International Journal of Environment & Water
ISSN 2052-3408

Distribution of Chemical Elements in Zooplanktons from Southern Iraqi Waters.

Shaker G.Ajeel Dept.Marine Biology
&
Faris J. M. Al-Imarah and Maryam F. Hameed
Dept. Marine Environ. Chem.
Marine Science Centre/Basrah Univ.
Basrah – Iraq.

ABSTRACT

Chemical elements Silver (Ag), Aluminum (Al), Barium (Ba), Beryllium (Be), Bismuth (Bi), Bromium (Br), Boron (B), Calcium (Ca), Lithium (Li), Magnesium (Mg), Manganese (Mn), Phosphorous (P),Potassium (K) Silicon (Si), Sodium (Na), Thorium (Th), and Titanium (Ti) were estimated by adopting ICP/MS instrument, in Zooplanktons collected from different stations of southern Iraqi waters at, 1) Shatt Al-Basrah channel, 2) Khor Al-Zubair, 3) Bouy 29, 4) Bouy 13, 5) Bouy 5 along Khor Abdullah, 6) Al-Masab (NW Arabian Gulf) as well as two stations along Shatt Al-Arab river estuary 7) Ras Al-Bisha, and 8) Al-Fao. Distribution of zooplanktons within these stations were different mostly Copepoda sp., Rotifers, and Cirripod larvae, being the most abundance are copepod sp. (30368 ind./m^3 in st. 7 (Ras Al-Bisha) during July 2009, followed by Rotifers as polychaetes (15020 ind/m^3 in St. 1 (Shatt Al-Basrah channel) during Feb. 2010, then Cirriped larvae (3614 ind./m^3)in St,1. During Feb. 2010. The As a total zooplanktons, the most abundance was 24136 ind./m^3 in St. 1 during Feb.2010, and the lowest was 152 ind./m^3 in St.7 during March 2010. Levels of chemical elements reported (µg/g) in the zooplanktons from southern Iraqi waters were range (26580-135403 Ca), (791.62-16085.06 P), (4108.15- 12463.09 Mg), (1462.64-11749.05 Al), (406.15-6028.21 Na), (11.66-7086.87 Ba), (110.52-3597.44 Si), (43.38-1849.68 K), (53.55-554.83 Mn), , (81.81-1568.27 Br), (12.59-337.37 Cr), (1.88-29.74 B), (0.42-17.71 Li), (0.04-2.53 Ag), (0.21-1.07 Th), (0.08-1.07 Be), (0.01-1.07 Bi), (ND-0.07 Ti). Highly pollution in Sts. 1,2 and 3 is expected due to untreated domestic water thrown into Shatt Al-Basrah channel, while highly pollution in Sts, 4, 5, 6, 7, and 8 could be arises from water circulation in the northern part of the Arabian Gulf. Some elements are related to the radioactive series decay of ^{238}U such as Th which exist in very low concentration.

Key Words: Zooplankton, Chemical elements. Pollution. Southern Iraq, Arabian Gulf

INTRODUCTION:

Southern Iraqi water ways represented by Tigris river as fresh water and Shatt Al-Arab river Canal, Shatt Al-Basrah, Khor Al-Zubair Lagoon, Khor Abdullah, and regional waters at North West Arabian Gulf as saline waters are liable to be threatened by the discharge of untreated sewage wastes from residential cities as well as untreated industrial effluents. These wastes carry enormous level of toxicants particularly the trace elements which are capable to accumulate into the basic food chain and move up through the higher tropic level and results in negative impact on the marine and freshwater resources, thus causing economic loss (Robin et al. 2012).

Phytoplankton is the major food producers in marine and estuarine ecology, while zooplankton plays a fundamental role in food chains as a secondary producers. It considered major food sources for the marine mammals, birds and fishes (Nilsson et al., 1995a; Nilsson, et al. 1995b; Percy, 1993). Thus zooplankton organisms may contribute to the transfer of chemical elements to the higher trophic levels and have been chosen among other as recommended organisms in baseline studies for marine environment (AMAP, 1995).

