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Impact of Wastewater Discharge Diversion on Some Heavy Metals Content in Alexandria Coast

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Abstract: Alexandria is the second largest city in Egypt and includes about 40% of the nation's industry. In the past, Alexandria city was discharging its wastewater either into the Mediterranean Sea along the city beaches or into Lake Maryut. In 1993, these outlets were closed except two main outlets at Qayet-Bey and EL-Mex Bay. The diverted wastewater is treated primarily and discharged into the sea at EL-Mex Bay. In the mean time, Environment Law 4/1994 prohibited all polluting establishments to discharge untreated wastes, which may cause pollution, along the Egyptian sea shores. The present work aims at assessing the improvement in the levels of some heavy metals in Alexandria coastal water after the diversion and the execution of Environment Law 4/1994.

The study concluded that Abou-Qir water, and to a less extent Qayet-Bey water, was characterized by high averages of dissolved Cu, Zn, Pb, and Cr. El-Agamy Bay water sustained the highest levels of Cd, Co, and Cr. Qayet-bey water represented the highest Ni average. Qayet-Bey water sustained the highest levels of particulate Cu, Zn, and to a less extent Co, Ni, and Cr. El-Agamy water contained the highest levels of both dissolved and particulate Cd. Contrary to the case of dissolved form, spring and to a less extent summer achieved the highest concentration of particulate Zn, Cd, and Ni. The results displayed that dissolved forms of most studied metals were higher in concentration than particulate ones. Zn and Cr, on the other hand, were found in particulate form to be slightly higher than those in dissolved forms. The presence of heavy metals in considerable levels in all the studied sites indicates that Alexandria coast is still subjected to the polluting land-based sources. The study suggested some recommendations to improve the situation including: industries should be enforced to treat their wastewater to comply with Law 4/1994, environmental impact assessment should be done for the new activities, continuous monitoring of the water quality of the beaches, and fishing from polluted areas should be prohibited.

INTRODUCTION

Alexandria is the second largest city and one of Egypt's most important industrial centers. It includes a wide variety of industries which cover about 40% of the nation's industry. It is also the main summer resort in Egypt; for about 4 million citizens and two million summer visitors.[1]

In the past, Alexandria city was planned to discharge its wastewater either by dilution into the Mediterranean Sea through Qayet-Bey outfall and another 20 minor

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outfalls located along the city beaches or into Lake Maryut.[2]

In 1993, these outlets were closed as a step to prevent the wastewater disposal into the sea except two main outlets at Qayet-Bey and EL-Mex Bay. The main waste outfall of Alexandria is located at Qayet-Bey which disposes off about 210000 m^3/day and 350000 m3 per day during winter and summer seasons, respectively. El-Mex Bay lies at the western part of Alexandria city. It receives a daily effluents of about 6-10 million m^3 of mixed industrial, agricultural, and domestic wastes from different sources.[3] Direct disposal of industrial wastes from petroleum refineries, chloro-alkali plant, cement, steel, and tanning industries takes place directly to the area without any pretreatment.

The diverted wastewater, due to closing of many outlets, is discharged into two wastewater treatment plants. Both plants are using primary treatment technology and discharge their primary treated effluents into Lake Maryut.[2] The flow from the Lake is directed to be combined with the wastewater of EL-Umum Drain which includes sewage, agriculture, and industrial wastes to end into the Alexandria coast through EL-Mex Bay.

In the mean time, Environment Law 4/1994 promulgates in article 69 that it is prohibited for all polluting establishments to discharge untreated wastes which may cause pollution along the Egyptian sea shores or adjoining waters.[4]

Heavy metals are the most important pollutants in the coastal area because of their toxicity and capacity to accumulate in living cells as well as in bottom sediments. They can reach the estuaries, coastal areas, and open waters of the Mediterranean Sea from land-based sources. The main anthropogenic sources of heavy metals are various industrial point sources. Some of these metals are important for animal nutrition in tissue metabolism and growth. Several imbalances, on the other hand, caused by exposure to elevated concentration can cause death. In fact, all heavy metals are potentially harmful to most organisms at some level of exposure and uptake. The effect of two or more toxicants can be additive, antagonistic, or it may even be synergetic.[5]

The present work aims at assessing the improvement in the levels of some heavy metals in Alexandria coastal water after the accomplishment of the new project of collection and treatment of wastewater, and the execution of Environment Law 4/1994.

