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Temporal and Spatial Distribution of Heavy Metals in Obhur Creek, A Coastal Red Sea Water Body North of Jeddah

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ABSTRACT. The present work is concerned with study of the concentrations of Mn, Cu, Zn and Cd in the water and their levels in the plankton inhabited the surface water of Obhur Creek. The vertical distribution pattern of dissolved metals shows that the mean values calculated for all metals in the surface water gave a slight decrease (except for Mn) in October and an increase in January (except for Cd) relative to that of the bottom water. The data suggest that stagnant conditions of the creek water have lead to such surface decrease and restriction of metal replenishment in October (late summer). The exchange of water inside the creek with that of the open Red Sea water outside the creek which takes place after summer, accompanied with a diminish in biological activity could be responsible for the relative increase in surface metal content in the creek water in January. Surface distribution of dissolved metals showed elevated values near the mouth or the head of the creek. The mixing between the surface water inside and outside the creek in the vicinity of its mouth could be responsible mainly for that high metal content near the mouth. Moreover, the injection of metal from enriched bottom water to the upper layer is also responsible for the high metal concentrations in the surface water near the head of the creek due to its shallowness. The metal content in the plankton reflects its main role in controlling the levels of heavy metals in the water of the creek. Comparison between the data of the present and previous studies with data from other regions reveals warning from the increase in concentrations of metals in Obhur Creek, due principally to human impact.

Introduction

Obhur Creek is a tidal narrow and winding creek located at 35 km north of Jeddah, between latitude 21°42'11" and 21°45'24" and longitude 39°05'12" and 39°08'48"E (Fig. 1). The creek, about 9 km with an average width of 0.5 km, is narrow and deep at its mouth, where a depth of about 50 m is reached. The water depth decreases gradually landward reaching about 3 m at its head. The fringing reef patterns of the coast continue into the outer part of the creek. Most of the creek sediments are indigenous carbonates mixed with clastic materials in different proportions (Behairy, 1980).

The creek is a public recreational area and consequently it is necessary to monitor the quality of its environment to protect human health. The creek was subjected to some investigations on its hydrobiology (Dowidar *et al.*, 1978) and geology (Behairy, 1980). The present work is concerned with the distribution of Mn, Cu, Zn and Cd in the water and their levels in the plankton in the surface water. These organisms have been selected as they represent the first trophic level in the food chain.

Materials and Methods

The study area and sampling sites are shown in Fig. 1 and 2. Six stations representing different sites of the creek were selected. Water and plankton samples were collected from surface layer at all stations. Subsurface water samples were also collected at all stations except the shallower station I. Collection of samples were carried out during four cruises for plankton and two cruises for water analysis.