There is a variety of significant human health and environmental associated issues with the geographically widespread prevalence of elevated level of both organic and inorganic compounds in freshwater and marine biota. A linkage is evident between the bioaccumulation of heavy metals and aquatic system and the atmospheric mobilization and deposition of heavy metals, which has local regional and global components (Manson, et al. 1994). Many pollutant problems can be linked to expanding to specific sources and there are particular concerns when such sources adjacent to estuarine and to marine systems supporting significant fisheries (Ninomiya, et al. 1995), such an example existed in Kuwait, south part of Iraq in Basrah governorate, and although no longer active, the legacy of its activities is still an important influence on the local contamination levels.

As in previous studies, the major point sources of pollution by heavy metals in southern Iraq are the heavy casualty using of projectiles used in the first and second Gulf war, the discharging of untreated sewages in rivers, the waste product discharges from oil refineries and petrochemicals closed to the Khour Al-Zubair (Al-Imarah, et al. 2010; Al-Imarah, et al. 2003; Karabedain, et al. 2009); and the salt and chlorine planet in Kuwait and petrochemical planet closed the north of Kuwait that has been affected on Northwest of Gulf under the influence of tide and sub tide of Gulf water (Al-Majed and Perston, 2000). The heavy metals in mixed zooplankton organisms generally found in higher concentration near the coast, due to the untreated discharged of many waste products of planets closed the coast or near the rivers (Rezai and Yusoff, 2011; Robin, et al. 2012).

Marin zooplankton constitute a major component of total biomass of marine environment, and there by play a vital role in the biogeochemical cycling of heavy metals in the sea (Shulz-Blades, 1992). Plankton are capable of concentrating heavy and trace metals from seawater. The average heavy metals content in zooplankton from north of Mediterranean was reported by many studies (Rezai and Yusoff, 2011).

The contamination of sea water, freshwater and estuarine water, due to direct exposure to atmospheric input, probably the major source of pollution in the all stations used in this study. There is significant industrial pollutant untreated waste has been discharged in River Shatt Al-Arab, Shatt Al- Basrah channel, Khour Al-Zubair, and the Gulf generated from discharging sewages; manufacturing industries such as of food, beverages palm, Oil refineries, petrochemical, manufacturing of fertilizers, textile pulp paper, tanneries and sugar (Chua, et al. 2000). The aim of this study is due to the lack of such studies concerned the evaluation of heavy metals especially in the zooplankton and phytoplankton in this area; the phytoplankton and zooplankton are the primary and secondary producers in the food chain; has not been taken in considerable studies in this area such that carried in the closed countries, India, (Robin, et al. 2012) and Saudi Arabia (Al-Tison and Chandy, 1995).

The physiology and ecology of planktonic organisms are influenced by the concentration, chemical speciation and resulting bioavailability of some chemical elements. The determination of the elemental structure of plankton is important for interpretation of physiological and functional states of aquatic ecosystems. The present study is focused on the structure and elemental composition of the zooplankton assemblages from the different aquatic zones along southern Iraqi water ways (Nekhoroshkov, 2014).

Study area:

This study covered the water ways of the Southern part of Basrah Governorate. Sampling stations for zooplanktons collection stretches from Shatt Al-Basrah channel Through Khor Al-Zubair, Khor Abdullah, towards the estuary of Shatt Al-Arab river. These stations are characterized by different nature and affected heavily by different factors.

Sampling

This study has been conducted during the period June 2009 – Feb. 2010. For collecting zooplanktons a plankton net of 120 micron mish-size and 40 cm in diameter of mouth aperture was towed behind a boat for 15 min. A flow-meter was mounted at the mouth of the net to determine the volume of water filtered by net (DeBernardi, 1984). Samples were preserved in freezer after washed with same water of each sampling station. Dry weight of the zooplankton was estimated by filtering the sample through a filter paper using a vacuum pump. Then the filter paper was oven – dried at 60 ºC for 24 hours.

