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The concentration of Cadmium (Cd) in the water of Tigris River and organs of *Carrasobarbus luteus* and *Cyprinus carpio*

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Abstract
Cadmium, heavy metal is a highly harmful environmental pollutant. It can cause many health problems that affect people around the world. This study intended to determine the concentration of cadmium in the water of Tigris River in Baghdad city, as well as in the fish living inside this river. Three stations from Tigris River in Baghdad city choose as study areas. From all stations, totally, 75 and 82 fish specimens were collected for *Hamri Carrasobarbus luteus* and common carp *Cyprinus carpio* respectively. Atomic absorption spectrometry used for measuring the quantities of Cadmium in water and fish samples. The results of this study showed no significant differences ($p>0.05$) in the concentration of dissolved Cd between examined water in all stations. No significant differences ($P>0.05$) also observed in the Cd concentration in the *C. luteus* gills, muscles, liver and kidney, between different length groups for each station, or between all stations during the period of the study. However, the length group 1-10cm at station 2 showed increasing differences ($P\leq0.05$) in compare with the same length group at station 1. Moreover, no significant differences ($P>0.05$) seen in Cd concentration in gills for *C. carpio* between different length groups for each station, or between all stations during the period of the study. Also, the station 2 recorded highest values of Cd in muscles and liver in compare with the stations 1 and 3 in different length group. Besides, the highest values of Cd in kidney reported in station 2 in compare with the other stations in different length groups. Further, in all length groups, significant increasing ($P\leq0.05$) recognized in station 2 in compare with station 1. In conclusion, the result of the present study approved the presence of Cd in the water of Tigris River and fish living inside it. In addition, the mean concentration of cadmium in water was more than in fish organs. The results also reported that Cd concentration was higher than the allowable WHO concentration. The authors recommend more future studies in different areas of Iraq to determine the real situation of Cd concentration in water and aquatic species in both main Iraqi rivers the Tigris and the Euphrates.

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Introduction

Cadmium is greatly rare in the Earth's crust. The high human activities, particularly with the rapid development of agriculture and industry, have resulted in a significant increase in the levels of pollutant such as heavy metals (Abdel-Baki *et al.,* 2011). Heavy metals potentially accumulated in the aquatic environment including water, sediments, and fish, and subsequently transferred to humans through the food chain (Phillips *et al.,* 2014). Many fish species are among the top consumers of trophic pyramids in aquatic ecosystems (Moriarty, 1984). Cadmium (Cd) is a toxic metal. It is widely used in mining, metallurgical operations, electroplating industries manufacturing vinyl plastics, which used in metallic and plastic pipes. Review of the literature regarding Cd studies in Iraq revealed limited publication. For that reason, it is very important to determine the concentration of cadmium in water in Iraq. More specifically, this study intends to measure the concentrations of Cadmium (Cd) in three stations on the Tigris River as well as in the internal organs (gills, liver, kidney and muscles) of two species of the fish *Carrasobarbus luteus* and *Cyprinus carpio*.

Materials and methods

Area of the study

Tigris River is one of the important rivers in Iraq, sharing with Euphrates River as the main water resources. Tigris River is about 1850 km long, rising in the Taurus Mountainous of eastern Turkey about 25 km southeast of the city of Elazig and about 30 km from the headwaters of the Euphrates (Isaev and Mikhailova, 2009). The present study was carried out in Tigris River near Al-Zafaraniyah. Diyala River is the most important easterly tributary of Tigris River, rising in the Zagros Mountains of western Iran. It covers a distance of 445 km of which 386 km in Iraq (Al-Ansari *et al.,* 1987). There are two wastewater treatment stations threw in Diyala River before coming to Tigris River. In the present study, three stations were chosen from Tigris River in Baghdad city (Figure. 1).

Determination of Cd concentration

The Measuring of Cd concentration was done according to equation describe previously (APHA, 1998) as follow:

$$Econ = \frac{A \times B}{C}$$

Econ: Concentration of metal in water (mg/l).
A: Concentration of metal in calibration curve (mg/l).
B: Final volume of sample (ml).
C: Initial volume of sample (ml).