Water Samples

Surface water samples were collected directly in 5 l

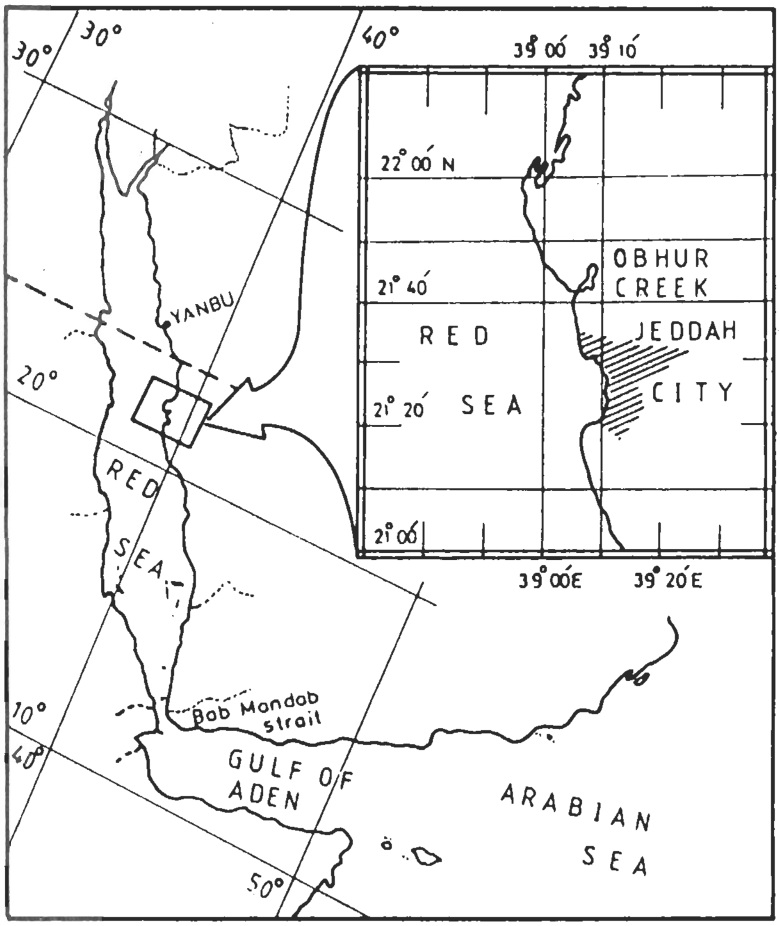

FIG. 1. Map of the Red Sea and location of Obhur Creek, north of Jeddah.

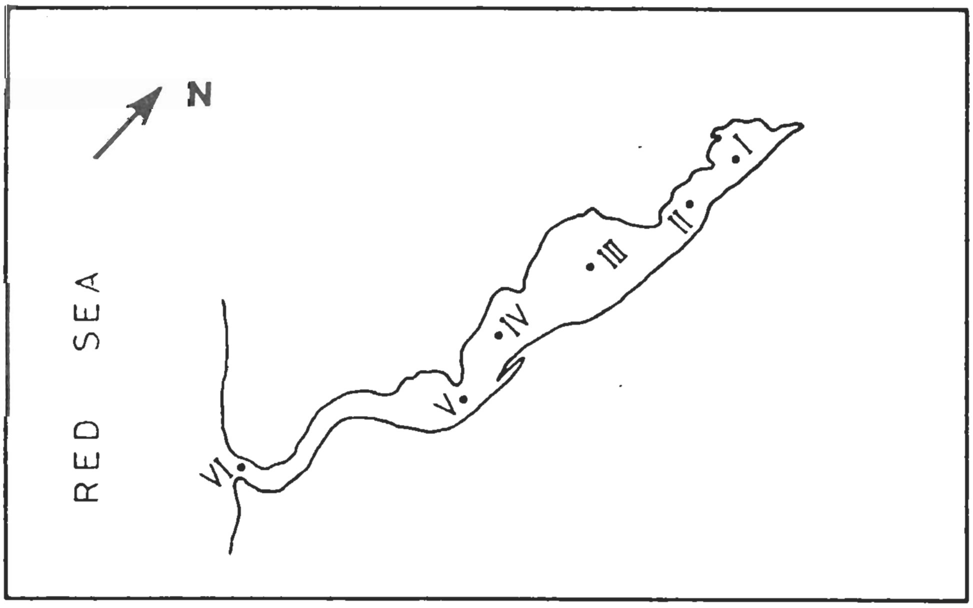

FIG. 2. Study area of Obhur Creek and position of stations.

acid washed high density white polyethylene at about 30 cm below the surface water to avoid contamination from the surface film. The subsurface water samples were also collected using plastic sampler. Before sampling, Jerrycans were cleaned by 6M HNO_3 and rinsed with deionized water. The water samples were filtered through 0.45 μm millipore membrane filters, which had been previously washed with deionized water. The filterate (5 l) was allowed to pass through a glass column containing the ammonium form of Chelex – 100 resin to preconcentrate the dissolved trace metals (Abdullah and Royle, 1974). The metals on the resin were eluted with silica distilled 2M HNO_3 and evaporated to near dryness. One ml of 6M HNO_3 was added to dissolve the metals in the residue and the volume was made up to 25 ml using deionized water. The blank was determined by passage about 5 l seawater stripped of heavy metals through a chelex – 100 column of ammonium form. The column had been treated in the same way like sample.