Chemical analysis:

All samples collected were analyzed for chemical elements by ICP/MS in maxxam analytical INC. in Canada, followed the typical procedure for trace elements analysis. In Teflon beakers, zooplankton samples were digested with an aqua solution (2:1 concentrated nitric acid and hydrochloric acid) heated to 70 °C for 8–10 h. After digestion, samples were centrifuged. Trace elements in each sample were analyzed by inductively-coupled plasma mass spectrometry (ICPMS).**(** Chen et al.,2000)

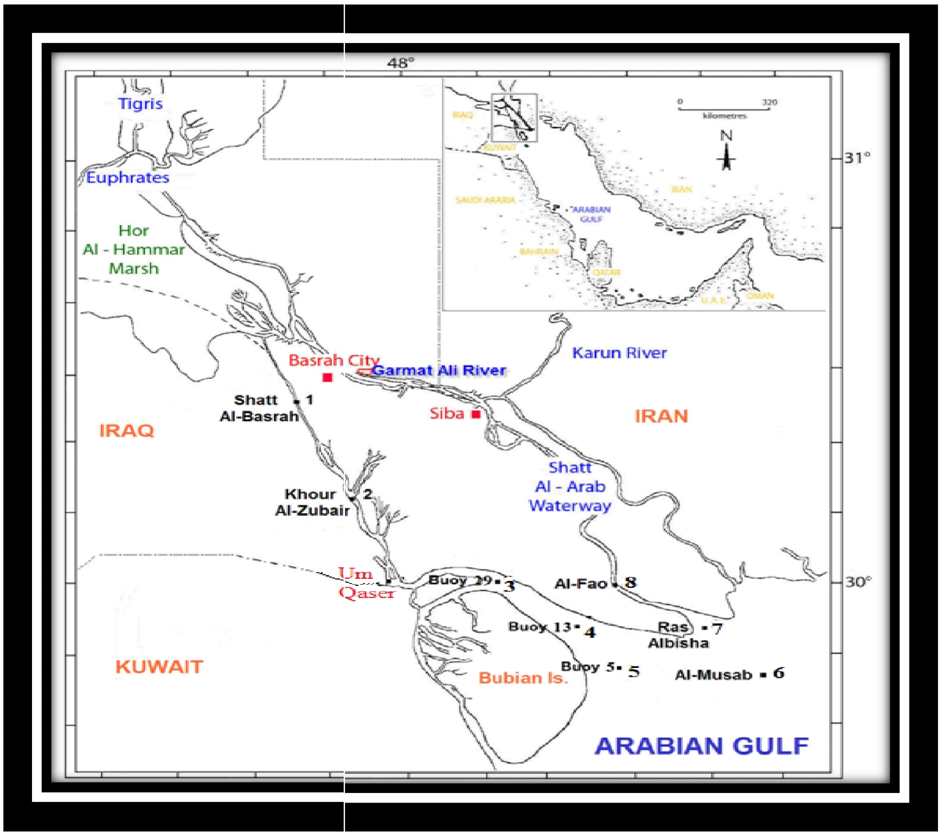

Figure 1. Location map of southern Iraq showing sampling stations.

Statistical Analysis

Statistical analysis was performed using analysis of variance (ANOVA) without replication was carried out to observe the special variation of metals variables. Significant level was considered at 95% confidence limit.

RESULTS

The density of zooplankton, categorized in groups according to their abundance as G1: Copepods, G2: Rotiffers, G3: Cirriped larvae, and G4: as minor species are shown in table I. The concentrations of 17 chemical elements : Li, Be, B, P, Na, Mg, Al, Si, K,Ca, ,Mn, , Br, Ag, Ba, Ti, Bi, and Th in the zooplankton communities of the aquatic ecosystems for all stations are shown in table II.

Table I. Density and diversity of zooplankton (ind/ m^3)from all selected stations in the studying area. (G1= group 1, G 2= group 2, etc. …..as dominant groups).