MATERIAL AND METHODS

Surface water samples were collected monthly along the year 1998-1999 from ten sites representing the coastal area in front of Alexandria city, along about 40 km, starting from Abou-Qir, at the east, till El-Agamy, at the west. They are I-Abou-Qir, II-Montazh, III-Miami, IV-Stanly, V-Shatby, VI-Eastern Harbour [EH], VII-Qayet-Bey, VIII-Ras El-Tin, IX-El-Mex, and X-El-Agamy. Determination of Cu, Zn, Ni, Co, Cr, Pb, and Cd in filtrate phase was done after preconcentration and extraction using atomic absorption spectrophotometer. They were also determined in particulate phase.[6]

RESULTS AND DISCUSSION

A- Evaluation of the heavy metals levels

The seasonal and annual variations of measured dissolved and particulate metals for the different studied sites during the period of investigation are shown in tables [1 to 7]. The coastal average annual variations for dissolved and particulate measured metals are illustrated graphically in figures [1 and 2].

1. Copper

The lowest average seasonal concentration of dissolved copper, 2.57μg/l [table 1] measured in spring [the period of biota high productivity] may be a result of its uptake by phytoplankton. Biological uptake of copper from water was stressed by Bruland.[7]

The highest average seasonal concentration of dissolved copper, 3.54μg/l measured in autumn may be due to the high decomposition rate of organic matter and the release of copper from decaying organisms by the action of bacteria, which agreed with Chester study.[8]

The relative high average of dissolved copper, 4.26μg/l at Abou-Qir water is probably due to the local anthropogenic input of industrial wastes in Abou-Qir Bay. Leaching of copper from ships anti-fouling paints could be a possible source for copper in this area as well as in Eastern Harbour water, 3.66μg/l [table 1]. Nessim *et al.*,[9] stated that most of the antifouling paints contained Cu and could be easily leached into seawater. El-Nady[10] attributed the increase in Cu concentration in Abou-Qir region to agricultural waste rather than industrial and sewage discharge. The lowest regional average of copper at Stanly area, 2.24μg/l indicates that dissolved copper is probably combined with dissolved organic matter [derived from industrial runoff], as has been found in the Scheldt Estuary, Netherlands.[11]

The concentration of individual samples particulate copper varied between ND-12.39μg/l. These two extremities were observed at Qayet-Bey area. The relative high concentration of particulate copper, 4.31μg/l [table 1] recorded at the coastal water adjacent to the heavily polluted area [Qayet-Bey] is related to the release of huge amounts of wastes.

Veglie and Vaissiere[12] studied the seasonal variation of zinc and copper in unfiltered samples in coastal water in the vicinity of Monaco. They found that the thermal stratification of water column in summer combined with the seasonal increase in anthropogenic pollution appeared to be the main cause of the enhanced concentration of metals in the surface layer.

They stated also that mixing process in autumn led to decrease the concentration of copper in the upper layer due to dilution effect.

The levels of the element in aquatic ecosystem cover a wide range of concentrations;[13] coastal sea water <0.01-50µg/l, with a tendency for high values to be related to source.

2. Zinc

High amounts of zinc in the sea may result from the discharge of industrial wastes from mining, electroplating, synthetic fiber, and other manufactures, in addition to agricultural and domestic effluents. The levels of zinc in the aquatic ecosystem cover a wide range of values, coastal sea: 0.20-210.0µg/l.[13]

As in the case of copper, Abou-Qir area recorded the highest annual average of dissolved zinc, being 8.61µg/l, [table 2]. This may be due to the paper industrial wastes discharged into the Bay. Maximum and minimum seasonal averages of dissolved zinc were recorded during winter and spring, being 17.14 and 2.06 µg/l, respectively. This finding is in agreement with Haritonidis and Malea[14] findings in Thermaikas Gulf, Greece. Increase of metal. concentration in seawater during winter might be due to the washout effects of heavy winter rain over the highly industrialzed areas,[15] while the decrease in dissolved zinc during spring may be attributed to its consumption by phytoplankton flourished in this season. This evidence might be supported by the highest seasonal average of particulate zinc in the same season.

