Indian Journal of Geo-Marine Science
Vol.44(9) ,September 2015. 1393-1400

Levels of some heavy metals in water and sediment compared with season and some physico-chemical parameters from Antalya Bay

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Received 04 June 2014; revised 25 June 2014

Main objectives of study were to monitor the metal levels in water and sediment seasonally, and identify relationships between some physico-chemical parameters and metal levels in water. In water, the temperature varied between 16.26-30.95 °C; the pH between 8.20-8.55; the dissolved oxygen between 8.05-10.06 mg l^{-1}; EC between 40461.4-53194 µs/cm and the salinity between 29.13-33.25. In water, Fe was the highest and while Cd is lowest. Generally, metal levels increased in summer and decreased in winter. Both positive and negative correlations were detected between their content in water and physico-chemical parameters. In sediment, Fe was the highest and Cd was the lowest. All metal levels increased in spring and decreased in winter. The results show that heavy metals are caused by the geochemistry, industry, tourism activities, urbanization, aquaculture and they are transported from the rivers to the Antalya Bay.

[Key Words: Accumulation; Pollution; The Antalya Bay; Seawater; Sediment.]

Introduction

Heavy metal in the biosphere are widely studied because of their toxicity, persistence and high levels in environment, and due to their human health impacts[1]. Heavy metals affect on ecological system since they are not removed from water as a result of purification but acumulate in sediment and enter the food chain[2].The natural structure of the earth crust consist of elements. However, human activities have introduced high loads of these constituents in the environment, making it difficult to differentiate natural and anthropogenic contributions[3]. Large amounts of heavy metals are transportedtothe coastal environments by rivers through estuaries. Anthropogenic origin of heavy metals near rivers and estuaries may be due to agriculture and industrial activities, urban development and tourism in coastal regions[4-6]. Heavy metals are in marine waters in both dissolved and solid forms. Some of these metals are rapidly and efficiently associated with the sediment because of adsorption, hydrolysis and co-precipitation [7,8].

Metals, once introduced into the marine environment, can be accumulated in the sediment[3]. Studies on the levels and seasonal variations of metals in the sediment analysis play an important role in assessments of pollution status of the marine environment[3,5]. Sediments are also important carriers of metals in the hydrological cycle, because metals are portitioned with the surrounding waters, and they can reflect the quality of an aquatic systems[9]. Indeed, analysis of sediments is an essential part of the environmental studies on marine environments, and a number of studies have showed that marine sediments are highly contaminated by metals [3, 10-14].

Antalya Bay (Mediterranean Sea, Southern Turkey) is one of the most important bays in Turkey, taking into consideration the importance of its fish resources. It lies between longitudes; 35°49′ and 30°22′ E and latitudes; 36°50′ and 31°06′ N along. Along the coast of Antalya Bay, there are many towns, hotels, orange and lemon gardens. It covers an area of 20820 km^2 including Antalya city and its towns and the coast is almost 640 km long[15]. Antalya Bay is polluted by some materials such as domestic waste water from tourist activities, pollutants brought by the Aksu and Düden streams, agricultural activities and marine transportation. Total population of Antalya and its towns are 1.7 million in winter. But there are dense tourist activities in summer. The total population is 10.2 million in summer. Because of this increase of population in summer it causes the pollution in Antalya Bay[15].

The objectives of this study are to investigate the seasonal variations of some heavy metals (Mo, Cd, Cr, Cu, Fe, Mn, Ni, Pb, Se and Zn) in water and sediment (1), to determine some physico-chemical parameters of water (2) and assess relationships between the metal levels in water and physico-chemical parameters (3).

Material and Methods

Water and sediment sampling was carried out monthly between March 2011 and February 2012 as at five stations in Antalya Bay of the Mediterranean Sea (Fig. 1). The temperature, dissolved oxygen, pH, conductivity and salinity values were measured at the same stations by using YSI multiparameter equipment. Seawater samples were taken 50 cm and 1 m below the water surface and acidified with the concentrated nitric acid. For heavy metal analysis water samples were immediately filtered through Whatman 0.45 µm glassfiber filter and transferred to polypropylene bottles.