From all stations, totally 75 and 82 fish specimens were collected for *Hamri C. luteus* and common carp *C. carpio* respectively. Fish were divided into three group's length to *Hamri C. luteus* and four groups length of common carp *C. carpio* with 10 cm for each length group. For each station, the fish were dissected, and about 50g of gills, muscles, liver and kidney were collected. These organs samples were taken into crucibles and washed with distilled water and placed on clean individual marked slides and dried to constant weight in the oven at 70 °C for 24 h. Flame atomic absorption spectrophotometer

(FAAS) was used for detection the Cd concentration. The FAAS is a technique that use for measuring quantities of chemical elements in environmental samples. It is measuring the absorbed radiation by the chemical element of interest (Szkoda and Żmudzki, 2005; García and Báez, 2012).

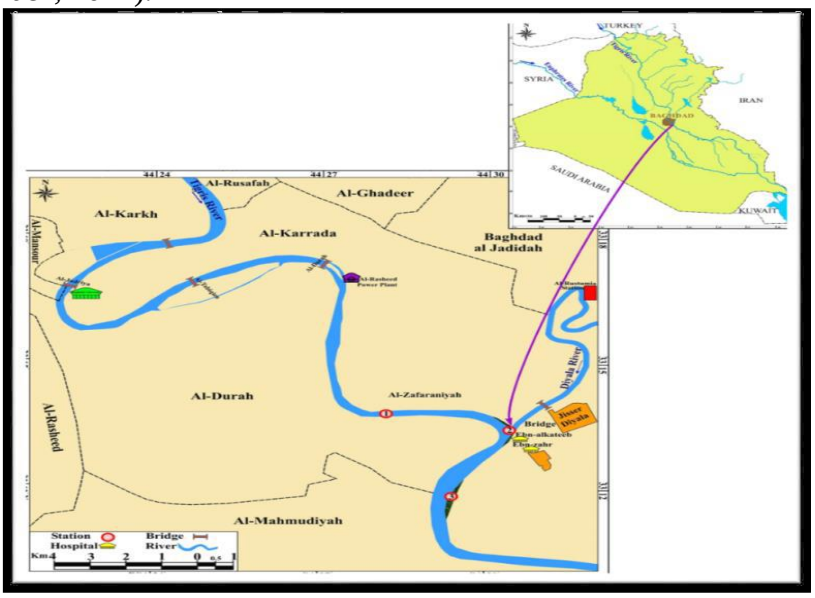

Figure. 1: Shows the map of the study areas of the Tigris River

The Concentrations of Cd were measured under specified condition, according to the instruction of the manufacturer (atomic absorption Spectrophotometer, GBC933 plus), (Szkoda and Żmudzki, 2005). The Cadmium concentrations in the tissues were expressed as µg/g dry weight. The concentrations of Cd in the tissues was carried out as per the following equation (Druckman, 1967; Federici et al., 2007):

$$\textbf{Cd } \boldsymbol{concentration}\ (\mu g/g) = \mathrm{V}\boldsymbol{ol.\ ml\ /\ sample\ wt.\ g \times\ igest\ conc.}\ (\boldsymbol{mg/l})$$

All data were analyzed using general Linear Model (GLM) in SAS program (2010) to investigate the effect of station, species of the fish (*C. luteus* and *C.carpio*), concentration of Cd metal in water and the length of fish within each station, on the level of Cd concentration in gills, muscles, liver and kidney. Two-way ANOVA with Least significant differences (LSD) post hoc test was performed to assess the significant difference among means. The $P \leq 0.05$ was considered as statistically significant.

Results and discussions

Cd concentration dissolved in water

The result of the current study showed the variations of the Cd concentration dissolved in water at all stations specimens that it ranged between the lowest value (0.002 µg/l) at station 1 in Nov. 2015, and the highest value (0.09 µg/l) in Jan. 2016 at station 2 (Table 1 and Figure 2). No significant differences ($p>0.05$) in dissolved Cd concentration

between all stations observed during the statistical analysis. The Cd concentrations were higher in winter months. The results of this study are in agreement with the previous studies (Al-Taee, 1999; Liang and Worng, 2003; Hassan, 2007; Vymazal, 2008; Al-Haidary, 2009; Muhsin, 2011).

