

Figure 4. Concentration of mercury in sediments in the Gulf of Suez 2001

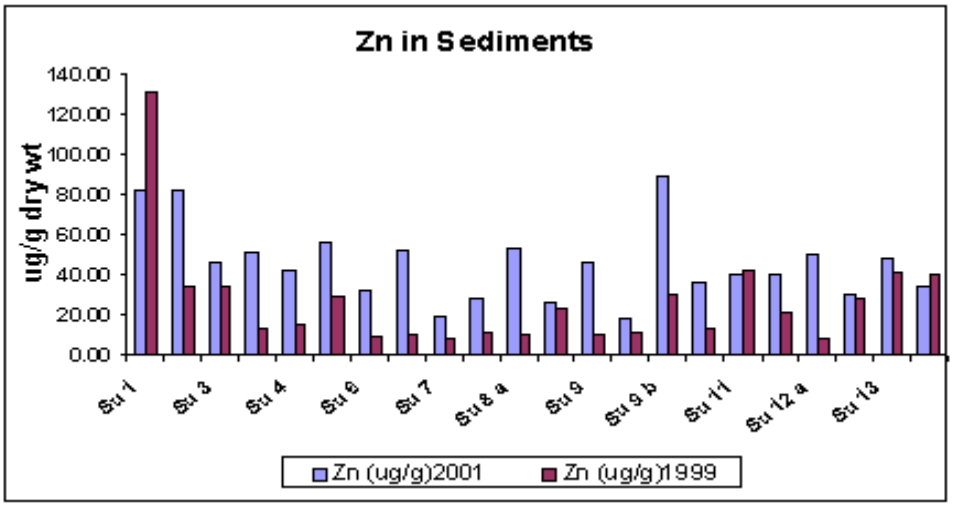

Figure 6. Concentration of Zinc in Sediments in the Gulf of Suez 1999 and 2001

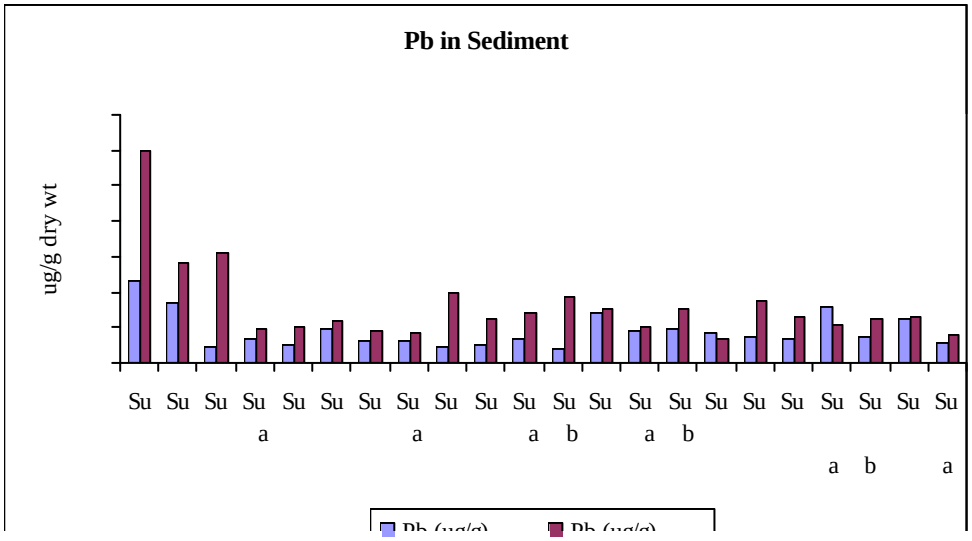

Figure 5. Concentration of Lead in sediments of the Gulf of Suez 1999 and 2001.

Excluding the highest value of mercury concentration of 153.3 ng/g dry weight in the Suez Bay the range was 0.002- 0.153 µg/g dry weight. This is lower corresponds to levels of 0.2-2.3 µg/g found in the Mediterranean (Ref 7). Zinc ranged between 8 and 131 µg/g dry weight ie same order of magnitude as concentrations found in the Mediterranean Sea (27.5-92.8 µg/g dry weight) (Ref 6).

Heavy metals in mussels

Figs 7-9 show the concentrations of copper, zinc and mercury in mussels collected in the Gulf of Suez in 2001.

The heavy metal content in the mussels did not follow the pattern observed in the sediments, where a clear gradient of decreasing concentration from the northern part of the Suez Bay towards the south was observed. In the mussels there were no clear patterns in concentration in relation to expected pollution sources.