Stations&& periods	Zooplankton total	G1 Copepods sp.	G2 Rotifers	G 3 Cirriped larvae	G 4
		St.1 Shatt Al-Basrah			
June 2009	17580	9895	7243	170	
Aug.2009	5811	4595	919	178	
Oct.2009	16533	12176	1284	1899	
Dec.2009	8453	3254	2939	2080	
Feb.2010	24536	3017	15020	3614	
		St.2 Khour Al-Zubair			
June 2009	5632	4732	411	141	
Aug.2009	4967	3509	176	1122	
Oct.2009	20328	18148	503	391	391
Feb.2010	8919	2563	3769	443	
Oct.2010	14882	11786	2186	293	
		St. 3 Buoy 29			
Jul.2009	996	886	43	32	
		St. 4 Buoy 13			
Jul.2009	5148	4896	72		
March 2010	2922	2691	77	55	
		St. 5 Buoy 5			
Jul. 2009	4484	3368	412	303	
March 2010	6455	5804	Polychaetes 163	Foraminifera 122	
		St. 6 Al-Masab			
Jul. 2009	26601	17450	Bivalve 6765	Cirripedslar. 588	Append. 556
		St. 7 Ras Al-Bisha			
Jul.2009	32855	30368	Cirripedslar. 790	Polychaetes 513	
March 2010	152	22	Megaloba 109		
		St. 8 Al-Fao			
Jul. 2009	16699	11826	Bivalve 3796	CirripedLar. 584	
March 2010	9800	9409	------	-------	----

The most abundant zooplankton species recorded within this study was copipoda which reported 30368 indiv. /m^3 in station 7 (Ras Al-Bishah) during July 2009 followed by Rotifera as polychaets to be 15020 indiv. /m^3 in station 1 (Shatt Al-Basrah) during Feb. 2010, then to a minor level Terriped larvae 3614 indiv. /m^3 in station 1 (Shatt Al-Basrah) during Feb. 2010. Most abundant zooplanktons as a total reported 32855 indiv/m^3 in station 7 (Ras Al-Bishah) during July 2009, the highly individual zooplanktons were the copipoda sp. as 30368 indiv. /m^3 , while the lowest were 152 indiv. /m^3 in the same site during March 2010 and again Copepoda was the lowest to be 22 indiv. /m^3 .

Table II. Concentrations (in µg/g) of chemical elements in zooplanktons from southern Iraqi waterways for the period June 2009 – Feb.