Plankton Samples

A phytoplankton net (50 μm mesh size) was used to collect plankton. The samples were filtered using pre-weighed 0.45 μm millipore membrane filter and then dried at 80°C to constant weight. Filters with their contents were hot digested with concentrated HNO_3 for the extraction of the metals according to the method described by Riley and Segar (1970). Blank determination was also carried out on the membrane filter.

The concentrations of metals in the water and plankton extracts were measured, using Flame Atomic Spectrophotometry (Pye – Unicam Sp 29) and the recommended standard procedures. Precision of metal analysis represented by coefficient of variation (CV) were 7.5, 5.4, 8.6 and 2.7% for dissolved Mn, Cu, Zn and Cd, respectively. Recovery of the method was evaluated using standard addition technique, and it was greater than 94%.

Results

The absolute concentrations and average values of dissolved Mn, Cu, Zn and Cd are shown in Table 1. Vertical and surface distributions are presented graphically in Fig. 3 and 4, respectively. The levels of these metals in the plankton of the creek during the four successive cruises are given in Table 2 and represented graphically in Fig. 5.

Water

The vertical and temporal distribution patterns of dissolved heavy metals varied noticeably. In October, the values of different metals showed maxima in the subsurface or deep waters of the creek and minima in the surface water except the minimum values of Mn and Cd which occurred in the subsurface water of station III. In January, the maximum values of dissolved

TABLE 1. Variations of dissolved Mn, Cu, Zn and Cd ($\mu g\ l^{-1}$) in water column of Obhur Creek.

Stations	Depth of stations (m)	Depth of samples (m)	Mn		Cu		Zn		Cd	
			Oct.	Jan.	Oct.	Jan.	Oct.	Jan.	Oct.	Jan.
I	1.65	0	2.72	1.44	1.37	1.46	6.29	5.94	0.89	0.80
II	5.85	0	1.05 –	3.17	0.93	1.76	4.50	4.39	0.73	0.69
		5	1.57	1.78	1.68	1.82	6.95	3.31	0.86	0.87
III	26.0	0	3.41	1.86	0.84 –	1.60	9.12	1.26 –	1.40	0.80
		5	3.49 +	2.16	2.41	1.55	12.11	3.87	1.66	0.72
		15	1.80	1.25	2.60	1.29	5.33	3.95	1.73 +	1.21
		25	1.05 –	2.23	1.30	1.24 –	3.97	3.78	0.41 –	1.22 +
IV	27.0	0	1.42	1.03 –	1.05	1.35	3.66 –	1.28	0.58	0.60
		5	1.64	1.76	1.37	1.60	11.72	7.22 +	0.74	0.69
		15	1.32	1.76	1.19	1.72	3.72	2.22	0.70	0.55
		25	1.54	1.30	1.53	1.49	7.02	1.98	1.02	0.51
V	28.0	0	1.29	3.50	1.58	2.72 +	5.29	3.52	0.81	0.96
		5	1.66	1.56	1.75	1.57	12.70 +	3.57	0.89	0.36 –
		15	1.66	2.28	2.08	1.88	6.63	4.61	0.86	0.43
		25	1.09	1.85	2.87 +	1.51	4.20	1.68	1.15	0.56
VI	32.5	0	1.38	2.92	1.84	1.83	7.95	2.69	0.63	0.61
		5	1.56	1.71	2.19	2.37	3.90	4.57	1.12	1.01
		15	1.97	1.81	1.24	1.28	7.14	1.54	0.80	0.78
		25	1.57	3.70 +	2.21	1.90	12.24	4.22	1.20	0.68
Averages			1.83	2.02	1.62	1.66	6.87	3.85	0.94	0.75
Means			1.93		1.64		5.36		0.85	
Standard deviation			± 096		± 0.51		± 2.42		± 0.23	

The minimum values are designated by (–) and the maximum by (+).

