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# The Clam Pseudodontopsiseuphraticus as a Bioaccumulation Indicator Organism of Heavy Metals in Tigris River at Baghdad Province, Iraq

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***Abstract:*** *The present work is aiming at investigating seasonal variations in levels of some heavy metals (Cd, Pb, Ni, Cr, Zn, Co, Cu, Fe andMn) in water-sediments-clam to investigate bioaccumulation of this metals by use fresh water clam Pseudodontopsiseuphraticus from Tigris river at Baghdad city. The study extended from March 2016 to February 2017. The heavy metals were studded in dissolved and particulate phase of water and in exchangeable and residual phase of sediments and in soft tissues of clam. Heavy metals accumulated according the system: water-sediment-clam because filter-feeding of this aquatic organism, and recorded bioaccumulation factor: 16.81, 12.04, 12.8, 12.36, 15.69, 20.73, 12.44, 15.79, 15.06 respectively.*

***Keyword:*** *Bioaccumulation, Heavy metals pollution, Tigris Sediment, clam Pseudodontopsiseuphraticus.*

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## I. Introduction

In recent years there have been increasing interests regarding heavy metal contaminations in the environments, apparently due to their toxicity and perceived persistency within the aquatic systems[1].There are basically three reservoirs of metals in the aquatic environment: water, sediment and biota [2].

In a river system, sediments have been widely used as environmental indicators and their chemical analysis can provide significant information on the assessment of anthropogenic activities [3].

Tigris River receives many pollutants especially heavy metals when it is passing through Baghdad city, due to many human activities and factories throw pollutants into the river without any real treatments.

In aquatic ecological risk assessment, bioaccumulation factor (BAFs) is used to quantify chemical accumulation in tissue relative to concentration in water or sediment [4]&[5]. Bioaccumulation of metal in the tissue of interest or the whole organism the results from all environmental exposure media, including air, water, soil phases, and diet [6].

Alhashemi *et al.*[7], studied determination of bioaccumulation factors (BAFs) by different tissue of fresh water clam *Pseudodontopsiseuphraticus*with respect to elemental concentrations in sediment. BAFs results indicated that Zn, Pb, and Cu had higher BAF than other elements. In Kuwait Bay, Bu-Olayan and Thomas [8], instigated to conduct toxicity and bioaccumulation tests of trace metals (Zn, Cu, Cd, and Fe) and they found bioaccumulation factors (BAFs) was sequence of Cd > Fe > Cu > Zn. for fish exposed for 60 day, and bioaccumulation exhibited increasing metal levels in liver followed by muscle tissue and gills.

The aim of this study is to evaluate the seasonal bioaccumulation of nine heavy metals in dissolved and particulate phase of water and residual and exchangeable phase of sediments and soft tissue of fresh water clam *Pseudodontopsiseuphraticus*(Bourguignat, 1852) living in Tigris river in Baghdad provinces of Iraq .

## II. Material & Methods

Samples of water, sediments and fresh water clam *Pseudodontopsiseuphraticus* were collected every two months for one year (from March, 2016up to February , 2017). Four stations were chosen on Tigris River in Baghdad city for this purpose. Station 1 (Al-Greaat), station 2 (Al-Atafia), station 3 (Bab Al-Mudhum) and station 4 (Al-Rashid power plant).

After all samples were removed from the substratum with a new stainless steel scraper, they were washed with clean river water at the site of collection, separated to species, placed in a clean plastic bag and transferred in a cool box to laboratory at the same day and then frozen at( -20 C°) until dissection [9]. All bottles were cleaned with 10% $HNO_3$ then rinsed with distilled water prior to use.

Clam samples were cleaned to remove mud and debris and subsequently washed with double distilled water, specimens were divided according to their size and 25 individual were obtained for each size class. There were (3) replicates for clam under study. Soft tissue of clam dried at 40-45 C° in overnight. The extraction and determination of heavy metals in clam soft tissues doing according to[10].

Water samples were collected from same site of clam collection by polyethylene bottles in 3 L to replicate and filtration by Millipore filter paper 0.45 µm, 47 mm diameter and preconcentration according to[11], to determine the concentration of dissolved heavy metals.