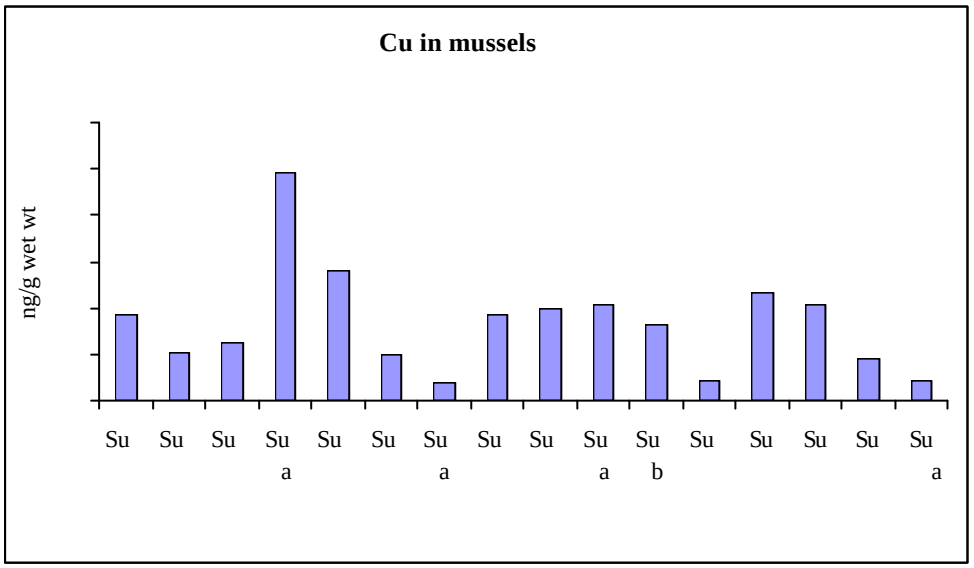

Figure 7. Concentration of Cu in mussels collected in the Gulf of Suez 2001

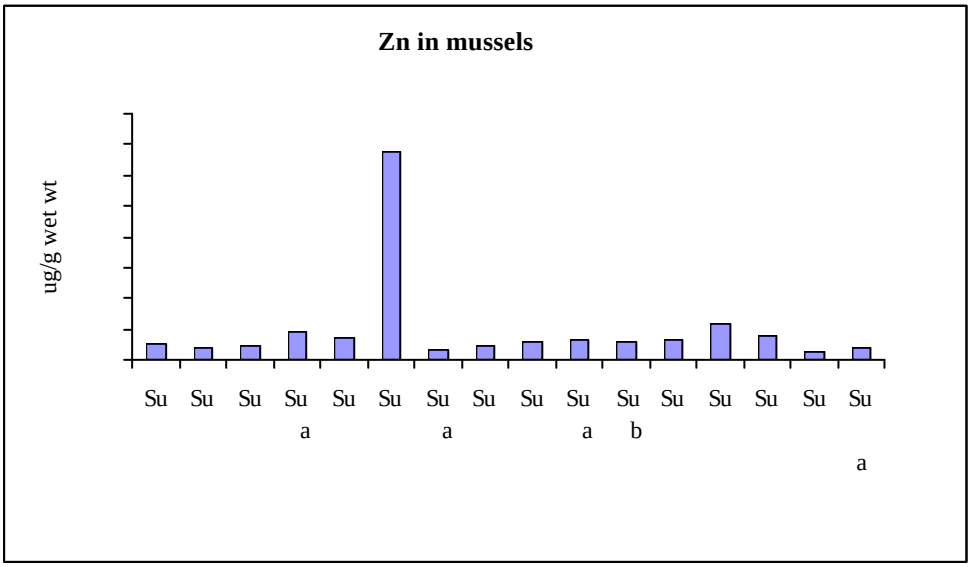

Figure 8. Concentration of Zinc in mussels collected in the Gulf of Suez in 2001

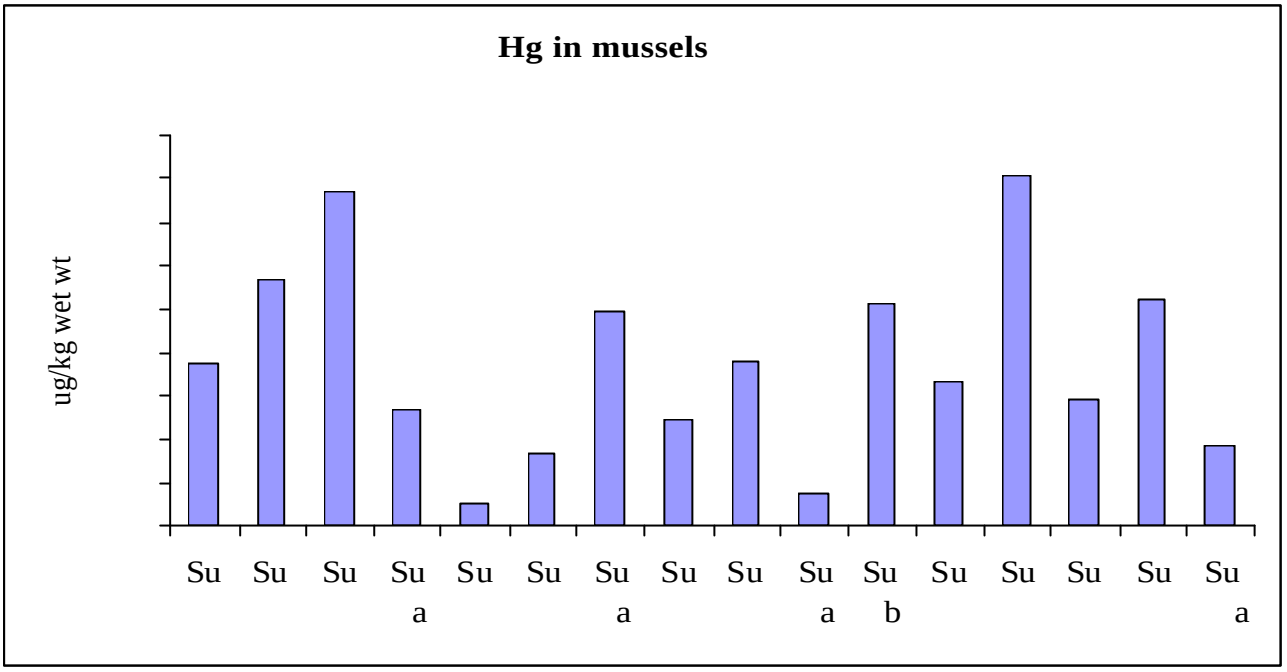

Figure 9. Concentration of mercury in mussels collected in the Gulf of Suez in 2001.

Organic hazardous pollutants

DDT

DDT has been used as an insecticide. Due to its harmful impact in the environment and its high carcinogenic potential in humans it has been banned for about 20 years in many countries. DDT is very persistent in the environment and is readily picked up in marine organisms and food webs because they are adsorbed on sediment and other organic matter. DDT gradually breaks down to toxic metabolites (DDE, DDD). DDT is very toxic to aquatic organisms such as fish and may impact reproduction and development as well as immune systems and nervous systems in birds and mammals. DDT also has a high carcinogenic potential in humans.

DDT in Sediments in Gulf of Suez

The measured concentrations of total DDT in sediments on individual stations are depicted in Fig. 10. Total DDT is the sum of DDT and the metabolites DDD and DDE. In table 4 the sediments on each location is classified according to the criteria set by OSPARCOM 1994. The most polluted sites are indicated by shading.

High levels of total DDT were encountered in the sediments at Ain Sukhna (SU6), Ras Abu Daragh (SU 6a), Ras Gharib (SU 8 a) and Ras Shukeir (SU 9 and SU 9b) (Fig 10). The sediment quality at these locations could be classified as poor to very in terms of content of DDT.

The sediment quality was good to fair at the remaining sites in the Gulf of Suez.