	Shatt-Al-Basrah (1)	Khor Al-Zubair (2)	Buoy 29 (3)	Buoy 13 (4)	Buoy 5 (5)	Al-Musab (6)	Ras Al-Bisha (7)	Al-Fao (8)
Silver Ag	0.180 ±0.034 (n=5)	0.914 ±0.277 (n=5)	0.330 ±0.00 (n=5)	0.330 ±0.057 (n=5)	0.305 ±0.105 (n=5)	1.020 ±0.000 (n=5)	0.180 ±0.057 (n=5)	0.750 ±0.369 (n=5)
Aluminum Al	6192,02 ± 1179.5 (n = 5)	3519.18 ± 476.70 (n = 5)	6225.95 ± 0.000 (n = 4)	3465.60 ± 40.36 (n = 4)	5572.80 ± 389.96 (n = 4)	1970.57 ± 0.00 (n = 4)	4832.30 ±1945.47 (n = 4)	8475.26 ±1473.89 (n = 4)
Barium Ba	1297.72 ± 781.009 (n = 5)	34.952 ± 3.942 (n = 5)	47.450 ± 0.000 (n = 4)	55. 555 ± 16.336 (n = 4)	357.320 ±181.357 (n = 4)	19.070 ± 0.000 (n = 4)	61.445 ± 28.743 (n = 4)	21.510 ± 4.243 (n = 4)
Berelium Be	0.510 ± 76. (n = 5)	30.96 ± 6.89 (n = 5)	12.07 ± 0.001 (n = 4)	81.11 ± 39.88 (n = 4)	15..10 ± 0.439 (n = 4)	11.58 ± 0.001 (n = 4)	156.5 ± 88.6 (n = 4)	30.52 ± 11.01 (n = 4)
Bismoth Bi	0.325 ± 0.115 (n = 5)	0.192 ± 0.057 (n = 5)	0.040 ± 0.000 (n = 4)	0.185 ± 0.089 (n = 4)	0.055 ± 0.259 (n = 4)	0.060 ± 0.000 (n = 4)	0.345 ± 0.287 (n = 4)	0.105 ± 0.317 (n = 4)
Boron B	18.673 ± 2.620 (n = 5)	11.290 ±2.693 (n=5)	16.160 ± 0.000 (n = 5)	9.710 ± 3.319 (n = 4)	21.485 ± 5.239 (n = 4)	10.000 ± 0.000 (n = 4)	4.955 ± 1.694 (n = 4)	7.640 ± 2.725 (n = 4)
Bromine Br	155.78 ± 23.299 (n = 5)	787.126 ±159.358 (n = 5)	257.41 ± 0.000 (n = 4)	400.275 ± 119.023 (n = 4)	389.255 ± 42.201 (n = 4)	1391.280 ± 0.000 (n = 4)	1311.585 ±596.007 (n = 4)	125.400 ± 18.571 (n = 4)
Calcium Ca	86452.496 ±11526.16 9 (n = 5)	96054.35 ±7169.00 0 (n = 5)	74548.46 0 ± 0.000 (n = 4)	73914.805 ±15304.59 1 (n = 4)	78786.515 ±15304.59 1 (n=4)	107728.28 0 ± 0.000 (n = 4)	72362.670 ±26374.80 3 (n = 4)	11625.960 ±11077.64 8 (n = 4)
Magnesium Mg	10291.980 ± 1690.842 (n = 5)	7891.674 ± 992.368 (n = 5)	11601.30 0 ± 0.000 (n = 4)	7568.835 ± 323. 775 (n = 4)	11387.030 ± 751.542 (n = 4)	4188.460 ± 0.000 (n = 4)	9048.660 ± 2646.146 (n =± 4)	14483.958 ± 43.685 (n = 4)
Lithium Li	8.031 ± 1.947 (n = 5)	5.398 ± 1.179 (n = 5)	7.220 ± 0.000 (n = 4)	6.030 ± 0.866 (n = 4)	8.400 ± 0.404 (n = 4)	2.350 ± 0.000 (n = 4)	5.350 ± 1.708 (n = 4)	9.410 ± 3.000 (n = 4)
Potassium K	662.946 ±184.083 (n=5)	530.338 ±116.092 (n=5)	1148.82 ±0.000 (n=4)	442.345 ±230.342 (n=5)	1150.615 ±226.901 (n=5)	471.820 ±0.000 (n=4)	503.925 ±167.168 (n=5)	1183.500 ±265.754 (n=4)
Sodium Na	1298.523 ±265.767 (n=4)	3114.174 ±523.736 (n=5)	1198.310 ±0.000 (n=4)	2273.450 ±264.362 (n=4)	2856.025 ±1114.889 (n=5)	3182.420 ±0.000 (n=4)	2133.200 ±323.223 (n=5)	1158.015 ±341.263 (n=5)
Phosphorou s P	5463.670 ±1491.380 (n=5)	5111.986 ±1010.49 2 (n=5)	4035.340 ±0.000 (n=4)	1921.090 ±325.827 (n=5)	1368.115 ±53.199 (n=5)	2105.810 ±0.000 (n=4)	5415.205 ±352.619 (n=5)	1062.000 ±156.103 (n=5)
Silicon Si	1137.795 ±318.001 (n=5)	1219.042 ±166.390 (n=5)	340.570 ±0.000 (n=4)	1413.050 ±752.016 (n=5)	612.150 ±129.222 (n=5)	119.130 ±0.000 (n=4)	2338.165 ±726.886 (n=5)	544.255 ±229.568 (n=5)

Thorium Th	0.631 ±0,087 (n=5)	0.422 ±0.048 (n=5)	0.510 ±0.000 (n=4)	0.535 ±0.106 (n=4)	0.485 ±0.101 (n=4)	0.290 ±0.000 (n=4)	0.685 ±0.262 (n=5)	0.695 ±0.020 (n=4)
Titanium Ti	o.030 ±0.005 (n=4)	0.026 ±0.000 (n=4)	0.060 ±0.000 (n=4)	0.030 ±0.005 (n=5)	0.090 ±0.011 (n=5)	0.010 ±0.000 (n=4)	0.000 ±0.000 (n=4)	0.030 ±0.011 (n=5)