Filter paper digested to determine the particulate heavy metals in water [10]. Sediment samples collected from the region near clam by Grab sampler, surface layer to 5 cm used to study of exchangeable and residual of heavy metals in these sediments according to [12]. The analytical blanks were run in the same way as the samples and concentrations were determined using standard solutions prepared in the same acid matrix[12].

Concentrations of heavy metals in water, sediments and soft tissues of clam were determined using pyeunicam Sp9 air-acetylene scientific model of flame atomic absorption spectrophotometer (FAAS).

Bioaccumulation factor determined according to[13]as:

$$\text{B.A.F.} = \frac{\text{conc. of metals in clam } (\mu\text{g/g})}{\text{conc. of metals in water } (\mu\text{g/L})}$$

Statistical variation analysis and correlation coefficient (r) were obtained.


Figure(1) : Map of Iraq and Baghdad showing the Station in Tigris River.
Source : Ministry of Water Resources ,2007 , Map Scale 1/100000 .

**Map of Iraq and Baghdad showing the station in Tigris river**

## III. Results & Discussion

Tables (1, 2) and Fig.(1;2) showed the seasonal concentrations and yearly average of nine heavy metals studied in ecosystem of water, sediments and soft tissue of fresh water clam *P.euphraticus*. The dissolved concentrations of heavy metals under study in water ranged between 0.023 µg/L of Ni as lowest metal levels and 190 µg/L of Fe as highest metal levels. The study found highly variation in heavy metals concentration between different season in same metal or different metals, may be due to variation of heavy metals pollution source and differ of amount discharge to river through seasonal studies, or because dilution factor or unstable of water levels in river under study [14].

High concentration of heavy metals were showed in particulate phase of water. The highest concentration of Fe is 630.5 µg/g dry weight was observed in Spring 2016 (Table-1). These concentrations increased in particulate phase compare to dissolved phase of heavy metals due to the increase in level of suspended matter by erosion process or soil drift from near land and rise of river slop [15], and tendency of heavy metals to adsorption on particulate matter surface in water column [16].

Sediment analysis showed that the highest concentration of heavy metals was found in Tigris river in period of study. The amount of heavy metals of (Cd, Pb, Ni, Cr, Zn, Co, Cu, Fe and Mn) in exchangeable phase of sediment ranged (5.3-6.97), (0.203-0.295), (0.082-0.097), (0.16-0.26), (27.5-33.00) (3.9-4.21), (5.98-8.12), (293.72-357.02) and (16.87-17.03) µg/g dry weight respectively, but in residual phase the study showed high similarity in metals concentration with values of these metals in exchangeable phase of sediments (Table-1), of what to signal of similarity in pollution source through different time sequence [17], of what make the sediments as potential source to heavy metals pollution and transplantation of this metals through food chain to aquatic system[18].

The increase of heavy metals concentration in sediments may be correlated with sediment count of organic matters and these concentrations were negative correlation with sediment grain size. These result agreed with study of [19] at refer to small grain size and tendency to (silt-clay) of Tigris river sediments addition to exposure this sediment to discharged of industrial and domestic waste and mining [20]. Higher concentration of heavy metals in sediment than in water was observed in different studies and the major depository of metals in some cases, holding more than 99 percent of total amount of a metal present in the aquatic system[21].

In soft tissues of fresh water clam under study mean concentrations of metals followed the sequence Fe<Zn<Mn<Cu<Cd<Co<Pb<Cr<Ni and the yearly average of this heavy metals at (3.30), (26.96), (1.36), (47.15), (1964), (117.35), (0.64), (1.71) and (200.11) µg/g dry weight respectively. The rise of metals concentration in clam may be return to ability of bioaccumulation in soft tissues in high levels[22].

The metal concentrations measured reflect a clear influence of anthropogenic activities, additionally, the effective exposure of organisms to different metals may be influenced by either changes in metal speciation or relative distribution of metals between particles of different sizes and densities[23].The strong relationship showed between metal concentration in clam soft tissues and concentrations of these in particulate phase of water this due to the filter-feeding and detritus feeding of this organisms and the organism under study may be accumulate the different pollutants more than sediments and water[24],[25].