The range of concentration encountered in the Gulf of Suez was 0.04- 5.87 ng/g dry weight. This is a little higher compared to levels of 0.23-2.9 ng/g dry weight found from Abadan to Hormuz (Ref. 9)

Table 4. Characterisation of sediment quality in terms of concentration of organic hazardous pollutants according to OSPARCOM 1994 (categories very good, good, fair, poor and very poor). Criteria for the characterisation are presented in Table 1 in Appendix)

Station	Location	DDT	PCB	HCH	Dieldrine
Su 1	Suez	Fair	Good	Poor	Good
Su 2	Suez	Fair	Good	Fair	Good
Su3	Suez	Fair	Good	Poor	Good-Fair1)
Su3a	Suez	Good	Good	Fair-poor1)	Very good1)
Su 4	Ain Sukhna	Good	Good	Good-Fair1)	Very good1)
Su 5	Ain Sukhna	Good-Fair1)	Good	Good-Fair1)	Good
Su 6	Ain Sukhna	Poor	Good	Fair-Poor1)	Fair
Su 6 a	Ras Abu Darag	Fair-Poor1)	Good	Poor	Good-Fair1)
Su 7	Ras Gharib	Fair	Good	Fair	Poor
Su 8	Ras Gharib	Fair	Good	Very Poor1)	Good-Poor1)
Su 8a	Ras Gharib	Fair-Poor1)	Good	Very Poor1)	Fair-Poor1)
Su 8b	Ras Gharib	Good-Fair1)	Good	Fair-Poor1)	Good-Fair1)
Su 9	Ras Shukeir	Poor	Good	Poor-Very Poor1)	Good-Poor1)
Su 9a	Ras Shukeir	Good-Fair1)	Good	Poor	Poor
Su 9b	Ras Shukeir	Fair-Poor1)	Good	Very Poor1)	Fair-Poor1)
Su 10	Ras El Sudr	Good-Poor1)	Good	Poor-Very Poor1)	Good
Su 11	Abu Zenima	Good-Fair1)	Good	Good-Poor1)	Poor
Su 12	Ras Budran	Good	Good	Good-Poor1)	Fair - Very good1)
Su 12a	Abu Rudeis	Good	Good	Good-Poor1)	Very good
Su 12b	South of Abu Rudeis	Good-Fair1)	Good	Poor	Good-Very good1)
Su 13	El Tur	Good-Fair1)	Good	Fair-Poor1)	Good-Very good1)
Su 13a	South of El Tur	Fair	Good	Poor	Poor

1) Different classification in 1999 and 2001

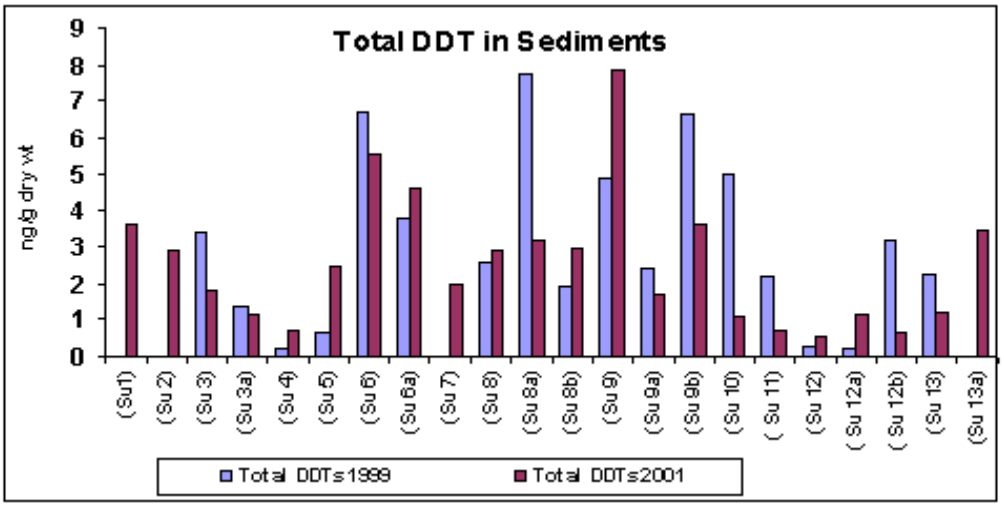

Figure 10. Concentration of total DDT in sediments collected in the Gulf of Suez 1999 and 2001

DDT in mussels in Gulf of Suez

The concentrations of DDT in the mussels did not follow the pattern observed for sediments. The highest concentration was observed at SU3a in the Bay of Suez, at a site were the concentration of DDT in was quite low in the sediment. (Fig 11).

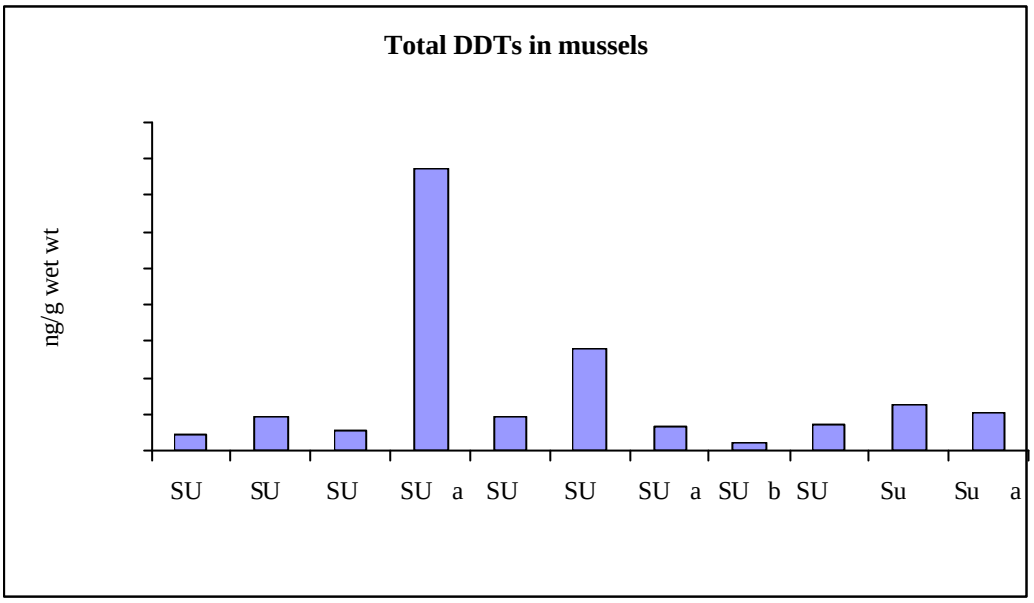

Figure 11. Concentration of total DDT in mussels collected in the Gulf of Suez 1999 and 2001