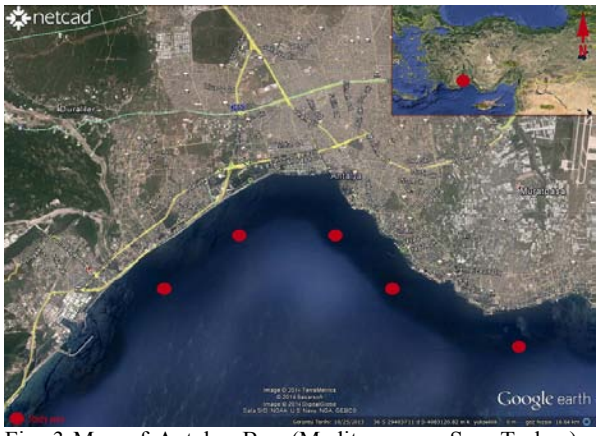

Fig. 3-Map of Antalya Bay (Mediterranean Sea, Turkey) (Taken from google earth) and different localities from where the samples were taken.

Sediment samples were collected with Ekman bottom sampler from the top 30 cm layer of the bottom and dried in an oven at 70º for 2-3 days. Then sediment samples passed through a 63 µm sieve. This fraction (< 63 µm) of sediment was used because it contains higher levels of elements than the sand fraction[16]. In fact, metals are more often associated with small grains[17]. Metal levels tend to increase from sand to silt[18]. Metal adsorption capacity was in order of sand<silt<clay, due to increases in surface areas[18]. For analysis, 0.5 g sediment samples were placed in decomposition beakers and 5 ml HNO_3 added to each, were kept at room temperature for 24 h. Then they were heated at 120ºC on hot plate for 2 h, until the solution evaporate slowly to near dryness. After cooling, added 1 ml H_2SO_4 and diluted to 25 ml with deionized water, then added 1-2 drop HNO_3[19].

The precision and accuracy of the analysis of the sediments was checked by using a certificated reference marine sediment (HISS 1, National Research Council, Canada). The certified values and the obtain values of elements from the reference material are given Table 1. Recovery rates ranged from 80% to 124% for all investigated elements.

Table 1. Concentrations of metals found in certified reference material HISS 1 from the National Research Council, Canada.

Metal	HISS 1 Certified	HISS 1 Observed	Recovery (%)
Cd	0.024±0.009	0.025±0.002	104
Cu	2.29±0.37	2.79±2.08	121
Mn	66.1±4.2	82.33±19.02	124
Ni	2.16±0.29	1.74±0.55	80
Pb	3.13±0.40	3.34±0.11	106
Se	0.05±0.007	0.048±0.13	96
Zn	4.94±0.79	4.72±1.25	95

All metals were determined by ICP-OES. The following absorption wavelength were used; Mo 202.032 nm, Cd 214.439 nm, Cr 267.716 nm, Cu 327.395 nm, Fe 238.204 nm, Mn 257.610 nm, Ni 231.604 nm, Pb 220.353 nm, Se 203.985 nm and Zn 213.857 nm. Each samples were analyzed in triplicate. Detection limits of elements are Mo 0.0008 mg/lt, Cd 0.0004 mg/lt, Cr 0.00005 mg/lt, Cu 0.0006 mg/lt, Fe 0.0004 mg/lt, Mn 0.00005 mg/lt, Ni 0.013 mg/lt, Pb 0.03 mg/lt, Se 0.005 mg/lt and Zn 0.0003 mg/lt.

The averages and standard deviations of the metal concentrations have been calculated in accordance with seasons. ANOVA, Duncan multiple and Pearson test was used to evaluate the effect of physico-chemical parameters and season over the metal accumulation in water and sediment. Statistical analysis of data was carried out using SPSS 18 package programs for Windows.