The results of the study to show clear variance in concentration of heavy metals through study seasons may be due to effective of metals availability in aquatic organisms by different environmental factors such as pH, water hardness and amount and compound of particulate matters [26], or may be as result of biological action change of this organisms and effected of amount of food and productivity by photoperiods [27].

From statistical analysis the study showed significant variation ($P<0.05$) in metals concentration in water, sediment and clam between seasons, and showed some correlation between heavy metals under study such as dissolved Cd and Cd in clam soft tissue ($P<0.05$, $r=-0.98$), particulate Cd and residual Cd ($P<0.05$, $r=0.99$), dissolved and particulate Co ($P<0.05$, $r=0.95$), particulate, residual Mn, dissolved Mn and Mn in clam ($P<0.05$, $r=-0.45$, $r=-0.98$) respectively, but not found any correlation between other heavy metals.

The present study deals with determination the mechanism of heavy metals accumulation through the system water-sediment-clam, than to observe the most metal under study to seize the same place in metals sequence in water, sediments and soft tissue of clam to confirm the interaction between the compound of this system, these result confirm in many studies[28],[29]and [30].

The pattern of variation of heavy metal accumulation in whole soft tissues of the clam appears to be influenced largely by the reproductive stage of the organism [31].

From the results (Table-2) become clear the different heavy metals under study Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, and Zn were accumulated in soft tissue of fresh water clam *P.euphraticus* by bioaccumulation factor (BAF) as (17.00, 21.02, 13.12, 13.03, 16.01, 16.02, 13.02, 11.01, & 16.03) than concentration in water respectively. This results provide good evidence of metals accumulation in aquatic organisms more than water and sediment that help use this organisms as bioindicators and as a good environmental tools to study of aquatic pollution[32].

The study of bioaccumulation factor (BAF) in aquatic organism's tissues useful to explain the best organism have the ability of heavy metals bioaccumulation in environment and help to used this organisms as clam in environmental monitoring programs [33].Determination of harmful and toxic substances in water, sediments and biota, gives direct information on the significance of pollution in the aquatic environment [34], [35].

**Table (1): Concentrations of heavy metals in water, sediments and soft tissues of fresh water clam *P.euphraticus***
**(μg/L to dissolved phase, μg/g to particulate phase and sediment and clam).**