Table.1: Shows the monthly variations of Cd µ/l dissolved in water (mean ± SE.) for all stations

Station \ Month		Nov. 2015	Dec.	Jan. 2016	Fab.	Mar.	Apr.	Mean ±SE.
1	Cd	0.002	0.014	0.040	0.006	0.006	0.081	0.024±0.01
2	Cd	0.089	0.010	0.090	0.065	0.065	0.041	0.060±0.01
3	Cd	0.006	0.027	0.076	0.054	0.044	0.033	0.040±0.01
LSD		0.0352						

All differences are not significant at (P≤0.05)

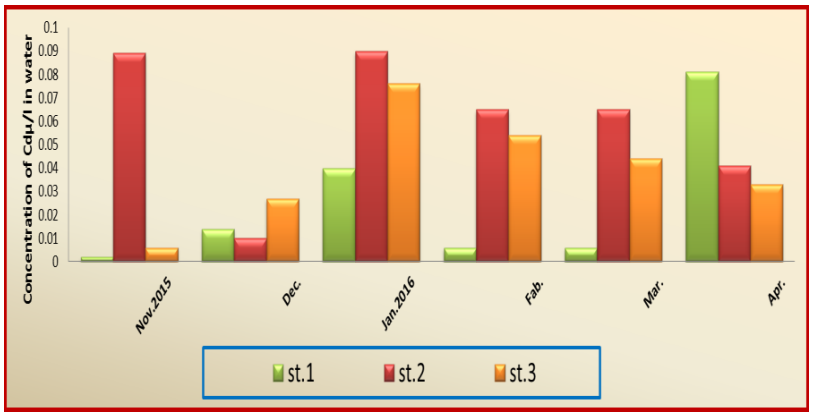

Figure 2: Shows the monthly variations of Cd µ/l dissolved in water for all stations

Concentrations of Cd in *C. luteus*

The results of the current study revealed that the concentration of Cd in gills of *C. Luteus* at station 1 ranged between 1.18 and 1.25µ/g in length group 1- 10cm and 21 – 30cm respectively (Table.2). Moreover, the ranged were 2.18- 2.24, 1.88- 1.98µ/g in length group 1- 10 and 21 - 30cm respectively at stations 2 and 3 respectively. The results of this study showed that station 2 recorded the highest values of Cd in gills compared to the other stations in different length group. However, the statistical analysis showed no significant differences (P>0.05) in gills between the various length groups for each station or between all stations during the period of the study.

The results of this study also showed variations in the concentration values of Cd in *C. luteus* in muscles according to the stations. The Cd muscle concentration ranged between 1.14 - 1.32 µ/g and 1.27 –1.56 µ/g in length group 1-10cm and 21- 30 cm respectively at station 1 and 2. Moreover, the range was between 0.98 µ/g and 1.81µ/g in length group 1 -10cm and 11- 20cm respectively at stations 3. Besides, no significant differences (P>0.05) in Cd residue in muscles of *C. luteus* seen between different length groups for

each station, or between all stations during the period of the study. The liver of *C. luteus* was also showed differences in the concentration of Cd according to the stations. It values ranged between 1.18, 2.65 and 1.70 to 1.30, 2.90 and 1.75µ/g in first and third length group at stations1, 2 and 3respectively. Moreover, the station 2 recorded the highest values in compare with other stations for different length group. No significant differences (P>0.05) in Cd concentration seen in the liver of *C. luteus* between the various length groups for each station, or between all stations during the period of the study. The kidney of *C. luteus*, also showed the variations in the concentration of Cd. It was ranged between 1.32, 3.76 and 2.18 to 1.38, 3.84 and 2.28µ/g in length group 1- 10 cm and 21 – 3-cm respectively at stations 1, 2 and 3 respectively (Table.2). And similarly, the station 2 recorded the highest values in compare to the other stations in different length group with no significant differences (P>0.05) between the various length groups for each station. Meanwhile, the length group 1-10cm at station 2 showed increasing differences (P≤0.05) in compare with the same length group at station 1. While no significant differences (P>0.05) appearance in Cd concentration of the kidney between station 3 and station 2 or between stations 3 and 1 in the smallest length group.

Table. 2: Shows the concentrations of Cd µ/g (mean ±SE.) in different organs of *C. luteus* according to length groups for all stations.