Result and Discussion

Some physico-chemical parameters determined in the Antalya Bay's water depend on seasons (Table 2). According to the table, mean water temperature ranged between 16.26ºC (winter) and 30.95ºC (summer), mean pH ranged between 8.20 (autumn) and 8.55 (spring), the mean dissolved oxygen changed according to the temperature and the measurements ranged between 8.05 mg L^{-1} (summer) and 10.06 mg L^{-1} (winter). Mean electric conductivity values ranged between 40461.4 µs cm^{-1} (spring) and 53194 µs cm^{-1} (summer) and mean salinity changed from 29.13 (spring) and 33.25 (winter). There are significant differences among seasons (< 0.05) for temperature, pH and dissolved oxygen. Coulibaly et al.[20] measured some physico-chemical parameters in Biétri Bay, and found

that pH values decrease in dry season while increased in rainy and swelling seasons. The pH value in water has a negative relationship with CO_2 level. Rising pH value in summer maybe

Table 2. Some physico-chemical parameters of Antalya Bay's water

	Temperature	pH	Dissolved Oxygen (mg/L)	Electrical Conductivity (µg/cm)	Salinity (‰)
Spring	19.27-20.73 19.93±0.53^{a*}	8.38-8.74 8.55±0.13^{c}	9.58-10.42 10.06±0.3^{c}	30436-47204 40461.4±7936.5^{a}	21.34-33.83 29.13±6.24^{a}
Summer	29.82-31.90 30.95±0,99^{b}	8.34-8.64 8.47±0.13^{bc}	8.11-9.31 8.62±0.48^{b}	46660-57317 53194±4945^{b}	27.40-33.00 30.91±2.58^{a}
Autumn	21.91-23.80 22.62±0.72^{c}	8.11-8.28 8.20±0.06^{a}	7.59-8.32 8.05±0.29^{a}	36596-49971 44018±6689.48^{a}	24.76-33.74 29.93±4.72^{a}
Winter	15.59-16.82 16.26±0.50^{d}	8.04-8.40 8.30±0.14^{ab}	8.86-10.71 10.04±0.73^{c}	33140-50015 42161.60±6669.49^{a}	26.67-39.72 33.25±5.60^{a}

*Means with the same superscript in the same row are not significant different according to Duncan's multiple range test ($p<0.05$)

related to diminishing gase solubility because of high temperature. In summer, CO_2 decrease because of photosynthesis, the pH value increase[21]. Dissolved oxygen was the highest in winter because of decreasing of temperature. Warmer water is unable dissolve as much oxygen gas[22]. EC reached the maximum level in summer. This can be due to at inorganic substances being increased as result of stong evaporation at water body in warm seasons.

A statistical summary of the ten elements in the water of the bay is listed in Table 3. Our results on metal levels in water show that Fe content was the highest and that of Cd was the lowest in water (Table 3). Mo ranged between 0.88 mg L^{-1} (in winter) and 1.87 mg L^{-1} (in autumn), Cd ranged between 0.40 mg L^{-1} (in winter) and 1.13 mg L^{-1} (in autumn), Cr ranged between 8.49 mg L^{-1} (in autumn) and 154.05 mg L^{-1} (in summer), Cu values varied from 33.24 mg L^{-1} (in winter) to 262.67 mg L^{-1} (in autumn). Fe levels ranged between 2842.99 mg L^{-1} (in autumn) and 20572.769 mg L^{-1} (in summer). Mn values changed between 57.77 mg L^{-1} (in winter) and 1773.42 mg L^{-1} (in spring). Ni levels ranged between 8.63 mg L^{-1} (in winter) and 446.77 mg L^{-1} (in summer). Pb ranged between 2.71 mg L^{-1} (in autumn) and 9.79 mg L^{-1} (in summer). Se levels varied form 12.98 mg L^{-1} (in autumn) to 51.33 mg L^{-1} (in summer). Zn levels ranged between 27.93 mg L^{-1} (in winter) and 451.57 mg L^{-1} (in summer). There are significant differences (<0.05) in the levels of metals (Cd, Cr, Cu, Fe, Mn, Ni, Pb and Se) among seasons. Coulibaly et al.[20] investigated concentrations of heavy metals in water of Bietri Bay and found the following concentrations: 0.01-0.30 mg L^{-1} for Hg, 0.68-0.88 mg L^{-1} for Cd, 2.40-4.80 mg L^{-1} for Pb, 9.05-9.68 mg L^{-1} for Cu and 12.05-19.87 mg L^{-1} for Zn. They reported that Hg, Cd and Pb levels were displayed the highest values during the dry season and the higher dry season levels of Hg, Pb, Cd and Zn may be attributed to the fact that heavy metal accumulation in water is dependent upon the physical and chemical properties of water such as pH, temperature, salinity, conductivity and dissolved oxygen levels[22]. In this study, generally, the metal levels increased in summer and decrease in winter. Total population of Antalya and its towns are 1.7 million in winter. But there are dense tourist activities in summer. The total population is 10,2 million in summer. Because of this increase of population in summer cause pollution in Antalya Gulf. Increasing in summer can be caused by evaporation in hot season. Besides this, the increasing of the input waste materials to Antalya Gulf can be effect of heavy metal levels in summer in gulf water. Decrease of metal concentrations caused by heavy rain in autumn. The results of heavy metals in water of Antalya Bay were compared with EC, WHO, TSE-266 and US EPA [23-26] standarts. According to these standarts, our results were lower than the permissible levels for drinking water except Fe and Mn.