HCH

HCH (Hexachlorocyclohexane) is very toxic and is used as an insecticide. HCH is banned or severely restricted in more than sixty countries. HCH is readily picked up in marine food webs because they are adsorbed on sediment and other organic matter and bioaccumulating. Bacteria and fungi can break HCH down into less harmful substances

HCH in Sediments in Gulf of Suez

There is a problem with HCH in the Gulf of Suez. The sediment quality regarding HCH is poor due to HCH (Table 4 and Fig 12). The worst affected areas are:

? Ras Gharib (SU 8 and SU 8a)

? Ras Shukeir (SU 9 and SU 9b)

? Ras El Sudr (SU 10)

In these areas very high levels of HCH in the range 1.7 - 4.9 µg/kg were encountered. According to the Canadian sediment quality criteria there is a high risk of toxic effects on aquatic organisms at these concentrations. The concentrations on the other sampling sites in the Gulf do not pose a severe risk of toxic impacts.

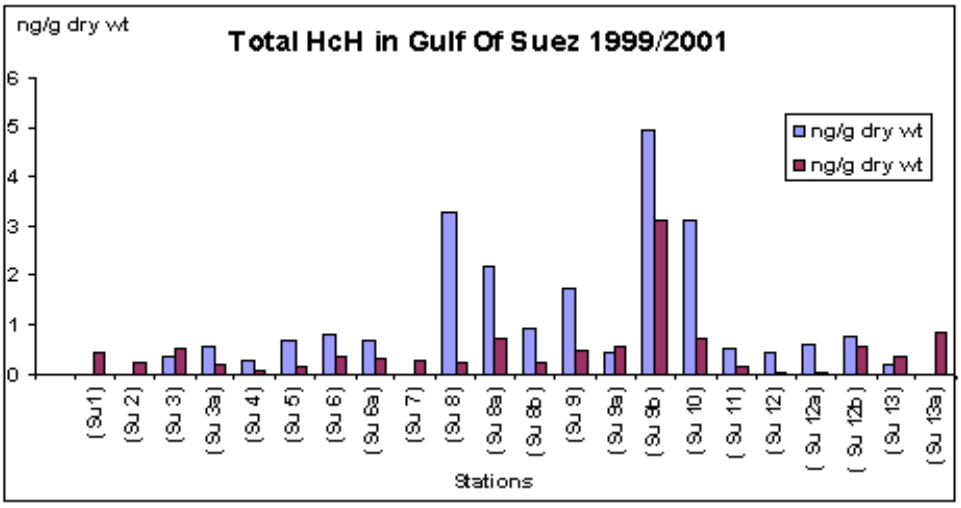

Figure 12. Concentration of total HCH in sediments in the Gulf of Suez 1999 and 2001

HCH in mussels in Gulf of Suez

The highest concentrations of HCH in mussels were encountered on the northernmost sites from Suez Bay to Ras Gharib. This is in contrast to the sediments, where the highest concentrations were measured further south (from Ras Gharib to Ras Shukeir) and at Ras El Sudr on Sinai.

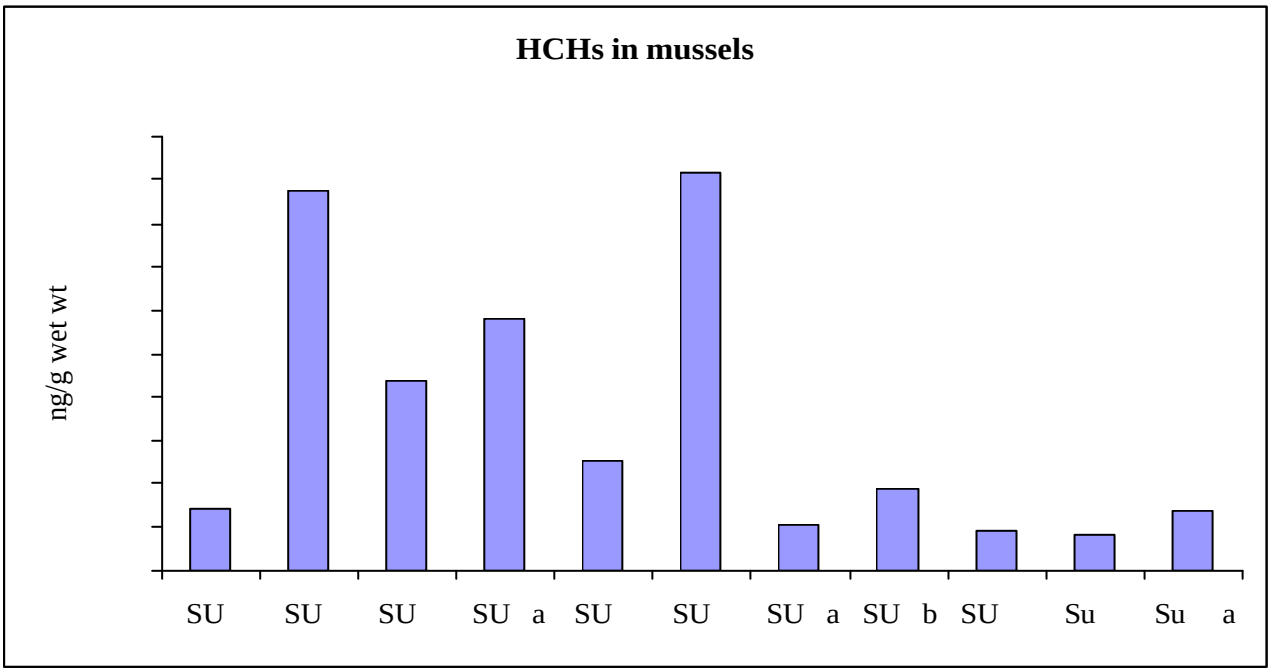

Figure 13. Concentration of HCH in mussels collected in the Gulf of Suez in 2001

Cyclodienes

Cyclodienes is a class of chemical compounds including such chemical as aldrin, dieldrin, chlordane and endrin. These chemicals are used as insecticides and rodenticides. Production of chlordane was suspended in 1976. Aldrin and dieldrin is banned in most developing countries. Cyclodienes are readily bioaccumulated and picked up in marine food webs because they are adsorbed on sediment and other organic matter.