The highest levels of chemical elements measured in the zooplanktons were in the range of 26580.17 – 135403, 4108.15 – 12463.09, 791.62 – 16085.06, 1462.64 – 11749.05, 11.66 – 7086.87, 406.15 – 6028.21, 110.52 – 3597.44, µg/g for Ca, Mg, P, Al, Ba, Na, and Si respectively. Ca and Mg are a part of the skeleton structure of the crustaceans, Na and K play a great role in regulating of the uptake and intake during the nutrition processes, Si has a great role in crustaceans. P is exists in each cell within the structure of the DNA. Al and Ba are exist within the earth crust. Moderate levels were in the range 43.38 – 1849.68, 81.81 – 1568.27, 53.55 – 554.83, 1.88 – 29.74 , µg/g for K, Br, Mn, and B while lower values were recorded in the range 0.42 -17.71, 0.04 – 2.53, 0.08 – 1.07, 0.01 -1.07, 0.21 – 1.07, ND – 0.07 for Li, Ag, Be, Bi, Th, and Ti respectively.

The nutrients (P and N) are crucial for the regulating of the zooplankton composition. However, in the studied waters, a deficiency of phosphorus did not observed. The values of phosphorous concentrations were similar in all stations , so this factor did not affect zooplankton density and the structure (dominating groups). (Ciszewski et al.,2013).

Among zooplanktons, Copepoda was the most abundant group. It seemed that this group is the least sensitive to pollution by chemical elements within the study area (Jak et al. 1996). It is possible that copepoda that live in saline water contaminated with chemical elements have been adapted to withstand the negative effects of those chemical elements. Other Groups such as rotofera and cladocera, which are more sensitive to chemical elements (Sarma et al. 2007b), were less abundant. The high density and diversity of zooplankton in aquatic system is affected by chemical elements, proved that as with phytoplankton, plankton fauna adapt to long-lasting contamination.

Chemical elements with moderate and lower levels are either naturally existence such as K, Mn, B, Li, or as a pollutants like Be, Bi, and Ti as a result of sinking vessels erosion and Th as a result of radiation pollution as it is incorporated within the radiation decay of ^{238}U pollutant reported in the study area (Al-Imarah and Ali,200). As well as the appearance of Uranium in the surrounding area (Fido and Al-saad, 2008) .

Statistical significant differences ($P < 0.01$) were found obvious between zooplanktons and concentrations for all heavy elements. This result is mainly in agreement with the similar investigations of Abdullah et al., (2014) and Al-Saad et al., (2014)

Discussion

The results showed in table I indicate that differences in zooplanktons recorded in selected sites were following the differences in their water salinities (Toruan, 2012). It has become increasingly evident that biogenous processes in aquatic surface layers play an important role in removing chemical elements from water column and transporting them to the bottom sediments. Planktons are strongly implicated in these processes and investigations of the chemistry of these organisms have demonstrated their ability to accumulate chemical elements to relatively high levels (Fowler, 1977).

Chemical elements which have the ability to form colloids in sea ,estuarine and brackish water will be able to adsorbed onto planktonic debris, resulted in higher concentration of these elements in zooplankton from aquatic waters (Robin*, et al*. 2012; Ritterhoff and Zauke, 1997; Safahieh, *et al.* 2011).

Pollution, associated with urbanization, agriculture, mining, or localized atmospheric deposition can lead to elevated and variable concentrations of chemical elements in aquatic organisms (Suchanek et al., 2008). Accumulation of toxic elements in aquatic food is an ongoing concern for human and wildlife health. At high levels, toxic elements can cause mortality or disease and suppress wildlife populations (Hinck et al., 2009). Even at low levels, effects of toxic elements together with other stressors can result in significant individual and population impacts on fish and other aquatic life (Chen et al., 2004; Folt et al., 1999)

Each chemical element had a consistent pattern of accumulation through the food web, and patterns differed widely across elements. These element-specific bioaccumulation patterns were consistent across the ecosystem, despite substantial differences in overall concentrations of most chemical elements across the ecosystem.