| Element | Seasons | Element concentration in water | | Element concentration in sediment(ug\g) | | | Element concentration in clam(ug\g) |
|---|---|---|---|---|---|---|---|
| | | Dissolved | Particulate | Exchange able | Residual | Total | |
| Cd | Spring 2016 | 2.50 | 10.90 | 5.02 | 5.35 | 10.45 | 35.29 |
| | Summer 2016 | 1.55 | 11.00 | 6.93 | 6.97 | 13.72 | 35.32 |
| | Autumn 2016 | 1.70 | 10.40 | 5.87 | 5.47 | 10.54 | 35.31 |
| | Winter 2017 | 2.65 | 11.25 | 5.13 | 5.31 | 10.49 | 35.29 |
| Pb | Spring 2016 | 0.10 | 0.550 | 0.226 | 0.271 | 0.535 | 1.70 |
| | Summer 2016 | 0.18 | 0.540 | 0.203 | 0.2 82 | 0.523 | 1.71 |
| | Autumn 2016 | 0.14 | 0.561 | 0.295 | 0.292 | 0.565 | 1.70 |
| | Winter 2017 | 0.142 | 0.601 | 0.279 | 0.298 | 0.565 | 1.70 |
| Ni | Spring 2016 | 0.023 | 0.182 | 0.093 | 0.098 | 0.193 | 0.63 |
| | Summer 2016 | 0.059 | 0.198 | 0.082 | 0.10 | 0.191 | 0.65 |
| | Autumn 2016 | 0.036 | 0.201 | 0.097 | 0.12 | 0.219 | 0.66 |
| | Winter 2017 | 0.053 | 0.220 | 0.091 | 0.12 | 0.219 | 0.66 |
| Cr | Spring 2016 | 0.05 | 0.40 | 0.16 | 0.29 | 0.43 | 1.38 |
| | Summer 2016 | 0.15 | N.D | 0.21 | 0.47 | 0.64 | 1.33 |
| | Autumn 2016 | 0.11 | 0.80 | 0.26 | 0.25 | 0.45 | 1.33 |
| | Winter 2017 | 0.13 | 0.18 | 0.17 | 0.41 | 0.60 | 1.38 |
| Zn | Spring 2016 | 15.06 | 59.91 | 31.15 | 31.40 | 61.47 | 200.04 |
| | Summer 2016 | 17.91 | 61.22 | 27.50 | 32.09 | 62.08 | 199.96 |
| | Autumn 2016 | 10.15 | 58.80 | 33.00 | 32.29 | 63.49 | 200.14 |
| | Winter 2017 | 8.59 | 63.30 | 29.08 | 34.06 | 64.17 | 200.09 |
| Co | Spring 2016 | 0.90 | 8.70 | 3.90 | 4.60 | 8.66 | 26.98 |
| | Summer 2016 | 1.91 | 9.10 | 4.21 | 4.54 | 8.63 | 26.97 |
| | Autumn 2016 | 1.35 | 8.90 | 3.08 | 4.78 | 8.83 | 26.96 |
| | Winter 2017 | 0.94 | 9.07 | 5.03 | 4.89 | 9.00 | 26.96 |
| Cu | Spring 2016 | 3.73 | 14.90 | 6.73 | 7.90 | 15.20 | 47.16 |
| | Summer 2016 | 4.52 | 15.01 | 7.01 | 7.85 | 15.30 | 47.14 |
| | Autumn 2016 | 3.99 | 14.89 | 5.98 | 7.20 | 14.17 | 47.11 |
| | Winter 2017 | 2.90 | 15.11 | 8.12 | 7.89 | 14.98 | 47.10 |
| Fe | Spring 2016 | 144.75 | 630.50 | 293.72 | 354.60 | 655.1 | 1937.9 |
| | Summer 2016 | 190.00 | 613.06 | 350.15 | 378.65 | 710.92 | 1942.6 |
| | Autumn 2016 | 93.32 | 619.43 | 357.02 | 360.30 | 700.49 | 1956.1 |
| | Winter 2017 | 69.54 | 625.11 | 334.23 | 381.09 | 702.27 | 2006.4 |
| Mn | Spring 2016 | 8.90 | 34.85 | 17.03 | 17.90 | 35.40 | 117.20 |
| | Summer 2016 | 10.61 | 35.09 | 16.93 | 17.89 | 35.22 | 117.69 |
| | Autumn 2016 | 6.70 | 36.07 | 16.87 | 17.46 | 34.71 | 118.13 |
| | Winter 2017 | 4.98 | 36.19 | 16.92 | 17.57 | 35.07 | 117.30 |

**Table (2): Yearly average of heavy metals concentration in water, sediments and clam soft tissues *P.euphraticus* and Bioaccumulation factor (BAF) in clam tissue.**
**( Dissolved= ug\l ; particulate ; sediment and clam =mg\g)**

| Element | Element concentration in water | | Element concentration in sediment | | | Element concentration in clam | BAF |
|---|---|---|---|---|---|---|---|
| | Dissolved | Particulate | Exchangeable | Residual | Total | | |
| Cd | 2.1 | 10.89 | 5.53 | 5.78 | 5.66 | 35.30 | 17.00 |
| Pb | 0.142 | 0.56 | 0.26 | 0.29 | 0.28 | 1.71 | 11.01 |
| Ni | 0.05 | 0.199 | 0.093 | 0.10 | 0.097 | 0.64 | 13.02 |
| Cr | 0.11 | 0.13 | 0.18 | 0.36 | 0.27 | 1.36 | 13.12 |
| Zn | 12.75 | 60.81 | 30.34 | 32.46 | 31.4 | 200.11 | 16.03 |
| Co | 1.3 | 8.94 | 4.07 | 4.70 | 4.38 | 26.96 | 21.02 |
| Cu | 3.79 | 14.98 | 7.21 | 7.54 | 7.38 | 47.15 | 13.03 |
| Fe | 124.30 | 622.50 | 323.53 | 368.66 | 346.10 | 1963 | 16.01 |
| Mn | 7.79 | 35.55 | 17.39 | 17.71 | 17.55 | 117.35 | 16.02 |