The relationships between metal and some physico-chemical parameters in water have been showed in Table 4. When the water temperature increase, Cd, Cr, Cu, Fe, Ni Pb and Se levels were decreased. There are negative relationships

between pH value and Mo, Cd, Cu, Se and Zn levels. Negative relationships were determined between dissolved oxygen and Mo, Cu, Mn and Zn, others are positive. The rising of conductivity value effect the levels of Mo, Cu, Se and Zn negatively. And finally, all the relationships were negative between salinity and all metals except Se. Tao et al.[1] , found negative relationships between pH and some metals like Cu, Cr, Sb, between temperature and Cd, Ni, Mn, between dissolved oxygen and Cu, Cr, Ni, Sb and Zn. We can say that the change of physico-chemical parameter depend on seasons effect the levels of some metals. Türkmen et al. [27] investigated correlations between metal levels and temperature, pH, dissolved oxygen and salinity of water of İskenderun Bay's (Turkey). They found negative relationships between oxygen and Cr and Cu. Other relationships were positive. The solubility of toxic heavy metal increase with the decrease of pH[28].

The residue data of the measured metals in sediment have been shown in Table 5. All the analyzed metals were determined in sediment. According to the table, Se and Pb were below detection limit in autumn and winter, while Mn was in only autumn and Pb in summer and autumn. Fe was the highest metal and Cd was the lowest among the analyzed metals. Mo ranged between 0.19 mg kg^{-1} (in winter) and 0.25 mg kg^{-1} (in summer), Cd has significant relationships among seasons (< 0.05). Cd values ranged between 0.0061 mg kg^{-1} (in summer) and 0.013 mg kg^{-1} (in autumn). There were not significant relationships among seasons (>0.05). The highest Cr value was in autumn (0.46 mg kg^{-1}) and the lowest in spring (0.06 mg kg^{-1}). Cr levels varied significantly among seasons (<0.05). Cu levels vary between 0.19 mg kg^{-1} (in summer) and 0.95 mg kg^{-1} (in spring). There are no significant relationships among seasons (>0.05). Fe value ranged between 1.18 mg kg^{-1} (in autumn) and 8.09 mg kg^{-1} (in spring). Fe levels did not vary significantly among seasons (>0.05). The highest Mn level was determined in spring with 1.05 mg kg^{-1}, and the lowest in winter with 0.0091 mg kg^{-1}. The Mo levels did not vary significantly from season to season (>0.05). Ni levels changed between 0.08 mg kg^{-1} (in summer) and 0.23 mg kg^{-1} (in spring). The highest concentration of Pb was in spring (0.09 mg kg^{-1}) and lowest in winter (0.017 mg kg^{-1}). Se levels changed between 0.31 mg kg^{-1} (in autumn) and 0.54 mg kg^{-1} (in summer). Zn contents did not vary significantly from season to season (>0.05). Zn levels ranged between 1.24 mg kg^{-1} (in autumn) and 5.45 mg kg^{-1} (in spring). There is not significant differences among seasons (>0.05).