Conclusion

It seems that all recorded zooplanktons from Southern Iraqi waters preferred waters that were higher in calcium and magnesium. The phase of chemical elements accumulation in zooplanktons within Iraqi aquatic system is either through uptake from the dissolved phase in water column or from phytoplanktos as an ingested food . For understanding the fate and effects of chemical elements in zooplankton, these two processes should be separated.

References:

Al-Imarah, F.J.M.; Abdul-Hussain, A.S. and Al-Salman Al-Mayah, Q.M. (2010). Toxic environmental parameter in water samples from some aquatic wetland southern Iraq. Basrah J. of Sci. Vol. 28 (2) 253 – 261.

Al-Imarah, F. J. M. and Ali, M. A.(2009). Evaluation of some radioactive elements in the ecosystem of Tigris, Euphrates, Shatt Al-Arab rivers, Main Outlet Drainage and southern Iraqi marshes. Proceedings of 3rd Scientific Conference for Rehabilitation of Marshland. Marine Science Centre, Basrah, 13-15 April 2009, pp83-90.

Al-Imarah, F.J.M.; Irabii, D.S. and Mahmood, A.A. (2003). Level of mercury in the water and sediments of southern part of Iraq. Jordanian. J. Applied Sci. 5 (1). 85-97.

Al-Majed, N.B and Perston, M.R. (2000). An assessment of the total and methyl mercury content of zooplankton and fish tissue collected from Kuwait territorial water. Marin pollution Bulletin Vol. 40. No. 4 pp. 298-307.

Al-Saad, H. T., Al-Qarooni, I. H., Bedair, H. M., DouAbul, A. Az. & Alhello, Az.(2014).Assessment of Heavy Elements in the Fresh Part and Shell of the Snail *Bellamyabengalensis* in Shatt al-Arab River, Iraq.**(In Process)**

Al-Tison, I.A. and Chandy, J.P. (1995). Distribution of heavy metals in plankton collected during the UmitakaMaru Cruise 11, in the Ropme sea area. Presented at UmitakaMaru Symposium, Tokyo, Japan, December 1995.

AMAP (1995). Guidelines for the AMAP: assessment. Aretic monitoring and assessment program. Oslo, report 95: 1

Chen C. Y., Stemberger, R.S., Klaue, B., Blum, J. D., Pickhardt P.C. and Folt, C. L. (2000). Accumulation of heavy metals in food web components across a gradient of lakes. Limnol Oceanogr. 45:1525–1536.

Chen CY, Hathaway KM, Folt CL. (2004) Multiple stress effects of Vision (R) herbicide, pH, and food on zooplankton and larval amphibian species from forest wetlands. Environ Toxicol Chem.,23:823–831.

Chua, T.E.; Gorre, I.R.I.; Ross, G.A.; Bernad, S.R.; Gervacio, B. and Ebarvia, M.C. (2000). The Malacca straits. Marine Pollution Bullitin 41 (1-6) 160-178.

Ciszewski, D., Aleksander-Kwaterczak, U., Pociecha, A., Szarek-Gwiazda, E., Waloszek, A., and Wilk-Woźniak, E. (2013)Small effects of a large sediment contamination with heavy metals on aquatic organisms in the vicinity of an abandoned lead and zinc mine Environ Monit Assess., 12: 9825–9842

De Bernardi, R.1984. Methods for the estimation of zooplankton abundance. In: Downing, J.A. and Rigler, F.H. (Eds). A manual on methods for the assessment of secondary productivity in fresh waters. IBP Hand book No. 17 Blackwell, Oxford. 55-86.

Fido, A. and Al-Saad, S. (2008). Toxic trace elements in hair of children with autism. Autism. 9: 290-298

Folt CL, Chen CY, Moore MV, Burnaford J. Synergism and antagonism among multiple stressors.Limnol Oceanogr. 1999;44:864–877.