Station	Length group(cm)	Gills	Muscles	Liver	Kidney ±SE.
1	1-10	1.18±0.31	1.14±0.22	1.18±0.30	A 1.32±0.30b
	11-20	1.22±0.30	1.31±0.26	1.25±0.33	A 1.37±0.33b
	21-30	1.25±0.30	1.32±0.26	1.30±0.35	A 1.38±0.33b
2	1-10	2.18±0.60	1.27±0.18	2.65±1.06	A 3.76±1.05a
	11-20	2.19±0.60	1.55±0.37	2.70±1.08	3.77±1.06a
	21-30	2.24±0.61	1.56±0.37	2.90±0.69	A 3.84±1.03a
3	1-10	1.88±0.34	0.98±0.11	1.70±0.34	A 2.18±0.84ab
	11-20	1.91±0.35	1.81±0.11	1.72±0.34	A 2.25±0.82ab
	21-30	1.98±0.36	1.10±0.12	1.75±0.35	A 2.28±0.48ab
LSD		1.26	0.71	1.94	2.27

Means with different capital letters between different length groups in same station differ significantly (P≤0.05).
Means with different small letters between same length groups in different station differ significantly (P≤0.05).

The same results obtained when the length groups 11-20 and 21- 30 cm observed. The order of the Cd concentration from the highest concentration in the examined organs of *C. luteus* at station1 were as the following sequence: kidney >gills> liver > muscles. While, in station 2 were: kidney>liver >gills> muscles, and kidney>gills>liver> muscles in station 3 (Figure.3).

Concentrations of Cd in *C. carpio*

The concentration of Cd in gills of *C. carpio* showed that the lowest values recorded in length group 1-10cm as a following: 2.26, 3.30 and 2.01µ/g at stations 1, 2 and 3 respectively. Moreover, the highest values found in length group 31-40cm were 2.29, 3.39 and 2.08 µ/g at stations 1, 2 and 3 respectively. In addition, the highest values of Cd in gills in compare with the other stations in different length group reported in station 2 (Table.3). However, no significant differences (P>0.05) in the Cd concentration in the gills observed in various length groups for each station, or between all stations during the period of the study. The concentration values of Cd in the muscle of *C. carpio* also revealed variations in different stations. It ranged between 0.58 – 0.74µ/g in length group 11-20 cm and 31-40 cm respectively at station 1, and between 2.44- 2.77µ/g in smallest and largest length group respectively at station 2. While the range at station 3 was between 0.99 – 1.37µ/g in the length groups 1-10 and 21-30cm respectively (Table.3 and Figure.4). Moreover, the highest values of Cd in muscles were reported in station 2 in compare to the stations 1 and 3 in different length group. A significant increasing (P≤0.05) in different length groups observed at station 2 in compare to the other stations. While no significant differences (P>0.05) found between stations 1 and 3 in different length groups.

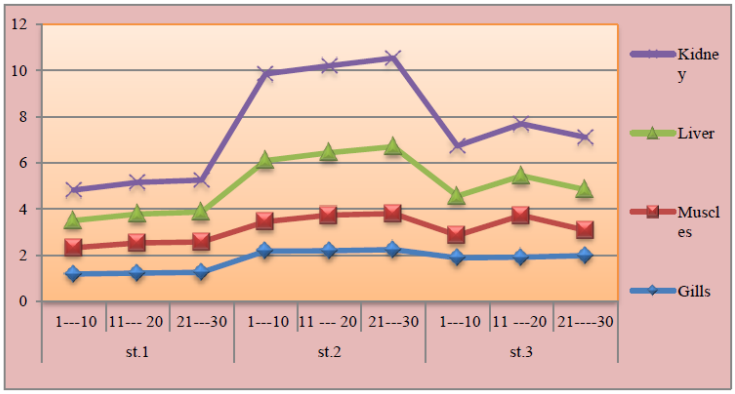

Figure 3: Shows the concentration of Cd µ/g in different organs of C. luteus according to length groups for all stations