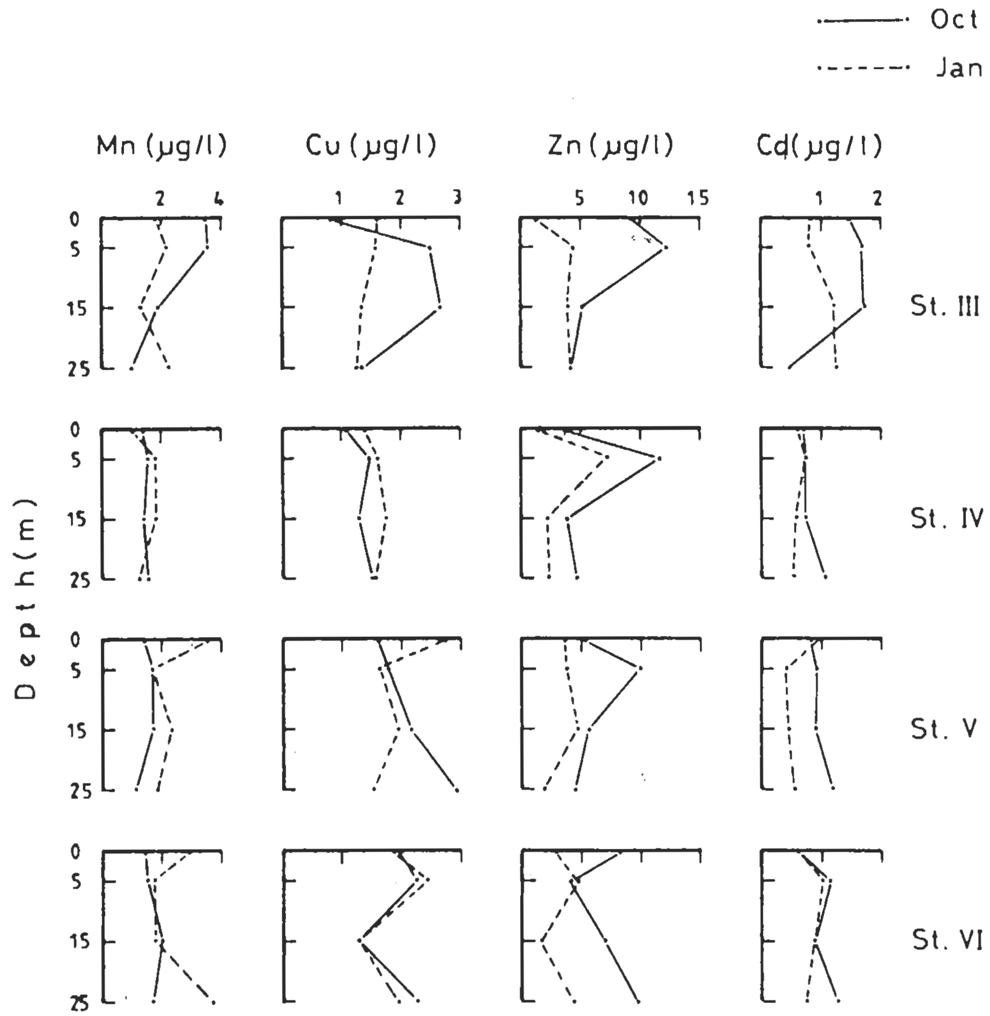

FIG. 3. Vertical distribution of dissolved Mn, Cu, Zn and Cd at the deeper stations III-VI in Obhur Creek.

Mn, Cu, Zn and Cd were obtained from the deep water of station VI, surface of station V, 5 m depth of station IV and deep water of station III respectively. On the other hand, the minimum values occurred in the surface water of stations III for Zn and IV for Mn, in the deep water of station III for Cu and at 5 m depth of station V for Cd.