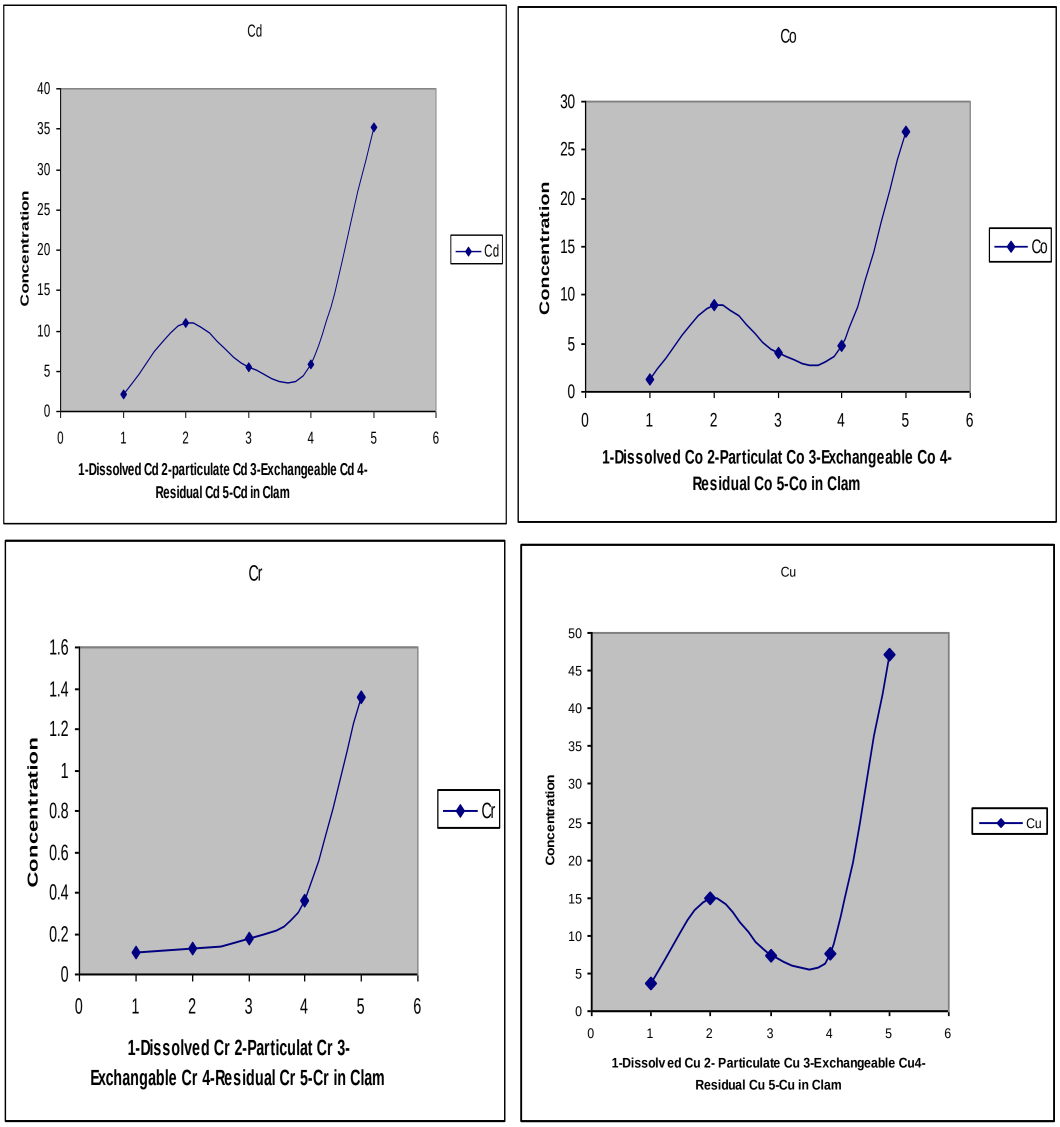


Fig.(1): Yearly average of(Cd ,Co, Cr, Cu) concentrations in water; sediment,; and clam soft tissues *P. euphraticus*.