The maximum and minimum seasonal concentrations of particulate zinc recorded in spring, 12.05µg/l and autumn 2.71µg/l, respectively, were in a good agreement with that of Haritonidis and Malea.[14] Qayet-Bey and Ras El-Tin areas recorded the highest

Table 1: Results of copper levels [μg/l] in surface water of Alexandria coast during 1998-1999.

Period	Stations										Coastal annual average
	I	II	III	IV	V	VI	VII	VIII	IX	X	
Dissolved Phase											
Spring average	5.04	2.11	1.76	1.23	2.11	3.69	2.64	2.81	3.08	1.23	2.57
Summer average	3.61	2.10	2.57	1.75	2.48	2.22	3.04	3.03	1.99	3.38	2.62
Autumn average	5.42	3.06	3.33	2.92	2.92	3.33	4.44	3.61	3.89	2.50	3.54
Winter average	2.98	3.22	2.46	3.08	7.28	5.42	2.60	2.82	2.17	2.21	3.42
Site annual average	4.26	2.62	2.53	2.24	3.70	3.66	3.18	3.07	2.78	2.33	3.04
Particulate Phase											
Spring average	2.29	1.25	1.98	0.94	1.88	1.35	2.97	1.98	1.25	1.33	1.77
Summer average	2.40	1.15	1.77	1.88	1.56	1.46	4.19	3.70	1.67	2.08	2.18
Autumn average	1.25	1.25	0.63	0.63	1.67	0.94	4.17	2.19	1.25	1.67	1.56
Winter average	0.97	1.24	1.06	0.80	1.12	1.33	6.73	1.45	1.21	1.36	1.54
Site annual average	1.73	1.22	1.36	1.06	1.56	1.27	4.31	2.33	1.35	1.61	1.78

Table 2: Results of zinc levels [μg/l] in surface water of Alexandria coast during 1998- 1999

Period	Stations										Coastal annual average
	I	II	III	IV	V	VI	VII	VIII	IX	X	
Dissolved Phase											
Spring average	4.29	1.80	2.80	1.02	0.89	1.51	2.11	1.58	1.58	1.11	2.06
Summer average	3.06	2.82	1.33	1.97	1.98	1.69	2.50	3.55	3.55	3.46	2.37
Autumn average	7.17	6.59	6.25	6.32	5.56	6.71	7.70	4.48	4.48	4.52	6.08
Winter average	19.91	10.45	16.92	24.89	14.83	19.31	22.00	12.74	12.74	17.02	17.14
Site annual average	8.61	5.42	6.82	8.55	5.81	7.31	8.58	5.59	5.59	6.53	6.91
Particulate Phase											
Spring average	2.72	2.67	4.53	3.49	32.46	7.84	12.20	42.37	42.37	2.61	12.05
Summer average	4.22	3.19	3.08	3.71	7.96	7.78	30.13	27.25	27.25	4.05	11.55
Autumn average	1.98	2.70	1.93	1.49	1.93	2.10	7.47	3.05	3.05	1.67	2.71
Winter average	3.51	3.06	1.64	2.71	2.59	3.11	9.03	4.03	4.03	3.19	3.38
Site annual average	3.14	2.95	2.63	2.79	9.30	4.97	15.53	17.06	17.06	2.90	6.96

concentrations of zinc resulting from the continuous sewage discharge through the main outfall at Qayet-Bey. A significant positive correlation founded between copper and zinc [r = 0.22] may be attributed to the same biological behaviour during assimilation in macrophyta.

3. Lead

The results in this study indicate that most of lead in the eastern part of the beach is concentrated in the dissolved form, table [3] and figures [1 and 2]. The particulate form reached its highest average of 4.49μg/l at Qayet-Bey, accompanied with huge amounts of sewage discharged at Qayet-Bey area.

The highest dissolved lead [5.44μg/l] and the lowest particulate form [2.48μg/l] in Abou-Qir area are coincided with the highest salinity [38.84‰] indicating that lead source in Abou-Qir area is probably originating from atmospheric and other inputs rather than from El-Tabia pumping station.[3]

The high level of Pb [4.95μg/l] in the near shore water of El-Mex Bay can be attributed to its release to the atmosphere with the fumes evolved from the nearby cement factory which agreed with the results of Aboul-Dahab.[16]

According to Jeftic *et al.*,[13] the levels in seawater cover a wide range of values; open sea 0.018-0.14μg/l, coastal seawater 0.016-20.5μg/l.