Horizontally, the surface water near the mouth is the most freely exchanged with the Red Sea water outside the creek compared with that inside the creek. Consequently, high levels of dissolved metals were obtained in October (Cu and Zn) and January (Mn and Cu) from the surface water, near the mouth of the creek. The absolute surface values of dissolved Cu and Zn showed an increase from the middle of the creek seawards in October. However, dissolved Zn showed an increase from the middle of the creek towards its head in January. Slight variations were found in the surface distribution of dissolved Cd during the two cruises.

Plankton

The metal contents in the plankton collected from the surface water of the creek (Table 2 and Fig. 5) showed varying distribution pattern. The regional average values (averages of all seasons at the same station) of Mn were characterized by an increase from the middle of the creek seawards. However the averages of the other metals recorded maxima near the head of the creek at station II for Cu and Zn and at station I for Cd.

The lowest regional average concentrations of these metals occurred in the plankton collected at station III for Mn, Zn and Cd, at station IV for Cu and also at station V for Cd. Regarding the seasonal variations of metals, the highest seasonal average values were, gen-

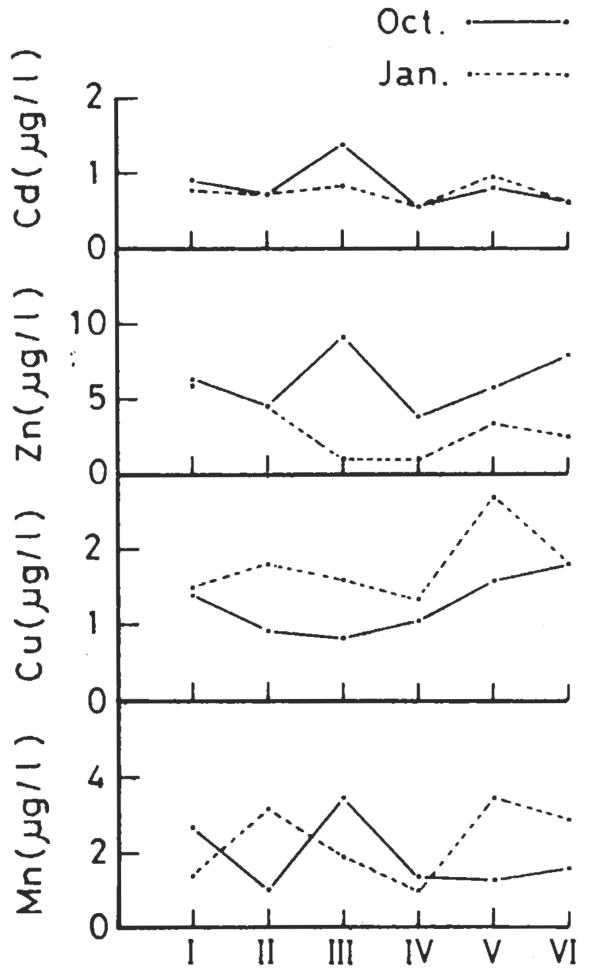

FIG 4. Variations of dissolved Mn, Cu, Zn and Cd in the surface water of Obhur Creek.

erally, obtained from plankton collected in summer or spring. However, the lowest seasonal averages were obtained from the plankton collected in winter or spring.

Discussion

The data of the present work indicate that appreciable variations occurred in the concentrations of dissolved heavy metals in the water column of Obhur Creek and that most of the values are generally close to the overall mean given in Table 1. The mean surface values calculated for the different metals recorded a slight decrease in October (except for Mn) and increase in January (except for Cd) relative to those in the bottom water. The consumption of metals by phytoplankton organisms as well as the sedimentation of descending abiotic and biotic materials carrying heavy metals during stagnant condition of the creek waters in October of late summer (El-Rayis, 1993) have lead to such surface decrease in October and revealed restriction of metal replenishment. However, the relative increase in the mean concentrations of dissolved metals in the surface water in January possibly reflects the metal replenishment in the creek surface water due to the entrance of surface Red Sea water into the creek and the relative decrease in uptake of metals due to diminish in biological activity in winter. El-Sheikh (1981) found near the mouth of Obhur Creek a layer with a maximum salinity at a level equal to the bottom depth of the creek. This layer originates mostly from the surface Red Sea water invading the creek, which sinks and flows back probably under its density gradient.