In this study, heavy metals in sediments taken from Antalya Bay would appear as Fe > Zn > Mn> Cu>Se>Mo>Ni>Pb<Cr>Cd. In comparison, Fe concentrations were the highest in Aqaba Gulf [29], Kalpakkam [5], Black Sea [12], Gulf of Tunis [3]. Iron is generally the most abundant metal in all of the reservoirs it is one of the most common elements in the Earth's crust [30]. Pyrite oxidation produced sulphate and the Fe^{2+} ion, which is oxidised to Fe^{3+} by microorganisms such as *Thiobacillus ferrooxidans* [31]. It is known that reduction of Fe in the sediment during the oxidation of organic matter results in its enrichment [32]. Kerrison et al.[33] reported that Cd accumulates slowly in the sediment. Cadmium is not found in the organic fraction for low adsorbtion constant and labile complexion with organic matter [34]. The Cr, Cu, Fe, Ni and Pb levels are lower than the values in Kalpakkam[5], Tunis Gulf [3] and Erdek Bay [10]. Zn level is higher than Tunis Gulf [3]. Generally, all metal levels increased in spring and decreased in winter. Tekin-Özan [35] reported that the Cu and Zn levels were the highest in the spring, while Fe and Mn were in autumn in Beyşehir Lake's sediments. In Yeniçağa Lake sediment, Mo, Ba, Cr, Mn, Co and Ni levels were highest in April-2008 [36]. The heavy metal concentrations of Karakaya Dam Lake's sediment were highest in spring and lowest in summer[37]. Due to their strong affinity for particles[38], metals tend to be accumulated by suspended matter or trapped immediately by bottom sediments[39]. This study show that the sediment from Antalya Bay consist of very high amount of metals when compared with their levels in water. Sediment are important hosts for pollutant heavy metals, therefore they have been used to monitor the pollution in aquatic environment. The source of the heavy metals can be geochemistry, industry, tourism, urbanization, aquaculture and rives.

Acknowledgements

This work supported by Süleyman Demirel University, SDÜBAP 2574-M-10 project. Author would like to thank Süleyman Demirel University–Scientific Research Project Management for their financial support.

Table 3. The concentrations of some heavy metals in Antalya Bay's water (ppb)

Season	Mo	Cd	Cr	Cu	Fe	Mn	Ni	Pb	Se	Zn
Spring	0.81-2.35 1.60±0.64^{a*}	0.25-1.33 0.81±0.50^{ab}	21.42-247.68 97.07±103.14^{ab}	28.10-186.89 84.55±65.29^{a}	9445.87-24903.60 15186.41±6316.16^{b}	1087.41-3219.10 1773.42±875.48^{b}	68.21-778.06 308.92±327.46^{ab}	5.17-12.73 9.69±3.56^{b}	9.57-29.22 20.97±7.67^{ab}	27.02-137.29 64.85±45.67^{a}
Summer	1.37-2.32 1.78±0.40^{a}	0.28-1.09 0.72±0.40^{ab}	25.73-367.25 154.05±131.13^{b}	57.96-101.68 87.13±5.78^{a}	14074.70-34556.90 20572.76±8226.88^{c}	1136.60-1709.87 1392.47±234.61^{b}	96.31-1100.90 446.77±403.62^{b}	5.14-15.15 9.79±4.69^{b}	9.49-107.02 51.33±45.13^{a}	297.10-675.00 451.57±180.76^{a}
Autumn	0.09-4.18 1.87±1.73^{a}	0.46-1.68 1.13±0.53^{b}	2.17-16.53 8.49±5.19^{a}	57.71-399.94 262.67±133.7^{b}	1345.99-6930.64 2842.99±2319.33^{a}	1155.10-2137.57 1678.21±414.01^{b}	7.78-36.26 16.43±11.29^{a}	0.29-5.14 2.71±2.05^{a}	1.94-25.31 12.98±8.85^{ab}	33.82-113.06 60.17±30.54^{a}
Winter	0.74-1.24 0.88±0.20^{a}	0.10-0.88 0.40±0.29^{a}	4.22-16.28 11.86±4.5^{a}	20.90-50.45 33.24±14.30^{a}	2937.42-10545.90 5967.99±3855.23^{a}	47.57-66.28 57.77±6.97^{a}	3.71-18.36 8.63±5.64^{a}	2.66-6.68 5.31±1.60^{a}	23.93-59.10 36.91±13.46^{b}	7.32-98.74 27.93±39.68^{a}

* Means with the same superscript in the same row are not significant different according to Duncan's multiple range test (p<0.05)

Table 4. Pearson correlation matrix showing the correlation coefficients between physico-chemical parameters of water and metal levels