4. Cadmium

The seasonal distribution of dissolved cadmium in the present study is similar to that of zinc, with a significant correlation between cadmium and zinc [r = 0.52]. Cadmium shows less significant correlations with copper [r = 0.21] and lead [r = 0.28]. The lowest seasonal average of dissolved cadmium during spring and summer, 0.27μg/l and 0.42μg/l, respectively, table [4], may be due to the uptake of this metal by phytoplanktons which flourish during spring

Table 3: Results of lead levels [µg/l] in surface water of Alexandria coast during 1998-1999

Period	Stations										Coastal annual average
	I	II	III	IV	V	VI	VII	VIII	IX	X	
Dissolved Phase											
Spring average	11.54	6.34	7.35	5.47	5.52	4.60	4.71	4.33	4.33	4.37	6.29
Summer average	1.94	2.28	2.39	1.69	1.63	1.82	1.54	1.18	1.18	4.80	2.12
Autumn average	4.29	4.60	3.98	1.23	2.15	3.98	3.68	3.98	3.98	4.90	3.80
Winter average	3.98	1.84	6.74	5.21	3.37	3.06	3.37	4.90	4.90	2.76	3.92
Site annual average	5.44	3.76	5.12	3.40	3.17	3.37	3.33	3.60	3.60	4.21	4.03
Particulate Phase											
Spring average	1.18	1.61	2.19	1.57	1.63	2.53	3.87	3.42	3.42	2.58	2.21
Summer average	3.01	1.95	2.12	2.23	2.22	2.12	5.34	2.34	2.34	4.23	2.87
Autumn average	3.23	6.24	2.58	3.55	3.66	4.09	4.95	4.95	4.95	4.74	4.36
Winter average	2.58	1.72	3.59	3.30	2.58	5.88	3.44	5.02	5.02	4.45	3.92
Site annual average	2.48	2.88	2.62	2.58	2.52	3.66	4.49	3.94	3.94	4.00	3.31

Table 4: Results of cadmium levels [µg/l] in surface water of Alexandria coast during 1998-1999

Period	Stations										Coastal annual average
	I	II	III	IV	V	VI	VII	VIII	IX	X	
Dissolved Phase											
Spring average	0.13	0.34	0.28	0.25	0.29	0.38	0.29	0.30	0.30	0.22	2.06
Summer average	0.26	0.36	0.48	0.29	0.49	0.23	0.88	0.34	0.34	0.56	2.37
Autumn average	0.82	0.72	0.62	0.46	0.82	0.46	0.62	0.51	0.51	0.72	6.08
Winter average	0.67	0.67	0.46	1.03	0.77	0.87	0.23	0.82	0.82	0.87	17.14
Site annual average	0.47	0.52	0.46	0.51	0.59	0.49	0.53	0.49	0.49	0.60	6.91
Particulate Phase											
Spring average	0.79	0.65	0.65	0.37	0.44	0.55	0.38	0.39	0.39	0.45	12.05
Summer average	0.67	0.29	0.40	0.62	0.39	0.52	0.87	0.35	0.35	0.40	11.55
Autumn average	0.39	0.77	0.27	0.35	0.23	0.54	0.50	0.23	0.23	1.08	2.71
Winter average	0.23	0.27	0.48	0.14	0.42	0.52	0.36	0.35	0.35	0.50	3.38
Site annual average	0.54	0.50	0.45	0.37	0.37	0.53	0.53	0.33	0.33	0.61	6.96

and early summer period. This result is in agreement with Ahdy.[3] Melerran and Holmes[17] stated that bacteria may play a significant role in the transport of Cd from seawater to the sediment during the period of high metabolic activity.

The highest seasonal average of dissolved cadmium [0.77µg/l] during winter could be attributed to the decrease of the rate of consumption by phytoplankton during this season. Mariam *et al.*,[18] attributed the high value of cadmium in winter to the vertical mixing of the water column and to the isotherm conditions observed in winter which favoured the passing of the element and nutrient from sediments to water.