The distribution of dissolved metals in the surface water of the creek showed elevated values near the mouth and/or the head of the creek. Mixing between surface water inside and outside the creek in the vicinity of its mouth might caused the high metal content there. Such distribution pattern suggests that the surface water inside the creek has a longer retention time relative to that near the mouth. In the restricted water inside the creek, the consumption of metals by or-

TABLE 2. Seasonal and regional changes in the levels of Mn, Cu, Zn and Cd ($\mu g\ g^{-1}$ dry weight) in plankton of Obhur Creek.

Stations	Mn					Cu				
	Oct.	Jan.	April	Aug.	Regional averages	Oct.	Jan.	April	Aug.	Regional averages
I	16.30 –	11.61	31.09 +	12.87	17.97	12.04	1.27	10.93 +	ND	6.06
II	22.50	17.19	13.37	9.94 –	15.70	13.99 +	0.61 –	3.68	186.90 +	51.30 +
III	17.60	10.91	7.04 –	23.56	14.78 –	6.50	0.85	1.07 –	15.35	5.94
IV	24.35	28.72 +	12.60	21.04	21.68	4.28 –	ND	2.12	ND	1.60 –
V	32.60	10.74 –	9.45	41.10 +	23.47	8.28	ND	4.09	3.37 –	3.94
VI	34.25 +	24.69	13.01	36.83	27.20 +	8.82	2.06 +	6.77	ND	4.41
Seasonal averages		24.60 +	17.31	14.43 –	24.19		8.99	0.80 –	4.78	34.27 +
Annual averages			20.13					12.21		

TABLE 2. Contd.

Stations	Zn					Cd				
	Oct.	Jan.	April	Aug.	Regional averages	Oct.	Jan.	April	Aug.	Regional averages
I	30.76	14.72	36.07 +	60.93	35.62	ND	0.62	2.58 +	1.24 +	1.11 +
II	39.07+	32.16	15.52	146.03 +	58.20 +	0.34 –	0.48	1.18	0.77	0.69
III	30.52	13.44 –	8.21	52.52	26.17 –	0.73	ND	1.08	0.40	0.55 –
IV	24.70 –	45.14 +	13.45	23.68 –	26.74	1.01 +	ND	1.50	0.34 –	0.71
V	32.38	14.82	7.36 –	75.22	32.45	0.89	0.15 –	1.17	ND	0.55 –
VI	32.41	29.34	16.39	61.73	34.97	0.92	1.50 +	0.80 –	ND	0.81
Seasonal averages	31.64	24.94	16.17 –	70.02 +		0.65	0.46 –	1.39+	0.46 –	
Annual averages		35.69					0.74			

ND = Not detected.
The minimum values are designated by (–) and the maximum by (+).