Cyclodienes in Sediments in Gulf of Suez

Poor sediment quality due to high concentrations of Dieldrin was found in sediments collected at Ras Gharib (SU7, SU 8 and SU 8a), Ras Shukeir (SU 9 and SU 9a and SU 9b), Abu Zenima (SU 11) and at El Tur (SU 13 a)(Fig 14 and Table 3). The levels were however not toxic. At the other sites sediment quality ranged from very good to fair.

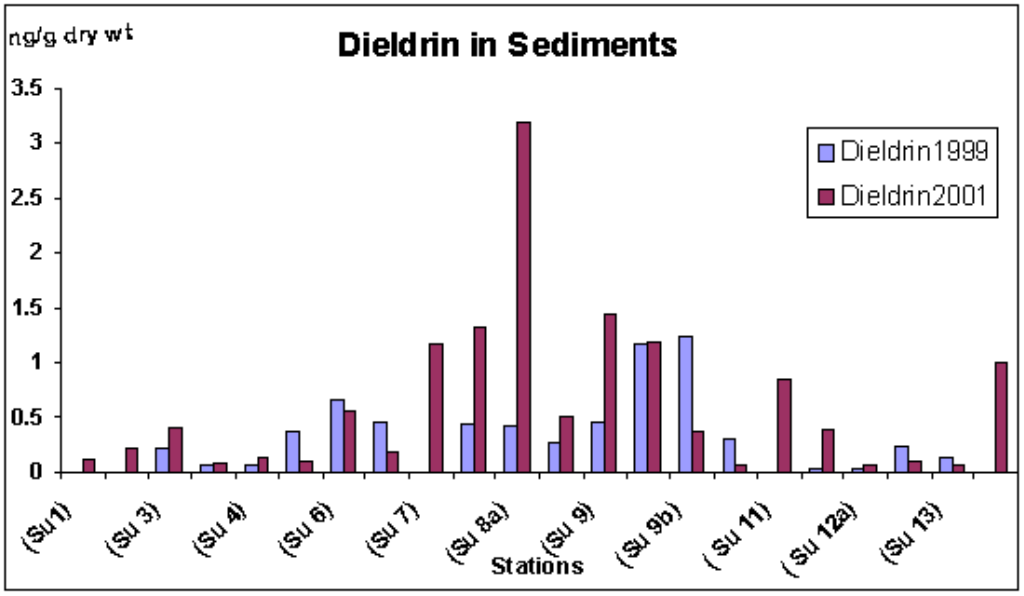

Figure 14. Concentration of Dieldrin in sediments collected in the Gulf of Suez in 1999 and 2001

Elevated concentrations of Aldrin were found at Ain Sukhna, Ras Gharib and Ras Shukeir (Figure 15) from

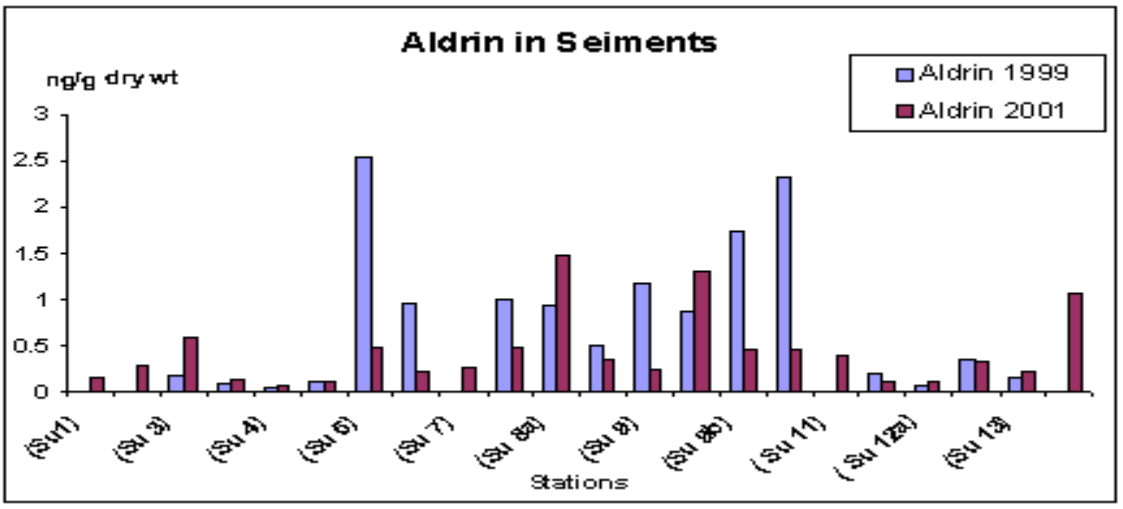

Figure 15. Concentration of Aldrin in sediments collected in the Gulf of Suez in 1999 and 2001

Cyclodienes in mussels in Gulf of Suez

As for HCH, the highest concentrations of cyclodienes in mussels were encountered on the northernmost sites from Suez Bay to Ras Gharib (Fig 16)

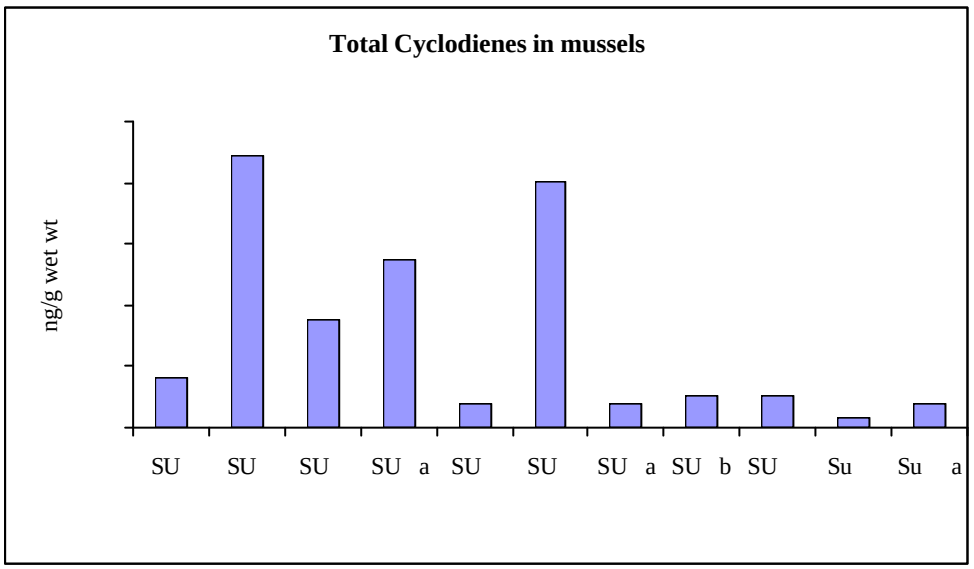

Fig 16. Concentrations of total cyclodienes in mussels collected in the Gulf of Suez 2001