Abou-Qir area had the lowest regional average of dissolved cadmium [0.47µg/l] accompanied by the highest regional average of salinity [38.84‰]. Abdullah and Royal[19] reported the same observation for the Bristol Channel, UK. The relatively high concentration of dissolved cadmium in Eeastern Harbour may be contributed to the use of cadmium pigments in ship paintings at the same area.[20]

The highest seasonal average of particulate cadmium was recorded during spring [0.52µg/l]. This may be attributed to the accumulation of a significant concentration of cadmium by phytoplankton. Kayser and Sperling[21] explained the reason for increasing the particulate cadmium in spring as a result of optimum temperature which enhanced the productivity of phytoplankton.

The relatively high concentrations of particulate cadmium at Qayet-Bey and Ras El-Tin areas [0.53 and 0.53µg/l, respectively] indicated that the two metals were contributed from similar origin [the main outfall pipe at Qayet-Bey area]. It is worthy noticed that dissolved Cd tended to increase gradually along the year of study, particulate forms on the other hand showed a reversible trend.

The levels of cadmium in seawater cover a wide range of values;[13] open sea 0.004-0.06μg/l, coastal sea <0.002-0.90μg/l, with a tendency for high values to be related to sources [estuaries and coastal mining].

5. Cobalt

The regional distribution of dissolved cobalt along Alexandria beaches reflected narrow range of variations [around 2μg/l, with some exceptions of relative low values of 1.25μg/l at Miami and high value of 2.90μg/l at El-Agamy region], table [5], indicating that it is not influenced by anthropogenic input, this finding is similar to that of Bernhard[22] on his survey at the gulf of Patras, [Greece].

Particulate cobalt was nearly depleted from most locations during the time of the study. The individual samples concentration ranged from ND to 0.62μg/l with an annual average of 0.13μg/l. Dissolved cobalt constitutes about 94% of the total cobalt in the studied area, figures [1 and 2].

Inverse correlations between cobalt and each of zinc [r = - 0.39], copper [r = - 0.33], and cadmium [r = - 0.25] were computed.

6. Nickel

It was noticed that the seasonal distribution of dissolved and particulate nickel [table 6] resembles that of copper indicating their similar role in marine ecosystem. The regional distribution of nickel occupied a narrow range [3.36-4.68μg/l at Abou-Qir and Qayet-Bey, respectively], indicating that it is not influenced by anthropogenic input. This finding is in agreement with that of Bernhard[22] in the Gulf of Patras, [Greece].

The chemical behavior of nickel as a strong chelating transition element is obviously clear from its strong correlation with other metals due to its tendency to form organic complexes that are more stable.[23] This evidence is well confirmed in this study

Table 5: Results of cobalt levels [µg/l] in surface water of Alexandria coast during 1998-1999

Period	Stations										Coastal annual average
	I	II	III	IV	V	VI	VII	VIII	IX	X	
					Dissolved Phase						
Spring average	3.47	3.47	2.82	5.21	4.99	2.39	3.90	3.90	2.82	6.51	3.95
Summer average	2.26	2.74	1.43	2.86	2.00	4.38	2.91	3.17	2.47	4.43	2.86
Autumn average	0.22	0.31	0.31	0.18	0.09	0.35	0.35	0.22	0.40	0.35	0.28
Winter average	0.62	0.28	0.43	0.59	0.45	0.48	0.32	0.48	0.35	0.33	0.43
Site annual average	1.64	1.70	1.25	2.21	1.88	1.90	1.87	1.94	1.51	2.90	1.88
					Particulate Phase						
Spring average	0.16	0.20	0.13	0.13	0.16	0.26	0.07	0.07	0.10	0.03	0.13
Summer average	0.07	0.07	0.16	0.03	0.13	0.03	0.19	0.21	0.13	0.10	0.11
Autumn average	0.10	0.10	0.16	0.10	0.10	0.11	0.23	0.07	0.10	0.03	0.11
Winter average	0.15	0.03	0.19	0.31	0.07	0.28	0.10	0.28	0.10	0.00	0.15
Site annual average	0.12	0.09	0.16	0.14	0.12	0.17	0.15	0.16	0.11	0.04	0.13

Table 6: Results of nickel levels [µg/l] in surface water of Alexandria coast during 1998-1999