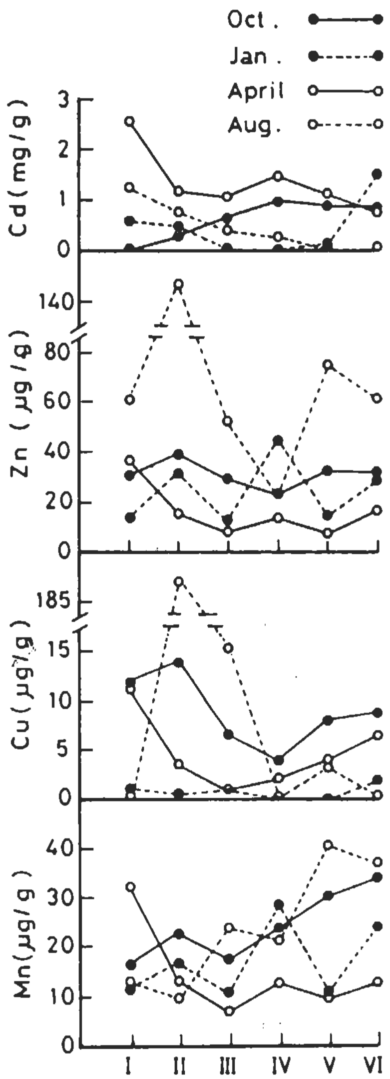

FIG 5. Seasonal and regional changes in the levels of Mn, Cu, Zn and Cd in plankton collected from surface water of Obhur Creek.

ganisms is not replinished causing the decrease in metal content compared with the near mouth water where the metals are replinished more or less continuously from the Red Sea (Behairy *et al.*, 1983). However, the injection of metals from enriched bottom water to the upper layer is also responsible for the high metal concentrations detected in the surface water near the head of the creek, due to its shallowness.

Distribution of nutrient salts (NO_2 , NO_3 , PO_4 and SiO_4) was also studied at the same time and locations of the present investigation (unpublished data). These data of nutrients show a distribution pattern similar to that of the trace elements. Nutrient contents sustained, in general, slightly lower surface values in October and higher values in January contrary to bottom water. This confirms the role of phytoplankton activity in controlling the levels of heavy metals in the water of Obhur Creek. Injection of metal enriched bottom water to the upper layer especially in the shallow region was also indicated.

Correlation matrix coefficients between the concentrations of dissolved heavy metals (D) and their levels in the plankton (P) in the surface water of Obhur Creek are presented in Table 3. The matrix shows a good positive association between DCd and DMn (r = 0.58671) and suggests that the conditions which affect the behaviour and distribution of these metals are similar. A significant negative correlation was found between DMn and PMn (r = – 0.51732) reflecting the important role of the plankton in the removal of DMn from sea water. DZn was found to be correlated positively with PCu (r = 0.54119) and DCd (r = 0.54551). These can represent the resultant of several processes which affect the distribution pattern of those elements. A positive association between

TABLE 3. Correlation coefficient matrix between dissolved heavy metals (D) and their levels in plankton (P) from surface waters of Obhur Creek.

	DMn	DCu	DZn	DCd	PMn	PCu	PZn	PCd
DMn	1.00000							
DCu	.38661	1.00000						
DZn	.18510	– .26573	1.00000					
DCd	.58671	– .11711	.54551	1.00000				
PMn	– .51732	– .19648	.12646	– .46138	1.00000			
PCu	– .25495	– .48228	.54119	.09726	.35322	1.00000		
PZn	–.29539	–.43287	.08546	–.24387	.71035	.42692	1.00000	
PCd	.01390	– .06384	.24757	– .20714	.48094	.03648	.05291	1.00000

The significant values are > 0.49952 or < – 0.49952
n = 12.

TABLE 4. Comparison between the mean concentrations of dissolved heavy metals in water ($\mu g\ l^{-1}$) and plankton ($\mu g\ g^{-1}$ dry weight) of Obhur Creek with the data from other regions.

	Mn	Cu	Zn	Cd	References
Water					
Obhur Creek	1.93	1.64	5.36	0.85	Present study
Obhur Creek	0.78	1.17	2.23	0.68	Behairy *et al.* (1983)
Bankalah region	14.60	1.52	–	0.79	El Rayis *et al.* (1984)
Bankalah region	6.68	1.69	6.52	1.05	Saad and Fahmy (in press)
Oceanic water	0.10	1.50	4.90	0.10	Brewer and Spencer (1975)
Plankton					
Obhur Creek	20.10	12.20	35.70	0.70	Present study
Obhur Creek	17.30	106.00	92.00	2.00	Behairy *et al.* (1983)
Bankalah region	41.00	196.00	179.00	3.80	Saad and Fahmy (1996)
Average composition of plankton	9.00	11.30	87.00	2.00	Turekian (1976)

PZn and PMn (r = 0.71035) suggest that scavengers for Mn and Zn are the same.