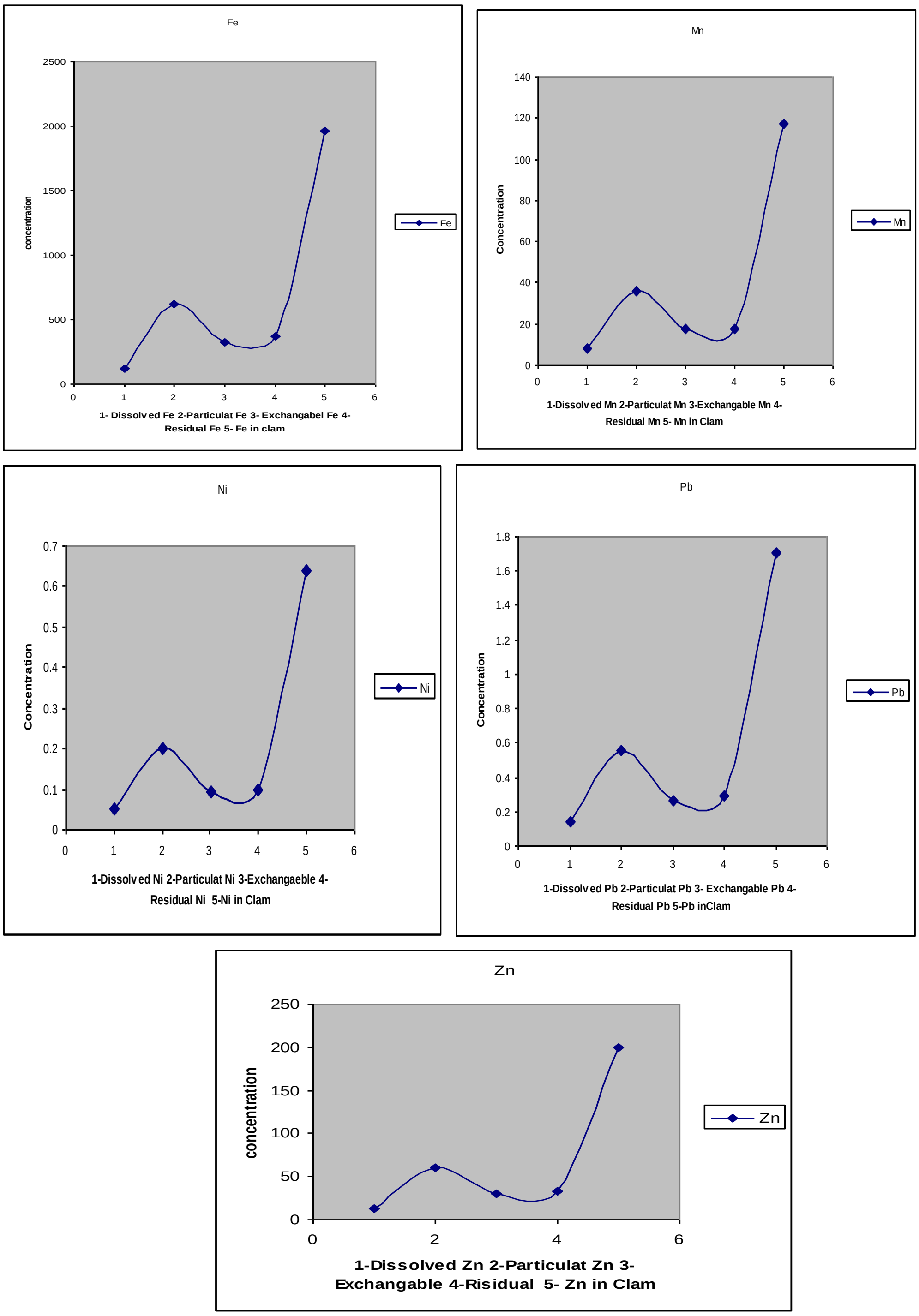


Fig.(2): Yearly average of (Fe ; Mn ; Ni ; Pb ; and Zn ) Concentrations in water , sediment and Clam soft tissue *P. euphraticus*.

