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# ASSESSMENT OF HEAVY METALS IN WATER AND SEDIMENT OF FIVE FISH FARMS IRRIGATED WITH DIFFERENT WATER SOURCES

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## ABSTRACT

This study was conducted to estimate the pollution of status of some heavy metals in water and sediments of five fish farms use different water sources during April 2013 - March 2014. The first farm (G1) used groundwater, the second one (G2) feed with agriculture drainage water, the third one (G3) used a mixture of groundwater and Nile water, the fourth farm (G4) sewage wastewater from Bahr El-Baqar drain after sedimentation and the fifth farm (G5) filled with water from Lake Manzala. G1, G2 and G3 are located at Abbassa, Sharkia Governorate, while G4 and G5 are located at Shader Azzam at the south region of Lake Manzala, Port Said Governorate. The results showed that, G1 had the highest concentration of heavy metals in water, while G5 showed the lowest one. The order of metals concentrations in water was as follows: Fe > Mn > Zn > Cu > Pb > Cd except at G3 where Cd > Pb. In sediment, the order was G5 > G4> G3> G2> G1. The differences among groups were highly significant for all studied metals in sediments. Concentrations of all tested metals in water and sediments were within the guidelines values. From this study, it could be concluded that all water sources in this study do not pose pollution with heavy metals and could be used in fish cultures.

**Key words:** Fish farms, heavy metals, sediments, water sources.

## INTRODUCTION

Egypt, as a semi-arid country, is facing great challenges in managing its water resources to meet the progressive demand of irrigation water for food production. Because of the shortage of water resources in many parts of Egypt, many people use drainage waste water and ground water in aquaculture (fish farms).

In aquatic ecosystems, heavy metals have received considerable attention due to their toxicity, accumulation in biota (Dural *et al*., 2006; Dundar and Altundag, 2007) and biomagnification in the food chain (Erdogrul and Ates, 2006). Some of these metals are essential for living organisms, such as Cu and Zn, however, some others like Pb and Cd are toxic for living organisms (Fatoki *et al*., 2002). Water sources from which water bodies are getting polluted by heavy metals are sewage disposal, agriculture drainage water containing pesticides, fertilizers and industrial effluents (Singh *et al*., 2007).

Also, more attention is being devoted to the study of pond sediment because it is a major factor in pond aquaculture which affect water quality and production. Sediments quality is a good indicator of pollution in water column as it tends to concentrate heavy metals and other organic pollutants (Ferreira *et al*., 1996). The chemical reactions in sediments can change the concentration of heavy metals and, as a consequence, in the overlying water (Qari *et al*., 2005).

So, the present study was conducted to investigate the possibility of using alternative sources for aquaculture through estimation of the degree of heavy metals pollution.

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# MATERIALS AND METHODS

This study was conducted during April 2013 - March 2014 at five fish farms (three earthen ponds each) using different sources of water.

1. The first farm (G1) located at Abbassa, Sharkia Governorate, which has sandy clay texture and irrigated with groundwater.
2. The second farm (G2) laid at Abbassa, Sharkia Governorate, which has sandy clay texture and irrigated with agriculture drainage water from Al-Bahnasawy drain.
3. The third farm (G3) situated at Abbassa, Sharkia Governorate, which has clay texture and irrigated with a mixture of groundwater and Nile water from Ismailia canal at a ratio of 1:1.
4. The fourth farm (G4) located at about 13 kilometer southward of lake Manzala, at Shader Azzam, Port Said Governorate. It has silty clay loam texture and irrigated with sewage water (domestic and industrial wastewater) from Bahr El-Baqar drain after sedimentation.
5. The fifth farm (G5) located at the southern part of lake Manzala, Port Said Governorate, which has heavy clay texture and irrigated with Lake Manzala water.

## Experimental Design

The design of the study was a randomized complete block "factorial", involving 2 factors as follows:

**Factor A**

The fish farms, where the location was detected upon the difference in sediment textures and water sources.

**Factor B**

The periods, where samples of water and sediment were taken monthly from three earthen ponds at each location during the study period. Thus, total number of treatments is 60 (5 groups' × 12 month).

The particle size distributions of sediments in fish earthen ponds are shown in Table 1.

**Water**

Water samples were taken monthly from each earthen pond at each farm to analyze heavy metals residues; iron (Fe), manganese (Mn), copper (Cu), zinc (Zn), cadmium (Cd) and lead (Pb).

A column sampler constructed from a PVC pipe (5-cm diameter, 1.5-m long) was used to collect water samples from five spots at each pond between 9.00 am and 12.00 pm at a depth of 30 cm below the water surface and mixed together in a plastic container (Boyd and tucker, 1992). Then one liter for heavy metals determination preserved by adding 2 ml conc. HNO3 and 5ml conc. HCl and kept in a refrigerator till analysis.