(°C)	Temperature	pH	Dissolved Oxygen (mg/lt)	Conductivity (µs/cm)	Salinity (‰)	Mo	Cd	Cr	Cu	Fe	Mn	Ni	Pb	Se	Zn
Temperature	1	-0.461*	-0.248	0.156	0.142	0.410	-0.161	-0.117	-0.129	-0.210	0.206	-0.116	-0.107	-0.017	0.026
pH		1	0.549*	0.067	-0.050	-0.051	-0.009	0.537*	-0.129	0.691**	0.302	0.549*	0.629**	-0.140	-0.273
Dissolved Oxygen (mg/lt)			1	-0.313	0.048	-0.162	-0.531*	0.076	-0.578**	0.207	-0.384	0.103	0.269	0.236	-0.283
Conductivity				1	0.736**	-0.032	0.084	0.159	-0.139	0.243	0.209	0.127	0.189	-0.127	-0.242
Salinity (‰)					1	-0.235	-0.121	-0.184	-0.294	-0.133	-0.290	-0.204	-0.097	0.253	-0.295
Mo						1	-0.152	0.092	0.143	0.106	0.427	0.103	0.036	-0.023	0.672**
Cd							1	-0.142	0.519*	-0.188	0.179	-0.138	-0.129	-0.066	-0.026
Cr								1	0.077	0.913**	0.709**	0.997**	0.545*	-0.393	-0.164
Cu									1	-0.073	0.471*	0.090	-0.366	0.052	0.537*
Fe										1	0.663**	0.913**	0.734**	-0.285	-0.148
Mn											1	0.716**	0.412	-0.396	0.213
Ni												1	0.541	-0.383	-0.153
Pb													1	-0.440	-0.274
Se														1	0.251
Zn															1

* and ** indicate the correlation coefficients were significant at 0.05 and 0.01 probability levels. using two-tailed test.

Table 5. The concentrations of some heavy metals in Antalya Bay's sediment (mg kg^{-1})

	Mo	Cd	Cr	Cu	Fe	Mn	Ni	Pb	Se	Zn
Spring	0.18-0.28 0.23±0.04^{ab**}	0.002-0.01 0.0068±0.004^{a}	0.05-0.07 0.06±0.01^{a}	0.28-2.76 0.95±1.20^{a}	0.92-17.82 8.09±5.75^{a}	0.79-1.32 1.05±0.37^{a}	0.0017-0.68 0.23±0.38^{a}	0.01-0.20 0.09±0.10^{a}	0.17-0.79 0.47±0.23^{a}	0.79-15.68 5.45±6.35^{a}
Summer	0.22-0.29 0.25±0.02^{b}	0.003-0.01 0.0061±0.003^{a}	0.21-0.58 0.36±0.18^{ab}	0.03-0.35 0.19±0.22^{a}	0.55-6.51 3.40±2.87^{a}	0.03-0.37 0.21±0.17^{a}	0.01-0.24 0.08±0.10^{a}	BDL	0.08-1.03 0.54±0.39^{a}	0.10-12.81 2.88±5.56^{a}
Autumn	0.20-0.24 0.22±0.01^{ab}	0.01-0.02 0.013±0.005^{a}	0.21-0.78 0.46±0.21^{b}	BDL*	0.18-2.44 1.18±1.14^{a}	BDL	BDL	BDL	0.27-0.35 0.31±0.03^{a}	0.03-5.05 1.24±2.16^{a}
Winter	0.18-0.25 0.19±0.02^{a}	0.007-0.01 0.0078±0.003^{a}	0.21-0.86 0.42±0.27^{ab}	BDL	2.45-2.48 2.46±0.01^{a}	0.009-0.02 0.0091±0.006^{a}	BDL	0.015-0.019 0.017±0.002^{a}	0.08-0.55 0.32±0.20^{a}	0.07-3.01 1.36±1.29^{a}

* Below Detection Limit

** Means with the same superscript in the same row are not significant different according to Duncan's multiple range test (p<0.05)