Comparisons between mean concentrations of dissolved heavy metals and their levels in the plankton collected from the surface water of Obhur Creek with other relevant data from other regions are shown in Table 4. Dissolved Cu and Zn in the present study are comparable to those found in oceanic water (Brewer and Spencer, 1975). Their levels in the plankton indicate a comparable value regarding Cu and markedly less level regarding Zn relative to the average composition of plankton (Turekian, 1976). This reflects that Cu and Zn can be possibly maintained in sea water and plankton more than the other metals. The data of dissolved metals in the study area when compared with those from the heavily polluted Bankalah Region during the same period reveal a marked decrease in the mean values for Mn and Cd and a more or less similar means for Cu and a slightly lower mean value for Zn. However, the mean levels of metals accumulated in the plankton of Obhur Creek were much lower than the corresponding mean levels found in the plankton collected from heavily polluted Bankalah Zone during the same period.

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تواجد وتوزيع المعادن الشحيحة فى شرم أبحر ، منطقة ساحلية بالبحر الأحمر شمال جدة

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المستخلص: يقع شرم أبحر (٣٥ كم شمال جدة) بين خطي عرض ٢١ْ ٤٢َ ١١ً و ٢١ْ ٤٥َ ٢٤ً شمالاً وخطي طول ٣٩ْ ٥َ ١٢ً و ٣٩ْ ٨َ ٤٨ً شرقا . يعتبر هذا الشرم من المناطق السياحية وبالتالي فإنه من الضروري أن تتم المتابعة المستمرة لدراسة حالته البيئية من أجل حماية صحة الإنسان. يهتم البحث الحالى بدراسة تركيزات المنجنيز ، النحاس ، الزنك والكادميوم في عمود المياه ومستوياتهم فى البلانكتون الموجودة فى المياه السطحية لشرم أبحر . يتضح من نظام التوزيع الرأسى للمعادن الذائبة أن قيم المتوسطات لجميع المعادن في مياه السطح قد أظهرت نقصا قليلا (ماعدا المنجنيز) فى أكتوبر وزيادة في يناير (ماعدا الكادميوم) وذلك بالمقارنة بمثيلاتها فى مياه القاع . وتقترح النتائج أن حالة سكون مياه الشرم فى أكتوبر (نهاية الصيف) قد أدت الى هذا النقص في المياه السطحية وحدث من استعاضة هذه المعادن . أما تبادل المياه داخل الشرم مع مياه البحر الأحمر المفتوح خارجه والتى تتم بعد فصل الصيف ، قد تكون المسئولة عن الزيادة النسبية في محتوى مياه السطح من المعادن خلال شهر يناير . أظهر التوزيع السطحى للمعادن الذائبة معدلات مرتفعة بالقرب من طرفى شرم أبحر وقد تعزى هذه الزيادة فى مياه منطقة الفم إلى عمليات المزج بين المياه السطحية داخل وخارج الشرم بالقرب من منطقة الفم (منطقة اتصال الشرم بالبحر الأحمر) أما زيادة المعادن الذائبة في المياه السطحية لمنطقة الرأس فقد ترجع أساساً إلى المعادن التى تأتى من مياه القاع الغنية وذلك نتيجة ضحالة عمود المياه فى هذه المنطقة . يعكّس محتوى المعادن فى البلانكتون الدور الأساسى الذى تلعبه هذه الكائنات في التحكم في مستويات المعادن الثقيلة فى مياه الشرم . تحذر مقارنة نتائج الدراسة الحالية مع مثيلاتها فى مناطق مختلفة من التغيرات فى مستويات المعادن في شرم أبحر والذى يرجع أساساً إلى تأثير الإنسان .