**Sediments**

Sediments samples were taken monthly from each earthen pond from the upper 20 cm surface layer by a sediments sampler to assess heavy metals, while particle size distribution was measured only at the beginning of the study.

Sediments samples were collected from three different sites at each pond. These samples were thoroughly mixed to make a representative sample of the pond, and then air dried, crushed, sieved through a 2 mm sieve and kept in polyethylene bags for further analyses.

## Methods of Analyses

**Water**

Total metals concentration (solid phase; particles and colloids, an aqueous phase; free ions and dissolved complexes and a biological phase; incorporated into cells or adsorbed on to biological surfaces) of Fe, Zn, Cu, Mn, Cd and Pb were measured after digestion with conc. $HNO_3$ and HCl (USEPA, 1992).

**Sediments**

**Mechanical analysis**

Particle size distribution was carried out by the pipette methods (Piper, 1950).

**Heavy metals**

Dried samples were digested with strong acids; concentrated nitric acids ($HNO_3$), hydrogen peroxide ($H_2O_2$) and hydrochloric acid (HCl) according to EPA Method (USEPA, 1996).

Metals conc. In water (mg/l) and sediments (mg/kg) were measured using flame atomic absorption spectrophotometer (Thermo ELECTRON CORPORATION S SERIES AA Spectrometer, UK)

**Table 1. Sediments mechanical analysis at the beginning of the study at the five fish farms**

| Group \ Item | Sand (%) | Silt (%) | Clay (%) | Textural class |
|---|---|---|---|---|
| **G1** | 48.89 | 11.72 | 39.39 | Sandy clay |
| **G2** | 49.81 | 10.89 | 39.30 | Sandy clay |
| **G3** | 41.20 | 15.50 | 43.30 | Clay |
| **G4** | 16.42 | 47.29 | 36.29 | Silty clay loam |
| **G5** | 10.94 | 25.78 | 63.28 | Heavy clay |

### Statistical Analysis

Statistical analysis of obtained results was carried out according to MSTAT- C (1988) program for ANOVA and LSD analysis.

## RESULTS AND DISCUSSION

### Heavy Metals in Water

#### Effect of fish farms

Regarding to the farms effect, data in Table 2 show that, G1 had the highest total annual mean of heavy metals (10.61 mg/l), while G5 had the lowest one (1.63 mg/l). From the presented data, it is clear that annual mean of metals concentration showed a very highly significant ($P \leq 0.001$) differences among the different fish farms.

At G4, metals concentration may be decreased due to sedimentation of Bahr El-Baqar Drain's water before irrigation of ponds, where solid particles, which absorb heavy metals, precipitate and reduce the heavy metals content (Adhikari *et al*., 2009).

Generally, the order of the annual mean values of total heavy metals concentration in water of different fish farms was as follows: G1 > G3 > G2 > G4 > G5.

The highest concentration of heavy metals at G1 in water may be resulting from the highest values of Fe and Mn. On the other hand, the lowest concentration of heavy metals at G5 in water may be attributed to the spreading of aquatic weeds and plants in the lake which absorbed heavy metals (Adhikari *et al*., 2009).

The highest values of Fe (10.21 mg/l), Mn (0.32 mg/l), Cu (0.019 mg/l) and Pb (0.0010 µg/l) were observed at G1. While Zn at G2 and Cd at G3 showed the highest values (0.13 mg/l and 1.30 µg/l, respectively). On the other hand, the lowest concentration of Fe (1.38 mg/l), Zn (0.01 mg/l), Cu (0.001 mg/l), Cd (ND) and Pb (ND) were detected at G5, while Mn recorded the lowest value (0.16 mg/l) at G3. From the previous data it is evident that the differences between G2 and G4 were not significant concerning Fe and Mn.

Increase of Fe and Mn at G1 may be due to groundwater which has high contents of these elements. Cd concentration increased at G3 as a result of using phosphate fertilizers which are considered the main source of cadmium, as cadmium constitutes up to 35 mg/kg of phosphorous pentoxide, a component of phosphate-based fertilizers (IARC, 1993).

The order of metals concentration in water at the five fish farms was as follows: Fe > Mn > Zn > Cu > Pb > Cd except at G3 where Cd > Pb. In the Egyptian irrigation system, the main source of Cu and Pb are industrial wastes as well as algaecides for Cu, while that of Cd is the phosphatic fertilizers used in crop farms (Mason, 2002).