PCB

PCBs (Polychlorinated biphenyls) are a group of highly toxic chemicals used for various industrial purposes (dielectrics, coolants and lubricants in electrical transformers, other electrical equipment, in heat transfer systems and in plastics). Released into environment from old electrical devices and the improper disposal of incineration of PCBs and waste containing PCBs. PCBs are persistent and readily picked up in marine food webs because they are adsorbed on sediment and other organic matter and are strongly bioaccumulating. PCBs may cause impacts on reproduction, immune systems and nervous systems in mammals and they have High carcinogenic potential in humans.

PCB in Sediments in Gulf of Suez

The concentrations of PCB in the sediments were low. The sediments could be characterised as of good quality regarding PCB and the values were well below the Canadian TEL values, indicating that the PCB concentrations were way below toxic concentrations. There were no clear gradient pattern in concentrations along the coast (Table 3 and Fig 17)

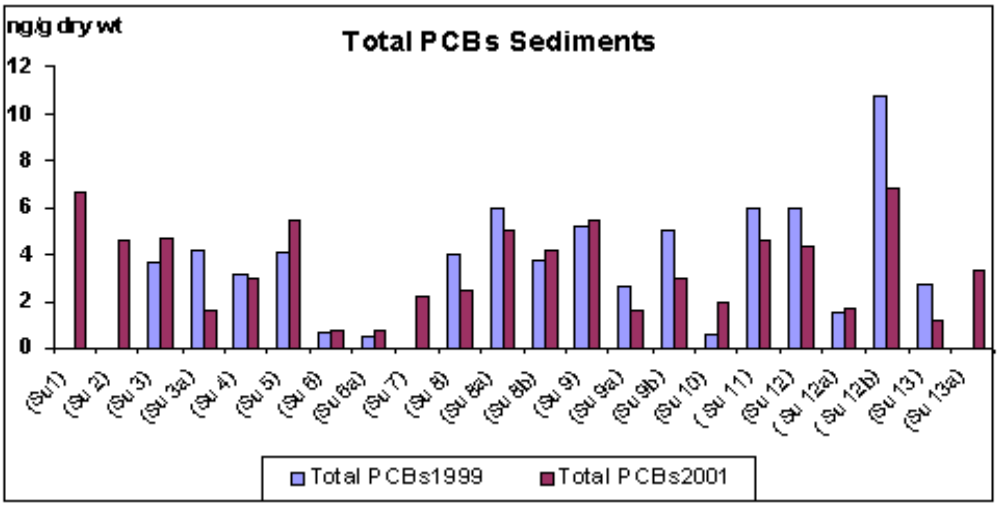

Figure 17. Concentration of total PCBs in sediments collected in the Gulf of Suez in 1999 and 2001

PCB in mussels in Gulf of Suez

The concentrations of PCB in mussels largely follow the pattern observed for sediments (Fig 18)

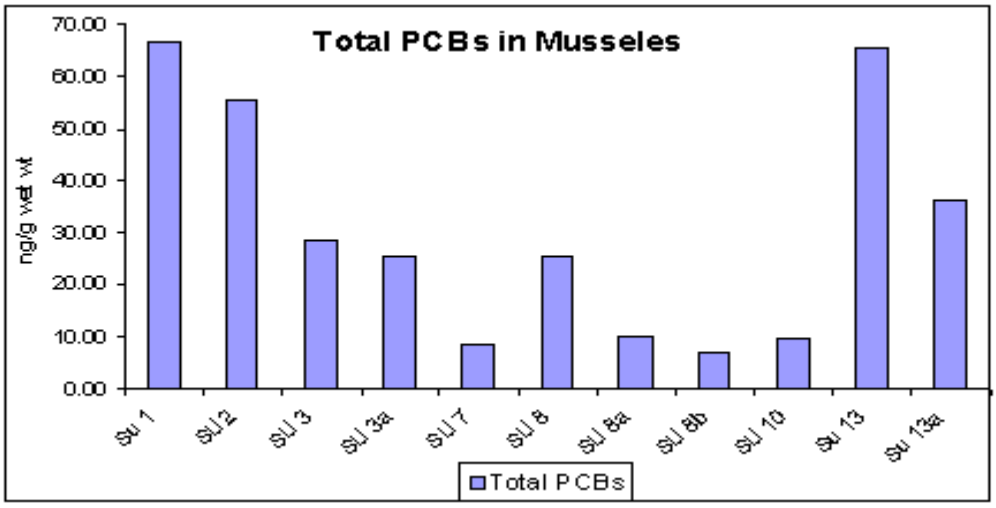

Figure 18. Concentration of total PCBs in mussels collected in the Gulf of Suez in 2001

PAH

Polyaromatic hydrocarbons (PAH) are components of raw oil and refined oil products. They are released into the environment from oil production facilities, refineries, ships, industries etc.. They are readily picked up in marine food webs because they are adsorbed on sediment and other organic matter and are bioaccumulating. PAHs are toxic to marine organisms and may be carcinogenic.