The liver of *C. carpio* was expressed different concentration of Cd according to the stations. Its values ranged between 0.33, 2.62 and 1.33 µ/g in length groups 31 – 40 and 1-10 cm respectively at stations1, 2 and 3. The Station 2 also recorded the highest values in compare with other stations in different length groups (Table.3). Moreover, no significant differences (P>0.05) in the Cd concentration in the liver of *C. carpio* between stations 2 and 3 in different length groups. Meanwhile, significant increasing (P≤0.05) observed at station 2 in compare with station 1 in all length groups. The same observations observed in the concentration of Cd in the kidney of *C. carpio*. At station 1, it ranged between 0.38 and 0.68 µ/g in length group 31- 40 cm and both length groups 11- 20 and 21 – 30 cm respectively. At station 2, it was between 1.96 – 2.18µ/g in smallest and largest length groups respectively. While, at station 3, it revealed the lowest value 0.77 µ/g in the length group 31 – 40 and the highest value 0.93µ/g in length group 21 - 30 cm (Table.3).

Table 3: Shows the concentrations of Cd µ/g (mean ±SE.) in different organs of *C.carpio* according to length groups for all stations.

Station	Length group(cm)	Gills	Muscles	Liver	Kidney ±SE.
1	1-10	2.26±0.47	A 0.61±0.08b	A 0.91±0.18b	A 0.64±0.07b
	11-20	2.27±0.48	A 0.58±0.11b	A 0.92±0.19b	A 0.68±0.07b
	21-30	2.28±0.49	A 0.64±0.08b	A 0.93±0.18b	A 0.68±0.093b
	31-40	2.29±0.48	A 0.74±0.09b	A 0.33±0.12b	A 0.28±0.19b
2	1-10	3.30±0.72	A 2.44±0.65a	A 2.62±0.81a	A 1.96±0.55a
	11-20	3.33±0.73	A 2.46±0.66a	A 2.85±0.90a	A 1.97±0.58a
	21-30	3.36±0.72	A 2.90±0.81a	A 3.07±0.89a	A 2.08±0.52a
	31-40	3.39±0.66	A 2.70±0.85a	A 3.02±0.44a	A 2.18±0.22a
3	1-10	2.01±0.68	A 0.99±0.36b	A 1.33±0.45ab	A 0.86±0.39a
	11-20	2.02±0.67	A 1.03±0.35b	A 1.97±0.77ab	A 0.88±0.40ab
	21-30	2.04±0.67	A 1.37±0.47b	A 2.00±0.77ab	A 0.93±0.38b
	31-40	2.08±0.86	A 1.27±0.44b	A 2.03±0.76ab	A 0.77±0.78b
LSD		1.81	1.36	1.89	1.11

Means with different capital letters between different length group in same station differ significantly (P>0.05)

Moreover, Cd concentration in the kidney of *C. carpio* showed no significant differences (P>0.05) between station 2 and 3 in the length group 1 – 10cm. Meanwhile, significant increasing (P≤0.05) seen in the values of station 2 in compare with station 3 in all others length groups. Significant increasing (P≤0.05) also recognized between stations 1 and 3. However, no significant differences (P>0.05) recorded between stations 1 and 3 in other length groups. The order of Cd concentration that recorded in the organs of *C. carpio* at stations 1 and 2 as the following sequence: gills >liver >kidney> muscles. While in station 3, it was: gills>liver >muscles >kidney (Figure.4).

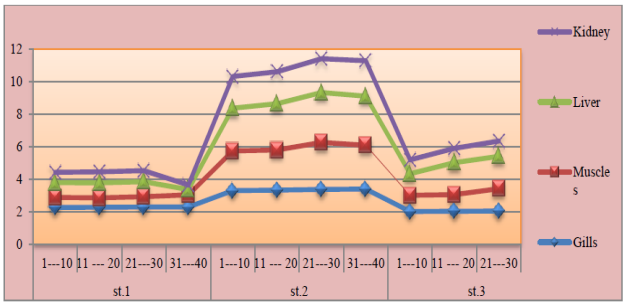

Figure. 4: Shows the concentrations of Cd µ/g (mean± SE.) in different organs of *C. carpio* according to length groups

The results of this study showed that the total mean for a concentration of Cd in gills in both *C.lutues* and *C. carpio* at station 1 is 1.22 and 2.20µ/g respectively. Moreover, it was between 1.91 – 2.27µ/g respectively at station 2, in contrary, station 3 recorded the highest value 3.33 µ/g in *C. lutues* and less 2.02 µ/g in *C. carpio* (Table.4). The statistical analysis of Cd concentration in gills showed significant differences (P≤0.05) between both species at stations 1 and 3, while no significant differences (P>0.05) found between both species at stations 2. Moreover, significant increasing (P≤0.05) in the Cd concentration in gills of *C. lutues* at station 3 in compare with stations 1 and 2 (Figure.5), while no significant differences (P>0.05) recorded between all stations for *C. carpio* (Figure.6).