Period	Stations										Coastal annual average
	I	II	III	IV	V	VI	VII	VIII	IX	X	
					Dissolved Phase						
Spring average	2.40	3.28	2.84	1.53	2.84	3.28	3.93	2.62	2.62	2.62	2.62
Summer average	1.66	3.66	4.08	3.53	4.11	3.53	2.42	3.19	2.21	3.21	3.21
Autumn average	6.03	6.03	6.70	6.03	4.69	7.04	7.37	5.03	6.37	6.70	6.70
Winter average	3.34	2.00	3.34	3.00	5.01	3.34	5.01	4.00	4.00	4.67	4.67
Site annual average	3.36	3.74	4.24	3.52	4.16	4.29	4.68	3.71	3.80	4.30	4.30
					Particulate Phase						
Spring average	2.86	5.36	4.05	2.14	2.86	3.75	3.69	3.99	3.21	3.33	3.33
Summer average	2.62	2.38	2.62	2.62	2.62	3.93	4.29	3.27	3.51	2.86	2.86
Autumn average	3.10	2.14	2.14	2.86	1.67	2.86	2.38	2.86	4.05	1.19	1.19
Winter average	3.25	3.75	4.42	2.00	1.59	2.59	2.25	8.18	2.92	2.42	2.42
Site annual average	2.96	3.23	3.31	2.41	2.18	3.28	3.23	4.57	3.44	2.45	2.45

from the positive correlation between nickel and each of zinc, copper, and cadmium [r = 0.16, 0.25, and 0.17, respectively]. cobalt and chromium, on the other hand, show inverse correlations with nickel [r = -0.40 and -0.32, respectively]. Morley *et al.*,[24] recorded, in the western Mediterranean, a relatively low concentrations of nickel fluctuating between 0.08 and 4.4646 nano Molar [nM]. The concentration of dissolved Ni in EH [0.3-6.73μg/l][10] was relatively lower than that of the present study. The concentration of nickel in the ocean is 2μg/l.[25]

7. Chromium

The typical Cr concentration in seawater is 0.3μg/l, mostly as hexavalent. The concentration of chromium in the ocean is 0.6μg/l.[25]

The average daily discharge of chromium from the main effluents west of Alexandria

Table 7: Results of Chromium levels [μg/l] in surface water of Alexandria coast during 1998-1999

Period	Stations										Coastal annual average
	I	II	III	IV	V	VI	VII	VIII	IX	X	
Dissolved Phase											
Spring average	2.11	1.19	1.71	0.79	1.19	1.85	1.19	0.92	1.32	1.45	1.37
Summer average	0.87	1.35	1.35	0.53	0.79	0.66	1.00	0.95	1.19	0.53	0.92
Autumn average	0.42	0.42	0.42	1.06	0.42	ND	0.64	ND	ND	0.21	0.36
Winter average	0.42	0.42	ND	0.21	0.85	0.42	0.21	1.27	1.06	1.70	0.66
Site annual average	0.96	0.85	0.87	0.65	0.81	0.73	0.76	0.79	0.89	0.97	0.83
Particulate Phase											
Spring average	0.80	2.39	0.64	0.95	0.80	0.32	0.36	0.91	0.48	0.52	0.78
Summer average	0.48	0.32	0.32	0.16	0.48	0.36	1.63	0.68	1.39	0.52	0.63
Autumn average	0.00	0.16	0.16	0.00	0.95	0.64	0.80	0.48	0.64	0.16	0.40
Winter average	0.48	2.55	1.43	0.85	0.16	0.80	0.32	7.11	1.80	0.48	1.73
Site annual average	0.43	1.26	0.64	0.49	0.60	0.53	0.82	2.29	1.13	0.42	0.86

ND = Not Detected

was computed by Aboul-Dahab and Halim[26] to be 37.2 kg/day from Qayet-Bey pumping station and 220.32 kg/day from tanneries effluent.

In the present study the seasonal distribution of dissolved chromium [ranging between 0.36 for autumn and 1.37μg/l for spring], table [7], is similar to that of cobalt. This was confirmed by a positive correlation between both elements [r = 0.27]. Generally, the concentration of dissolved chromium in the studied areas [ND-5.09μg/l] is comparable to that of Aboul-Dahab and Halim[26] in El-Mex Bay water [0.035-4.38μg/l] and El-Nady[10] at EH [ND-2.88μg/l] but is much higher than those of Emara and Shriadah[27] in Eastern Harbour water [0.10-0.37μg/l] and in El-Mex Bay water [0.11-0.37μg/l].