PAH in Sediments in Gulf of Suez

The highest concentrations of PAH were found in sediments at (Cf. Fig. 19):

? Suez Bay (SU1, SU2,and SU3)

? Ras Abu Darg (SU 6a)

? Ras Gharib (SU 8b)

? Ras Shukeir (SU 9b)

? Ras El Sudr (SU 10) and

? Abu Rudeis (SU 12a, SU 12b)

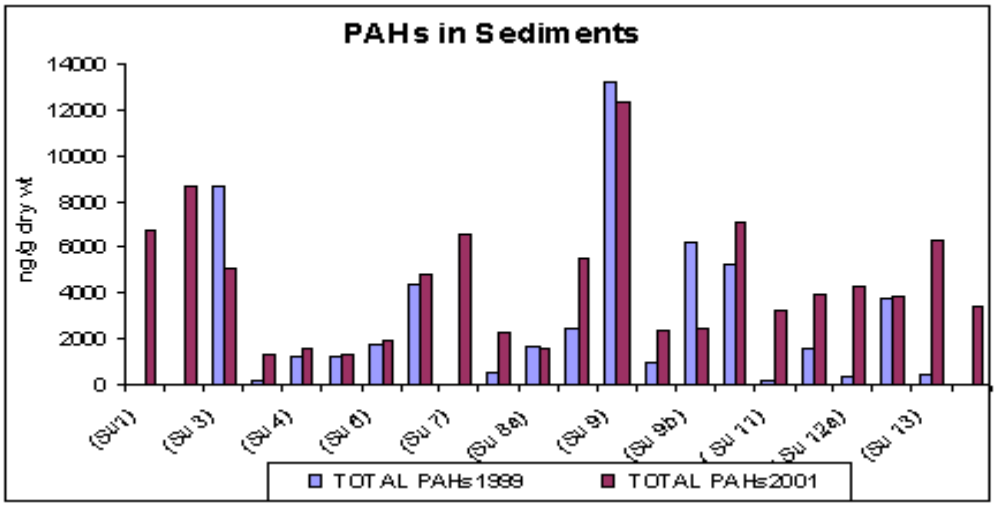

Figure 19. Concentration of total PAHs in sediments collected in the Gulf of Suez in 1999 and 2001

PAH in mussels in Gulf of Suez

The highest concentrations of PAHs in mussels were encountered in Gulf of Suez (Fig 20)

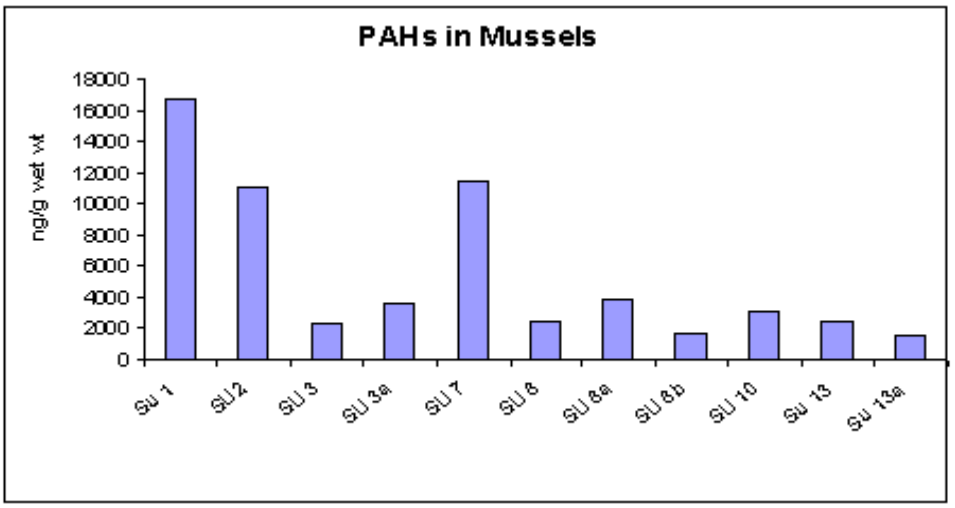

Figure 20. Concentration of total PAHs in mussels collected in the Gulf of Suez in 2001

Aliphates

Aliphates are components of raw oil and refined oil products. They are released into the environment from oil production facilities, refineries, ships, industries etc.

Aliphates in Sediments in the Gulf of Suez

The highest concentrations of aliphates were found in sediments at (Cf. Fig. 21):

? Suez Bay (SU3)

? Ain Sukhna (SU4, SU 6))

? Ras Abu Darg (SU 6a)

? Ras Gharib (SU 8, SU 8b)

? Ras Shukeir (SU 9, SU 9a, SU 9b)

? Abu Zenima (SU 1)

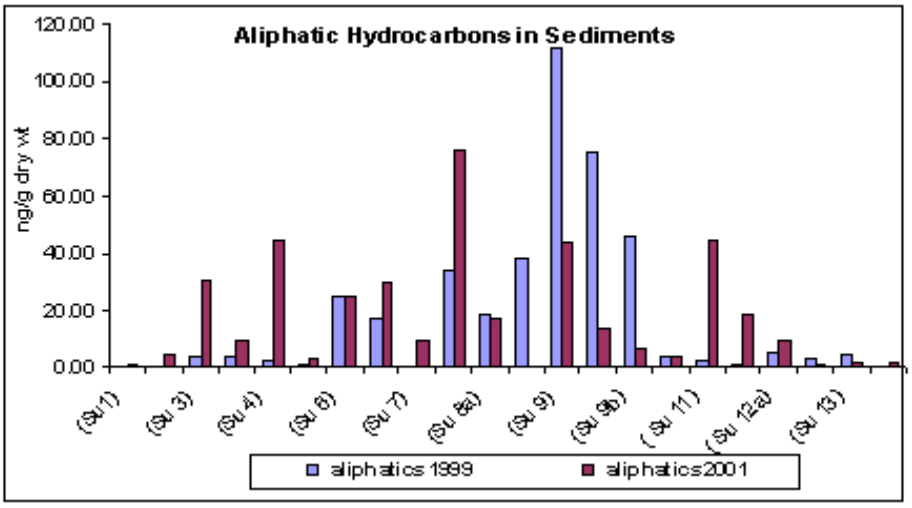

Figure 21. Concentration of aliphatic hydrocarbons in sediments collected in the Gulf of Suez in 1999 and 2001

Discussion and conclusion

The major findings of the sediment and biota monitoring in 1999 and 2001 can be summarised as follows:

? The sediments were not polluted or only insignificantly polluted by heavy metals at the majority of the investigated sites in the Gulf of Suez. Generally, the sediment quality was good and at some sites even very good regarding the content of heavy metals and the concentrations was well below toxic levels. There was a decreasing trend in concentrations of copper, mercury, lead and zinc when moving from Suez Bay and southwards. In the areas around Ras Gharib and Ras Shukeir the sediment quality can be classified as poor to very poor due to elevated concentrations of cadmium. However, the concentrations are well below the level for which there is a significant risk of toxic effects. The sediment quality on the northernmost station in Suez bay is also poor due to elevated concentrations of heavy metals, but the levels are well below the levels for which there is a significant risk of toxic effects.