Table. 4: Shows the concentrations of Cd µ/g (mean ±SE.) in gills of *C. luteus* and *C. carpio* for all stations

Station	Fish	
	C. luteus **mean ±SE.**	***C. carpio*** **mean ±SE.**
1	B 1.22±0.16b	A 2.20±0.32a
2	A 1.91±0.18b	A 2.27±0.25a
3	A 3.33±0.39a	B 2.02±0.36a
LSD	0.80	

Means with different small letters in the same column differ significantly at (P≤0.05)
Means with different capital letters in the same row differ significantly at (P≤0.05)

The total mean of the concentration of Cd in muscles in *C. lutues* and *C. carpio* at station 1 was 1.26 and 1.46µ/g respectively. At the same time, the highest values of Cd in muscles of *C. carpio* in compare with *C. lutues* recorded in stations 2 and 3 (Figure .6). Moreover, the highest values of Cd in *C. lutues* found at station 3, but in *C. carpio* was in station 1 in compare with other stations (Table.5 and Figure.6). No significant differences (P>0.05) observed in the Cd concentration in muscles between both species at stations 1 and 2, while significant differences (P≤0.05) recognized between both species at station 3. Significant increasing (P≤0.05) also recognized in the Cd concentration of *C. lutues* at station 3 in compare with stations 1 and 2. Moreover,

significant differences (P≤0.05) also recorded between stations 1 and 2 for *C. carpio* (Table. 5).

Table. 5: Shows the concentrations of Cd µ/g (mean ±SE.) in muscles of *C. luteus* and *C. carpio* for all stations

Station	Fish	
	C. luteus **mean ±SE.**	***C. carpio*** **mean ±SE.**
1	A 1.26±0.13b	A 1.46±0.17a
2	A 1.08±0.08b	A 0.61±0.05b
3	A 2.60±0.39a	B 1.13±0.22ab
LSD	0.59	

Means with different small letters in the same column differ significantly (P≤0.05)
Means with different capital letters in the same row differ significantly (P≤0.05)

The total mean for the concentration of Cd in the liver in *C. lutues* and *C. carpio* at station 1 were 1.24 and 2.69µ/g respectively (Figure .5 and 6). It appeared that stations 2 and 3 recorded the highest values of Cd in the liver of *C. lutues* 1.72 and 2.85 µ/g respectively in compare with *C. carpio* (Table. 6). No significant differences (P>0.05) observed between both species at station 2, while significant differences (P≤0.05) found between both species at stations 1 and 3. However, significant increasing (P≤0.05) observed in the concentration of Cd in the liver of *C. lutues* at station 3 in compare with stations 1 and 2. Moreover, significant differences (P≤0.05) also recorded between stations 1 and 2 for *C. carpio* (Table. 6).

Table. 6: Shows the Concentrations of Cd µ/g (mean ±SE.) in the liver of *C. luteus* and *C. carpio* for all stations

Station	Fish	
	C. luteus **mean ±SE.**	***C. carpio*** **mean ±SE.**
1	B 1.24±0.18b	A 2.69±0.58a
2	A 1.72±0.18b	A 0.91±0.09b
3	A 2.85±0.49a	B 1.77±0.37ab
LSD	0.97	

Means with different small letters in the same column differ significantly at (P≤0.05)
Means with different capital letters in the same row differ significantly at (P≤0.05)

In the present study, a total mean for concentration of Cd in kidney in *C. lutues* and *C. carpio* at station 1 were 1.36 and 3.79µ/g respectively. It appeared that stations 2 and 3

recorded the highest values of Cd in the kidney of *C. lutues* 2.24 and 2.00 µ/g respectively in compare to the *C. carpio*, which reached 0.67 and 0.89 µ/g respectively (Table.7, Figure.5 and 6). Significant differences (P≤0.05P) in Cd concentration in kidney were seen between both species at different stations. While, no significant differences (P>0.05) were seen between all stations in the concentration of the Cd in the kidney of *C. lutues*. However, significant increasing (P≤0.05) were recorded between station 1 in compare to the stations 2 and 3 for *C. carpio* (Table. 7).