## IV. Conclusion

The Tigris river ecosystem in the present study area has considerable amount of heavy metals came from anthropogenic sources . Metals in this study concentrated in the particulate phase more than the dissolved phase of the water , while their concentrations in the sediment were higher than their concentration in water . Different patterns of metals concentration were observed in the different tissues , and muscle tissues contain less concentration of these metals.

## References


[1]. Tijani, M. N.; Onodera, S. and Adeleye, M. A. (2005). Environmental implications of adsorbed and total trace metals concentrations in bottom-sediments of an urban drainage network in a developing country. Mater. Geoenviron. 52 (1): 127-130p.

[2]. Kennish, M.J. (1992). Heavy metals in water. North Carolina State Univ. Available at http://www.ter.ncsu.edu/ watersheds/ info/ hmetal.html.

[3]. Shriadah, M. M. A. (1999). Heavy metals in mangrove sediments of the United Arab Emirates Shoreline (Arabian Gulf). Water Air Soil Pollut. 116: 523−534p.

[4]. Eggleton, J. and Thomas, K. V. (2004) A review of factors affecting the release and bioavailability of contaminants during sediment disturbance events. Centre for Env., Fisheries and Aqua. Science (CEFAS), Remembrance Avenue, Burnham on Crouch, Essex CM0 8HA, UK.

[5]. Rainbow, P.S.(1995) Bio-monitoring of heavy metal availability in the marine environment. Marine Pollution Bulletin Vol. 31 (4), pp 183-192.

[6]. (EOSCA) European Oilfield Specialty Chemicals Association (2000). Bioaccumulation Potential of Surfactants: A Review.

[7]. Alhashemi, A. H.; Karbassi, A.; Kiabi, B. H.; Monavari, S. M. and Sekhavatjou, M. S. (2012). Bioaccumulation of trace elements in different tissues of three commonly available fish species regarding their gender, gonadosomatic index, and condition factor in a wetland ecosystem. Environ. Monit. Assess. 184: 1865-1878p.

[8]. Bu-Olayan, A. H. and Thomas, B V. (2008). Trace metals toxicity and bioaccumulation in Mudskipper PeriophthalmuswaltoniKoumans, 1941 (Gobiidae: Perciformes). Turk. J. Fish. Aquat. Sci. 8: 215-218p.

[9]. Turkmen, A.; Turkmen, M. &Tepe, Y. (2005). Biomonitoring o heavy metals from Iskenderun Bay using two Bivalve species Chama pacificaBroderip, 1834 &OstreastentinaPayraudeau, 1826. Turk. J. Fish. Aquat. Sci., 5: 107-111.

[10]. APHA (American Public Health Association) (2003) Standard methods for examination of water and waste water, 20th ed .Washington DC, USA.

[11]. Seady, N. I. (2001). Evaluated of heavy metals in meats and offal of various animal species slaughtered in menoufia governorate. Ph.D. Thesis. Faculty of Veterinary Medicine, Moshtohor, University of Zagazig, Benha Branch.

[12]. Tsoumbaris, p. (1990). Heavy metals determination in food stuff, Ph.D. Thesis. Aristotle University of Thessaloniki, Greece.

[13]. Demina, L.L.; Galkin, S.V. &Shumilin, E.N. (2009). Bioaccumulation of some trace elements in the biota of hydrothermal fields of the Guaymas Basin (Gulf of California). Boletin De LA SociaededGeologica Mexicana, 61 (1): 31-45.

[14]. Win, X. and Nicholas, S. (1997). Accumulation of trace elements in a marine copepoda . Limnol. Oceanogr. 43 (2) : 273-285.

[15]. Mebane, C.A. 2006. Cadmium Risks to Freshwater Life: Derivation and Validation of low – Effect Criteria Value using Laboratory and field Studies. US Geological Survey. Scientific Investigations Report 2006-5245. Version 1.1

[16]. USEPA (United State Environmental Protection Agency). 2002. National Recommended Water Quality Criteria. EPA-822-R-02-047.