B- Assessment of the wastewater diversion process and Emvironment Law 4/94 execution

Comparing the results of heavy metals levels of the present study with the available results of the previois studies showing that:

At Abou-Qir Bay, total copper level in the present study [5.99μg/l] exceeded the level found by EL-Nady[28] and Emara[29] [4.2μg/l and 0.98μg/l, respectively]. The total Cd level [1.01μg/l] exceeded the level found by Emara[29] [0.13-0.36μg/l]. The total Zn level [11.75μg/l] was lower than what has been found by Khaled[20] [53.55μg/l]. The dissolved Pb level [5.44μg/l] exceeded the level found by Ahdy[3] [1.48μg/l] while Cd level [0.47μg/l] was lower [0.73μg/l]. The dissolved Pb, Zn, and Cd levels [5.44, 8.61, and 0.47μg/l, respectivèly] were lower than what have been found by El-Deek[30] [9.92, 53.32, and 1.55μg/l, respectively].

The average concentrations of dissolved Cu of the present study at Abou-Qir and EH waters [4.26 and 3.66μg/l, respectively] were lower than what has been found by Badr[31] [5.55μg/l].

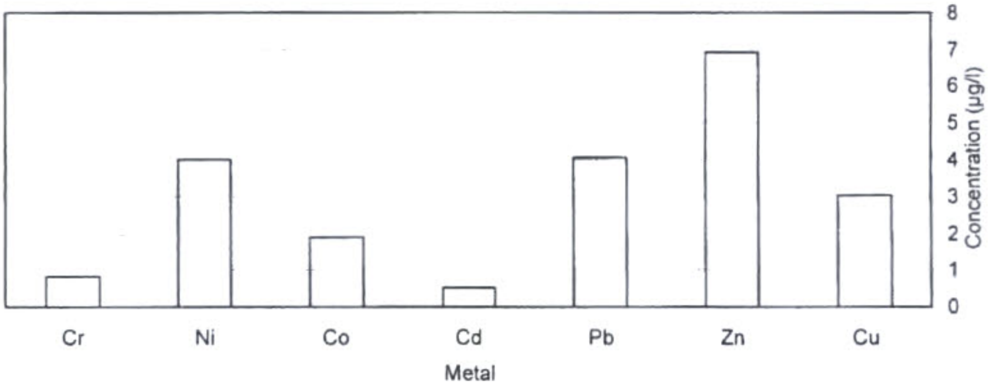

Fig. [1]: Results of annual average dissolved heavy metals in the surface water of Alexandria coast during 1998-1999

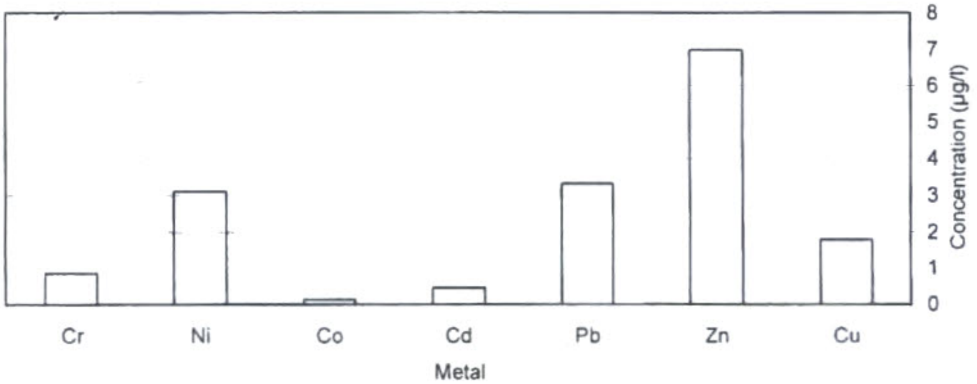

Fig. [2]: Results of annual average particulate heavy metals in the surface water of Alexandria coast during 1998-1999