Table. 7: Shows the concentrations of Cd µ/g (mean ±SE.) in kidney of *C. luteus* and *C.carpio* for all stations

Station	Fish	
	C. luteus **mean ±SE.**	***C. Carpio*** **mean ±SE.**
1	B 1.36±0.17a	A 3.79±0.56a
2	A 2.24±0.45a	B 0.67±0.04b
3	A 2.00±0.29a	B 0.89±0.21b
LSD	0.93	

Means with different small letters in the same column differ significantly at (P≤0.05)
Means with different capital letters in the same row differ significantly at (P≤0.05)

The results of the present study are compatible with the observations reported by many researchers previously (Al-Maliky, 2009; Malik *et al.*, 2010; Abdel-Baki, *et al.*, 2011). They found that the Cd was accumulated in the kidney of fish. The suggested concentration for Cd was 50 µ /u. The results of the present study revealed that the levels of the metal in the muscles of the fish were higher than the allowable concentration that suggested by WHO (2005) and cause a threat to the public health.

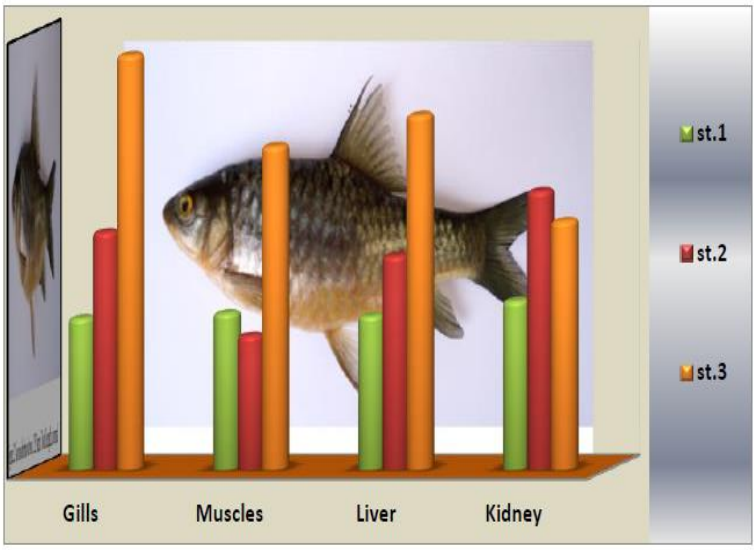

Figure. 5: Shows the concentrations of Cd µ/g in all organs of *C. luteus*

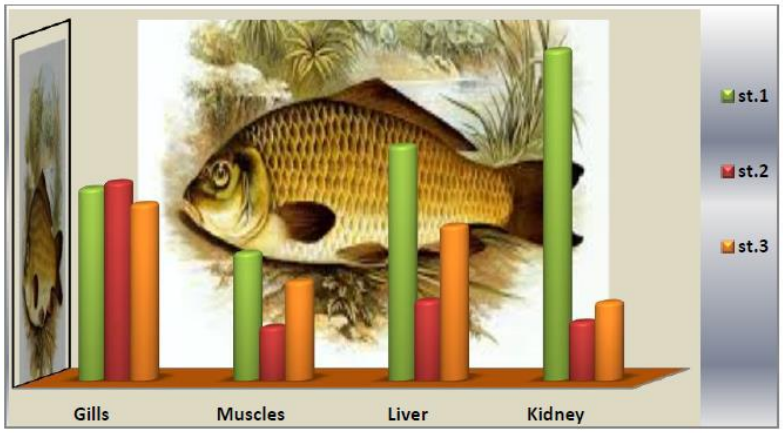

Figure. 6: Shows the concentrations of Cd µ/g in all organs of *C. carpio*

In conclusion, the results of the present study approved the variations of the Cd concentration dissolved in water specimens. Moreover, the presence of various concentration of Cd in the internal organs of the fish that lived in the Tigris River. The results also reported Cd concentration which was higher than the allowable WHO concentration that might threaten the public health. The authors recommend more future studies in different areas of Iraq to determine the real situation of Cd concentrations in aquatic species that live in the Tigris and Euphrates rivers as well as the water.