References

1. Tao, Y.Z., Yuan, M.W., Xiaona, X., Characterization of heavy metals in ater and sediments in Taihu Lake, China, *Environmental Monitoring and Assessment,* 184 (7) (2012) 4367-4382.
2. Loksa, K., Wiechulla, D., Application of principal component analysis for the estimation of source of heavy metal contamination in surface sediments from the Rybnik Reservoir, *Chemosphere,* 51 (2003) 723-733.
3. Ennouri, R., Chouba, L., Magni, P., Kraiem, M.M., Spatial distribution of trace metals (Cd, Pb, Hg, Cu, Zn, Fe and Mn) and oligo-elements (Mg, Ca, Na and K) in surface sediments of Gulf of Tunis (Northern Tunisia), *Environmental Monitoring and Assessment,* 163 (2010) 229-239.
4. Morton, B., Blackmore, G.G., South China seak, *Marine Pollution Bulletin,* 42 (2001) 1236-1263.
5. Satpathy, K.K., Mohanty, A.K., Prasad, M.V.R., Natesan, U., Sarkar, S.K., Studies on the variations of heavy metals in marine sediments off Kalpakkam, East Coast of India, *Environ. Earth. Sci.,* 65 (2012) 89-101.
6. Govindasamy, C., Azariah, J., Seasonal variations of heavy metals in coastal water Coromandel coast, Bay of Bengal, India, Indian Journal of Marine Sciences, 28 (1999) 249-256.
7. Horowitz, A.J., *A primer on sediment-trace elements chemistry*, (Lewis Publishers, Chelsea, Michigan) 1991, pp. 144.
8. Szefer, P., Szefer, K., Glasby, G.P., Pempkowiak, J. Kaliszan, R., Heavy metal pollution in superficial sediments from the southern Baltic Sea off Poland, *Journal of Environmental Science and Health,* A31 (10) (1996) 2723-2754.
9. Turner, A., Millward, G.E. Morris, A.W., Particulate metals in five major North Sea estuaries, *Estuar. Coast. Shelf. Sci.*, 32 (1991) 325-346.
10. Balkıs, N., Çağatay, M.N., Factors controlling metal distribution in the surface sediments of the Erdek Bay, Sea of Marmara, Turkey, *Environmental International,* 27 (2001) 1-13.
11. Zabetoglou, K., Voutsa, D., Samara, C., Toxicity and heavy metal contamination of surficial sediments from the Bay of Thessaloniki (Northwestern Aegean Sea) Greece, *Chemosphere,* 49 (2002) 17-26.
12. Topçuoğlu, S., Kırbaşoğlu, Ç., Güngör, N., Heavy metals in organisms and sediments from Turkish Coast of the Black Sea, 1997-1998, *Environmental International,* 27 (2002) 521-526.
13. Gargouri, D., Azri, C., Serbaji, M.M., Jedouni, Y., Montacer, M., Heavy metal concentrations in the surface marine sediments of Stax Coast, Tunisia, *Environmental Monitoring and Assessment,* 175 (2011) 519-530.
14. Hosseini, M., Daryashekan, M., Kashefi, M., Monikh, F.A., Level of Cd, Hg, Mn and Pb in sediment and invertebrate of North Persin Gulf, *Indian Journal of Geo-Marine Sciences,* 43 (4) (2014) 5661-563.
15. Tuğrul-İçemer, G., Keles, C., Karaca, H., Influence of inter annual variations on total and fecal kolform levels in Antalya Bay, paper presented at the *10th International specialized conference on diffuse pollution and sustainable basin management*, İstanbul, 2006.
16. Tom N.F.Y., Wong, Y.S., Spatial variation of heavy metals in surface sediments of Hong mangrove swamps, *Environmental Pollution,* 110 (2000) 195-205.
17. Morillo, J., Usero, J., Gracia, I., Heavy metal distribution in marine sediments from the southwest coast of Spain, *Chemosphere,* 55 (2004) 431-442.
18. Haque, M.A., Subramanian, V., Cu, Pb and Zn pollution of soil environment, *CRC Critical Reviews in Environmental Control,* 12 (1982) 13-90.
19. Crompton, T.R., *Determination of metals and anions in soils, sediments and sludges*, (Taylor and Francis Group, New York) 2001, pp. 725.
20. Coulibaly, S., Atse, B.C., Koff, K.M., Sylla, S., Konan, K.J., Kouassi, N.J., Seasonal accumulations of some heavy metal in water, sediment and tissues of black-chinned tilapis *Sarotherodon melanotheron* from Biétri Lagoon, Ivory Coast, *Bulletin of Environmental Contamination and Toxicology,* 88 (4) (2012) 571-576.
21. J. Tanyolaç, *Limnoloji*, (Hatipoğlu yayınları, Ankara) 2006, pp. 235.
22. Wong, C.K.C., Cheung, R.Y.H., Wong, M.H., Heavy metal concentration in green-lipped mussels collected from Tolo harbor and markets in Hong Kong and Shenzhen, *Environmental Pollution,* 109 (2000) 165-171.
23. European Commission., Council directive 98/83 Ec of 3 November 1998/ on the quality of water intended for human consumption. Maximum levels for certain contaminants in foodstuffs, 1998.
24. WHO (World Health Organization)., Guidelines for drinking-water quality. Fourth edition, Geneva, 2011.
25. TS-266 (Turkish Standards Institute)., Water intended for human consumption," Institution of Turkish Standards publications, ICS 13.060.20., 2005.
26. US Environmental Protection Agency, Aquatic Biodiversity. [on-line] http://www.epa.gov/bioiweb1/aquatic/pollution.html. Accessed 20 February 2012. 2009.
27. Türkmen, A., Türkmen, M., Naz, M., İskenderun Körfezi Deniz Suyu Ağır Metal Konsantrasyonları ile Sıcaklık, pH, Oksijen ve Tuzluluk Değerleri Arasındaki Korelasyonlar, *Turkish Journal of Aquatic Life,* 2 (3) (2004) 400-407.
28. Hellawell, M.J., Toxic substances in rivers and streams, *Environmental Pollution,* 50 (1988) 61-85.
29. Youssef, D.H., El-Said, G.F., Assessment of some heavy metals in surface sediment of the Aqaba Gulf, Egypt, *Environ. Monit. Assess.,* 180 (2011) 229-242.
30. Usero, J., Izquierdo, C., Morillo, J., Gracia, I., Heavy Metals in Fish (*Solea vulgaris, Anguilla anguilla* and *Liza aurata*) from Salt Marshes on the Southern Atlantic Coast of Spain, *Environmental International,* 1069 (1988) 1-8.
31. Cabrera, F., Vlemente, L., Diaz Barrientos, E., Lŏpez, R., Murillo, H.M., Heavy metal pollution of soil affected by the Guadiamar toxic Hood, *The Science of the Total Environment,* 242 (1999) 117-129.
32. Francois, R., A study on the regulation of the concentrations of some trace metals (Rb, Sr, Zn, Pb, Cu, V, Cr, Ni, Mn and Mo) in Saanich Inlet Sediments, British Columbia, Canada, *Marine Geology,* 83 (1988) 285-308.
33. Kerrison, P.H., Annonsi, D., Zerini, S., Ravera, O., Moss, B., Plankton effects of low concentrations of heavy metals on plankton community dynamics in a small, shallow, fertile lake, *Journal of Plankton Research,* 10(4) (1988) 779-812.