[17]. Barsytelovejoy, D. (1999). Heavy metal concentrations in water, sediments and Mollusks tissues. ActaZoologicaLituanica, Hydrobiologia, 9 (2): 12-20.

[18]. Hart, D.D. and C.M. Finelli. 1999. Physical-biological coupling in streams: The pervasive effect of flow on benthic organisms. Annual reviews. 30: 365-395.

[19]. Al-Helaly, S. H. E. (2010). An investigation of some heavy metals in water, sediment and some biota of Al-Gharraf River, south of Iraq. M.Sc. Thesis. College of Science, University of Baghdad, Iraq. 151 pp.

[20]. Chindah, A.C.; Braide, A.S. &Sibeudu, O.C. (2004). Distribution of hydrocarbons and heavy metals in sediment and acrustacean (Shrimps-Penaeusnotialis) from the Bonny/New Calabar river Estuary, Niger Delta. Ajeam-Regee, 9: 1-17.

[21]. Verma, P.S. and V.K. Agarwal. 2007. Environmental biology. Principles of Ecology. S. Chand & Company LTD. New Delhi_ 110055. pp. 135-137.

[22]. Malhat, F. (2011). Distribution of heavy metal residues in fish from the River Nile tributaries in Egypt. Bull. Environ. Contam. Toxicol. 87: 163-165p.

[23]. USEPA (United State Environmental Protection Agency). 2009. Guidance for Implementing the January 2001 Methyl mercury water Quality Criterion, Final. Office of science and Technology. Washington. D.C. 20460.

[24]. Luoma, S.N. 1989. Can we determine the biological availability of sediment-bound trace elements? Hydrobiologia. 176: 379-396.

[25]. McCulloch, W. L.; Goodfellow, Jr. and Black, J. A. (1993). Characterization, identification and confirmation of total dissolved solids as effluent toxicants, Environ.Toxicol. Ris. Assess. 2: 213-227p.

[26]. Morgan, M.D. 1980. Grazing and predation of the grass shrimp Palaemonetespugio. Limnol. Oceonogr. 25: 896-902.

[27]. Gbaruko, B.C. & Friday, O.V. (2007). Bioaccumulation of heavy metals in some fauna and flora. Int. J. Environ. Sci. Tech., 4 (2): 197-202.

[28]. Hassan, F. M. (2004). Limnological features of Diwanyia River, Iraq. J. of Um- salama for Science, 1 (1): 119 – 124p.

[29]. AL-Lami, A. A. and AL-Jaberi, H. H. (2002). Heavy metals in water, suspended particles and sediment of the upper-mid region of Tigris River, Iraq. Proceedings of International Symposium on Environ. Poll. Control Waste Manag. 97-102 p.

[30]. Rasheed, K. A.; Sabri, A. W.; Al-Lami, A. A.; Kassim, T. I. and Shawkat, S. F. (2001). Distribution of some heavy metals in water, suspended solid, sediments, fish and aquatic plants of the River Tigris, Iraq. Sci. J. Iraq Atomic Energy Commis. 3(1): 198-208p.

[31]. Van Gestel, C.A.M.; E.M. Dirven-Van Breemen and R. Baerselman. 1993. Accumulation and Climination of cadmium, chromium and zinc and effects on growth and reproduction in Eisenia Andrei (Oligochaeta: Annelida). Sci. Total Environ. (Suppl.): 585-597.

[32]. Mackay, D. 2001. Multimedia Environmental Models: The Fugacity Approach. 2nd Ed., UK: Lewis Publishers. 261pp.

[33]. Rosenberg, D.M. and V.H. Resh. 1993. Freshwater biomonitoring and benthic macroinvertebrates. Chapman & Hall. London.

[34]. Price, G.D. and N.J.G. Preace. 1997. Biomonitoring of pollution by Cerastodermaedule from the British Isles: a laser ablation ICP-MS Study. Mar. Pollut. Bull. 34: 125-131.

[35]. Bargagli, R. 1998. Trace Elements in Terrestrial Plants. An Ecophysiological Approach to Biomonitoring and Biorecovery. Springer. 324.


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