? High levels of total DDT were encountered in the sediments at Ain Sukhna, Ras Abu Daragh, Ras Gharib and Ras Shukeir.. The sediment quality at these locations could be classified as poor to very poor regarding content of DDT. The sediment quality was good to fair at the remaining sites in the Gulf of Suez.

? There is a problem with HCH in the Gulf of Suez. The sediment quality is poor due to HCH. The worst affected areas are: Ras Gharib, Ras Shukeir and Ras El Sudr. In these areas very high and potentially toxic levels of HCH were encountered. The concentrations on the other sampling sites in the Gulf do not pose a severe risk of toxic impacts.

? Poor sediment quality due to high concentrations of Dieldrin was found in sediments collected at Ras Gharib, Ras Shukeir, Abu Zenima and at El Tur. At the other sites sediment quality ranged from very good to fair.

? The concentrations of PCB in the sediments were low in the entire Gulf. The sediments could be characterised as of good quality regarding PCB and the values were well below toxic concentrations.

? The highest concentrations of PAH were found in sediments at Suez Bay, Ras Abu Darg, Ras Gharib, Ras Shukeir, Ras El Sudr and Abu Rudeis.

? The highest concentrations of aliphatic hydrocarbons were found in sediments at Suez Bay, Ain Sukhna, Ras Abu Darg, Ras Gharib, Ras Shukeir and Abu Zenima.

Table 5 summarises pollution "hot-spots" in the Gulf of Suez and the pollutants found in high concentrations at the sites.

Table 5. Pollution "hotspots" in the Gulf of Suez, i.e. areas severely polluted by one or more pollutants

Area	Pollutants
Suez Bay	Heavy metals (Copper, mercury, lead, zinc) on the northernmost site), PAH, Aliphatic hydrocarbons.
Ain Sukhna	DDT, Aldrin aliphatic hydrocarbons
Ras Abu Darag	DDT, PAH, aliphatic hydrocarbons
Ras Gharib	Cadmium, DDT, HCH, Dieldrin, Aldrin, PAH, aliphatic hydrocarbons
Ras Shukeir.	Cadmium, DDT, HCH, Dieldrin, Aldrin, PAH, aliphatic hydrocarbons
Ras El Sudr	HCH, PAH
Abu Rudeis	PAH
Abu Zenima	Dieldrin, aliphatic hydrocarbons
El Tur	Dieldrin

The worst affected areas are Ras Gharib and Ras Shukeir where the sediments are severely polluted by cadmium, pesticides (DDT, HCH, Dieldrin, Aldrin) and petroleum hydrocarbons (PAH and Aliphates) followed by Suez Bay which is polluted by heavy metals in the northern part and with PAH and aliphatic hydrocarbons.

The sources of PAH and aliphatic hydrocarbons in Suez Bay, Ain Sukhna/Ras Abu Darag, Ras Gharib , Ras Shukeir, Abu Rudeis and Abu Zenima are the oil production facilities in the areas:

? In Suez , there are three oil refineries located in the harbour area of Suez City, immediately east of the Suez Canal, in addition ships awaiting transit through the Suez Canal may be sources of oil pollution

- Ain Sukhna houses the oil terminal for the SUMED oil pipeline for transmission of oil to Alexandria
- The most extensive oil activity in Egypt takes place in the Ras Ghârib area. There are activities approximately 40 km north and 40 km south of Ras Ghârib (both offshore production platforms and onshore facilities).
- Ras Shukheir houses the Gulf of Suez Petroleum Co (GUPCO) facility and offshore oil production platforms
- There are offshore oilfields off Abu Zenima
- Immediately north of Abu Rudeis City there is a receiving facility for offshore oil fields (Suez Oil Company).

The sources of pesticides (DDT, HCH, Dieldrin and Aldrin) at Ras Gharib, Ras Shukeir and Ain Sukhna should be investigated, as there are no known agricultural activities, which normally are the sources of pesticides.

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APPENDIX 1

Criteria for the classification of the degree of pollution by heavy metals and hazardous organic pollutants in sediments.

Table 1. Criteria for the characterisation of sediment quality according to concentration of Cadmium, Mercury, Copper, PCB, Total DDT and Dieldrin. Assessment criteria elaborated by the Oslo and Paris Commission 1994.

	Very Good	Good	Fair	Poor	Very Poor
Cadmium (mg/kg DW*)	Background levels	< 0.34	0.34 -0.68	> 0.68 - 4.21	> 4.21
Mercury (mg/kg DW*)	Background levels	< 0.07	0.07 - 0.13	> 0.13 - 0.7	> 0.7
Copper (mg/kg DW*)	Background levels	< 9.35	9.35 - 18.7	> 18.7 - 108	> 108
PCB (µg/kg DW*)	Less than limit of detection	< 10.8	10.8 - 21.6	>21.6 - 189	> 189
Total DDT (µg/kg DW*)	Less than limit of detection	< 1.95	1.95 - 3.89	> 3.89 - 5.17	> 5.17
HCH (µg/kg DW*)	Less than limit of detection	< 0.16	0.16 - 0.32	> 0.32 - 0.99	> 0.99
Dieldrin (µg/kg DW*)	Less than limit of detection	< 0.36	0.36 - 0.72	> 0.72 - 4.3	> 4.3

*DW=dry weight

Table 2. Criteria for the characterisation of sediment quality according to Canadian sediment quality standards.

	TEL1)	PEL2)
Cadmium (mg/kg DW*)	0.7	4.2
Mercury (mg/kg DW*)	0.13	0.7
Copper (mg/kg DW*)	18.7	108
Lead (mg/kg DW*)	30.2	112
Zinc (mg/kg DW*)	124	271
Total PCB (µg/kg DW*)	21.5	189
HCH (Lindane) (µg/kg DW*)	0.32	0.99
Dieldrin (µg/kg DW*)	0.71	4.30
DDTs:		
DDD (µg/kg DW*)	3.54	8.51
DDE (µg/kg DW*)	1.42	6.75
DDT (µg/kg DW*)	1.19	4.77

1) TEL = Threshold effect level

2) PEL = Probable effect level

The two guideline values TEL and PEL delineate three concentration ranges for a particular chemical:

? Concentrations below the TEL value represent concentrations, which are not expected to cause any adverse biological effects.

? Concentrations equal to and above TEL, but below the PEL represent a range of concentrations within which effects may occasionally occur on sensitive organisms, but there is only a slight risk.

? Concentrations equivalent to and above the PEL value represent a probable-effects range within which adverse biological effects would frequently occur