Fowler, S. W. (1977).Trace elements in zooplankton particulate products.Nature 269:51 - 53

Hinck JE, Schmitt CJ, Chojnacki KA, Tillitt DE, (2009). Environmental contaminants in freshwater fish and their risk to piscivorous wildlife based on a national monitoring program. Environ Monit Assess. 152:469–494.

Jak RG, Maas JI, Scholten MCT. (1996) Evaluation of laboratory derived toxic effect concentrations of a mixture of metals by testing freshwater plankton communities in enclosures. Water Research.,30:1215–1227.

Karabedian, S.; Al-Imarah, F.J.M. and Ibraheem, H.K. (2009). Determination of Mercury in hair samples of Iraqis population living in Safwan and Al- Zubair Southern Basrah . J. Duhok Univ. Vol. 12 , No. (Special issue). PP. 23- 27.

Khudhair, A. Y., Khalaf, T. A., Ajeel Sh. G. and Saad, R. (2014). Determination of heavy metals in Zooplankton from Basrah, Southern Iraq. (In Process).

Manson, P.; Fitzgerald, F. and Morel, M. (1994). The biochemical cycling of elemental mercury anthropogenic influences. Geochimica et Cosmochimicoacta. 58. 3191 – 3198.

Nekhoroshkov, P. S., Kravtsova1, A. V., Frontasyeva, M. V. and Tokarev, Yu. N. (2014).Neutron Activation Analysis and Scanning Electron Microscopy of Phytoplankton in the Coastal Zone of Crimea (The Black Sea). Am. J. Anal. Chem., 5(5): 4236-4245.

Nilssen, K.T., Hug, T., Petelov, V,; Stasenkov, V.A. and Timoshenko, Y.K. (1995a). Food habits of harp seals (Phocagroemlanlamdica) during location and moult in March- May in the southern Barents Sea and White sea. ICES J. Marin. Sci. 52: 33- 41.

Nilssen, K.T., Hug, T., Petelov, V. and Timoshenko, Y.K. (1995b). Feeding habits of harp seals (Phocagroenlandica) during early summer and autumn in the northern Barents sea. Polar Biol. 15: 485 – 493 .

Ninomiya, T. Ohmori, H.; Hashimoto, K.; Tsuruta, K. and Ekino, S. (1995). Expansion of methyl mercury poisoning outside of Minamata: An epidemiological study on chronic methyl mercury poisoning outside of Minamata. Environmental Research 70.47 -50.

Percy, J.A. (1993). Reproduction and growth of the Arctic hyperiid amphipod Themistolibellula. Mandt. Polar Biol. 13: 131 -139.

Rezai, H. and Yusoff, F.M. (2011). Heavy metals in neuston from the straits of Malacca. J. of (Persian Gulf) Marine scie. Vol. 2 No. 4 june 2011 pp 1-10.

Ritterhoff, Ji and Zauke, GP. (1997). Trace metals in field samples of zooplankton from the fram Strait and the Greenland Sea. The Science of the total Environment. 199: 255-270.

Robin, R.S.; Mudulli, P.R.; VishmuVardhan, K. ; Ganguly, D.; Abhilassh, K.R. and Balasubramanian, T. (2012). Heavy metal contamination and risk assessment in the marine environment of Arabian sea, along the southwest coast of India, Amr. J of Chemistry. 2(4): 191 – 208.

Safahieh, A.; Abdolahpur, Monikh, F. and Savari, A. (2011). heavy metals contamination in sediments and sole fish (Euryglassaarientalis) from Musa Estuary (Persian Gulf) world J. of Fish and Marine sciences. 3-4). 290- 297.

Schulz-Bald, M. (1992). Baseline study on Cd, Cu, and Pb concentration in Atlantic concentration in Atlantic Neuston organism. Marine Biology. 112; 211 –222.

Suchanek TH, (2008). Mercury cycling and bioaccumulation in a mine-dominated aquatic ecosystem: Clear Lake, California. Ecol Appl. 18:A1–A2.

Toruan,R. L. (2012). Zooplankton community emerging from freshwater and salin wetlands. Ecolg. Hydro. 12(1):53-63.