At EL-Mex Bay, the total levels of Cu and Pb of the present study [4.13 and 8.91µg/l, repectively] exceeded Tayel *et al.*,[32] results [3.41 and 1.08µg/l, respectively]. The total Zn level [14.22µg/l] was lower than what have been found by Khaled[20] and Tayel *et al.*,[32]] [28.20 and 38.48µg/l, respectively]. The total level of Cd [0.82µg/l] was lower than what has been found by Tayel *et al.*,[32] [4.19µg/l]. The dissolved Cd and Pb levels [0.49 and 4.95µg/l, respectively] exceeded the levels found by Halim[33] and Mahmoud,[34] [0.33 and 4.46µg/l, respectively]. The particulate level of Pb [3.96µg/l] was lower compared with Mahmoud[34] study [9.83µg/l]. However it was higher compared with El-Rayis *et al.,*[35] study [0.55µg/l]. The particultate individual Cr samples levels [ND-3.82µg/l] lied within the levels found in a previous study[26] [0.09-7.11µg/l]. The particultate Zn and Cu levels [8.29 and 1.35µg/l, respectively] were lower than the levels found by El-Rayis *et al.*,[35] [9.90 and 2.42µg/l, respectively].

At the Eastern Harbour, the total individual Cr samples levels of the present study, being ND-7.00µg/l, lied within the level found in a previous study[26] [ND-0.90µg/l]. The total Zn level, being 12.28µg/l, was lower than what has been found by Khaled[20] [64.44µg/l].

The average total Zn and Cd levels in Eastern Harbour and EL-Mex Bay [13.25 and 0.85µg/l, respectively] were lower than the levels found by Emara *et al.*,[36] [110 and 1.91µg/l, respectively]. On the other hand, the average total Pb, Ni, Cr, and Co levels [7.97, 7.41, 1.64, and 1.85µg/l, respectively] exceeded the levels found by Emara *et al.*,[36] [0.53, 0.46, 0.14, and 0.06µg/l, respectively]. The average total Cu level, being 4.53µg/l, almost equals the level found by Emara *et al.*,[36] [4.84µg/l].

From the previous discussion, it is clear that there are great fluctuations between the results of heavy metals levels of the present study and that of the previous studies. These fluctuations can be attributed to many factors including the variability of the land-based sources, the change in industrial production quantity and activities, the effect of sea hydrographical parameters,...,etc. At the same time, the presence of all the measured heavy metals in considerable levels in all the studied sites indicates that neither diversion process nor Environment Law 4/1994 excecution has been effective uptill now in removing them and the coast of Alexandria is still subjected to the polluting land-based sources.

CONCLUSIONS AND RECOMMENDATIONS

Based on the obtained results, the following has been concluded:

1. The dissolved heavy metals reflected temporal as well as spatial variations. Abou-Qir area and to a less extent Qayet-Bey area are characterized by high averages of dissolved Cu, Zn, Pb, and Cr. El-Agamy water sustained the highest levels of Cd, Co, and Cr. Qayet-Bey water represents the highest Ni average.
2. Low seasonal averages of the essential metals Cu and Zn in addition to Cd and Ni were recorded during spring.
3. A significant direct correlation [r=0.52] was found between the dissolved forms of Zn and Cd. Dissolved cobalt shows inverse correlations with each of Cu [-0.33], Ni [-0.40], and Zn [-0.39]. The concentration of dissolved metals in Alexandria beaches water could be arranged as follows: Zn>Pb>Ni> Cu>Co> Cr>Cd.
4. Qayet-Bey area sustained the highest levels of particulate Cu, Zn, and to a less extent Co; Ni; and Cr. El-Agamy area contained the highest levels of both dissolved and particulate Cd. Contrary to the case of dissolved form, spring and to a less extent summer were characterized with the highest concentrations of particulate Zn, Cd, and Ni. Concerning the distribution of heavy metals in the particulate form it follows the order: Zn>Pb>Ni>Cu>Cr>Cd>Co.
5. It is clear that only the first four elements

in both orders [dissolved and particulate] occupy similar pattern. The results displayed that dissolved forms of most studied metals are higher in concentration than particulate ones. Zn and Cr, on the other hand, were found in particulate form slightly higher than those in dissolved forms.[37]

6. The presence of heavy metals in considerable levels in all the studied sites indicates that Alexandria cost is still subjected to the polluting land-based sources.

According the following conclusion, the following is recommended:

1. Continuous elevation of such heavy metals from anthropogenic origin in the aquatic environment must be taken into consideration.
2. Industries should be enforced to treat their wastewater to comply with Law 4/1994 before discharge.
3. Environmental impact assessment should be done for the new activities.
4. Continuous monitoring of the water quality of the beaches is necessary.
5. Fishing from polluted areas should be prohibited.

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