References

Abdel-Baki AS, Dkhill MA and Al-Quraishy S. (2011). Bioaccumulation of some heavy metals in tilapia fish relevant to their concentration in water and sediment of Wadi Hanifah, Saudia Arab. Afr. J. Biotech. 10(13): 2541 -2547.

Al-Ansari NA, Salman HH and Al-Sinawi GT. (1987). Periodicity of selected water quality parameters for the Tigris water at Baghdad. J. Wat. Res. (6):11–17.

Al-Haidary MJS. (2009). Distribution of heavy metals in Mesopotamia marsh ecosystem, Iraq. Ph.D. Thesis, Coll. of Sci. for Women, Univ. of Baghdad. pp163.

Al-Maliky RNA. (2009). Biogeochemical assessment of trace metals in Al-Hammar marshes, Iraq. Ph.D. Thesis, Coll. Sci. for women, Univ. of Baghdad, pp 253.

Al-Taee MM. (1999). Some metals in water, sediments, fishes and plants of Shatt Al-Hilla River, Ph.D. Thesis. Univ. of Babylon, Iraq, pp 128.

APHA. American Public Health Association (1998). Standard methods for the examination of water and waste water.13th ed., New-York. 1193 P.

Druckman D. (1967). Analytical methods for atomic absorption spectroscopy. atom. Absorpt. Newsl., 6: 311P.

Federici G, Shaw BJ and Handy RD.(2007). Toxicity of titanium dioxide nanoparticles to rainbow trout (Oncorhynchus mykiss): Gill injury, oxidative stress and other physiological effects. Aquatic Toxicol. 84: 415-430.

García R and Báez AP.(2012). Atomic Absorption Spectrometry (AAS), Atomic Absorption Spectroscopy, Muhammad Akhyar Farrukh (Ed.), ISBN: 978-953-307-817-5.

Hassan WF. (2007). Hydrochemical and geochemical study of the Shatt Al-Arab river sediments. Ph. D. Thesis, Coll. of Agri., Univ. of Basrah, pp189.

Isaev VA and Mikhailova MV. (2009). The Hydrology, evolution, and hydrological regime of the mouth area of the Shatt Al-Arab River, Water Res. 36 (4): 380-395.

Liang Y and Worng MH. (2003). Spatial and temporal organic and heavy metal pollution at Mai Po marshes, Nature Reserve, Hong Kong, Chemosphere. 52: 1647-1658.

Malik N, Biswas AK, Qureeshi T, Borana K and Virha R. (2010). Bioaccumulation of heavy metals in fish tissues of a freshwater lake of Bhopal. Environ. Monit. Assess. 160: 267-276.

Moriarty F. (1984). Persistent contaminants, compartmental models and concentration along food-chains. Ecol. Bull. 36: 35-45.

Muhsin AH. (2011). Pollution by heavy metals and bioaccumulation in Aquatic invertebrates in water surface in Basrah. Ph.D. Thesis, Coll. of Edu. Univ. of Basrah. pp 214.

Phillips NR, Stewart M, Olsen G and Hickey CW. (2014). Human health risks of geothermally derived metals and other contaminants in wild caught. Fish.J. of Toxi . and Environ. Health. 77:346- 365.

SAS. (2010). SAS/STAT Users Guide for Personal Computer. Release 9.1.SAS Institute.
Szkoda J and Żmudzki J. (2005). Determination of lead and cadmium in biological material by Graphite Furnace Atomic Absorption Spectrometry Method. Bull. Vet. Inst., 49: 89-92.

Vymazal J. (2008). Wastewater Treatment, Plant Dynamics and Management in Constructed and Natural wetlands, Springer Book, 121-133.

WHO (2005). Guidelines for drinking-water quality. Geneva, pp5-7.