34. Barron, J., Legret, M., Astruc, M., Study of interactions between heavy metals and sewage sludge: determination of stability constants and complexes formed with Cu and Cd, *Environmental Technology,* 11 (1990) 151-162.
35. Tekin-Özan, S., Determination of heavy metals in water, sediment and tissues of tench (*Tinca tinca* L., 1758) from Beyşehir Lake (Turkey), *Environmental Monitoring and Assessment,* 145 (2008) 295-302.
36. Saygı, Y., Yiğit, S.A., Heavy metals in Yeniçağa Lake and its potential sources: soil, water, sediment, and plankton, *Environmental Monitoring and Assessment,*184 (3) (2012) 1379-1389.
37. Karadede, H., Ünlü, E., Concentrations of some heavy metals in water, sediment and fish species from the Atatürk Dam Lake (Euphrates), Turkey, *Chemosphere,* 41 (2000) 1371-1376.
38. Luorna, S N, Processes. Affecting metal concentrations in Estuarine and Coastal Marine sediments, in: *Heavy metals in the marine environment,* edited by W. Furness & PS Rainbow (CRC, Florida) 1990, pp. 51-66.
39. Dauvalter, V.A., Heavy metals in the bottom sediments of the Inari-Pasvik lake-river system, *Water Resources,* 25 (1998) 451-457.