Percentage of Fe from total heavy metals were (96, 85, 93, 89 and 84%) followed by Mn (3, 10, 4, 10 and 15%) then Zn (1, 5, 3, 1 and 1%) at G1, G2, G3, G4 and G5, respectively. Percentage of Cu, Cd and Pb $\simeq$ 0% at all fish farms. In this respect, similar pattern for heavy metals concentration in water of earthen fish ponds was observed at Abbassa and Maruit fish farms (Saeed, 2103).

Data in Table 2 show that, concentrations of all studied metals were lower than the guidelines values reported by WHO (2011).

**Table 2. Heavy metals content of water as affected by fish farms**

| Item / Group | Fe (mg/l) | Mn (mg/l) | Zn (mg/l) | Cu (mg/l) | Cd (µg/l) | Pb (µg/l) | Total (mg/l) |
|---|---|---|---|---|---|---|---|
| **G1** | 10.21 | 0.32 | 0.06 | 0.019 | 0.20 | 1.00 | 10.61 |
| **G2** | 2.60 | 0.31 | 0.13 | 0.008 | 0.30 | 0.30 | 3.05 |
| **G3** | 3.31 | 0.16 | 0.09 | 0.006 | 1.30 | 0.20 | 3.58 |
| **G4** | 2.68 | 0.31 | 0.03 | 0.006 | ND | 0.10 | 3.03 |
| **G5** | 1.38 | 0.24 | 0.01 | 0.001 | ND | ND | 1.63 |
| **#GV (mg/l)** | - | 0.4 | 3.0 | 0.20 | 0.003 | 0.01 | |
| **Significance** | *** | *** | *** | *** | *** | *** | *** |
| **LSD at0.05** | 0.336 | 0.033 | 0.015 | 0.001 | 0.060 | 0.110 | 0.345 |

#Guideline values according to WHO, 2011; - No health-based guideline value is proposed for iron because it is not of health concern at levels found in natural water (0.5-50.0 $mgl^{-1}$); ND = Not detected; Significance level ***$P \leq 0.001$.

## Effect of Periods

Data recorded in Table 3 show that, the highest value of total heavy metals was in February (6.50 mg/l), while the lowest value was in August (3.32 mg/l). Fe showed the highest value (6.13 mg/l) in February and the lowest one (3.04 mg/l) was recorded in August. The highest value of Mn was in February (0.32 mg/l) while, the lowest value (0.22 mg/l) was reported in December. The highest (0.27 mg/l) value of Zn was observed in December while, the lowest value (0.01 mg/l) was detected in September. The maximum value (0.013 mg/l) of Cu was measured in April and May while, the minimum value (0.004 mg/l) was reported in September. It is also clear that, there were very highly significant ($P \leq 0.001$) differences among months concerning metals concentration. Ruelas-Inzunza *et al*. (2011) mentioned that higher metals concentrations was observed during the rainy season due to the increase in washing, leaching and transport (erosion) during rainfall.

Concerning the interaction effect between farm and period, data in Table 4 show that, the highest value of total heavy metals was recorded at G1 in February (19.89 mg/l), while the lowest value was observed at G5 in April (0.90 mg/l). From the previous data and data in Table 5 it is evident that there were very highly significant ($P \leq 0.001$) differences in values of total heavy metals according to the interaction effect between fish farms and period.

Data in Table 5 show that, the highest source of variation in heavy metals, Fe and Cu (68.80, 69.55 and 50.00%, respectively) were referred to the farms effect, while the highest source of variation in Mn, Zn, Cd and Pb (57.91, 54.21, 53.70 and 46.94%, respectively) were referred to the interaction effect between farms and period.

## Heavy Metals in Sediments

### Effect of fish farms

Most of the heavy metals become bound to particles in sediment, but a small quantity becomes dissolved in the water and can spread widely in the food chains (Khadr, 2005). The increase of metals content in water attributed to the decomposition of organic matter in sediments and release of metals to the overlying water (Hamed *et al*., 2013).

Regarding to the farms effect, data in Table 6 show that G5 had the highest (59.10 g/kg) annual mean value of each of total heavy metals; Fe (58.30 g/kg), Mn (683.13 mg/kg), Zn (69.06 mg/kg) and Cu (43.36 mg/kg), while G2 and G4 had higher annual mean values of Cd and Pb (0.64 and 4.95 mg/kg, respectively). The highest Cd concentration observed at G2 may be due to using of agriculture drainage water which

**Table 3. Heavy metals conc. (mg/l) in water as affected by periods**

| Item / Period | Fe (mg/l) | Mn (mg/l) | Zn (mg/l) | Cu (mg/l) | Cd (µg/l) | Pb (µg/l) | Total (mg/l) |
|---|---|---|---|---|---|---|---|
| **Apr-13** | 3.34 | 0.28 | 0.02 | 0.013 | 0.20 | 1.90 | 3.66 |
| **May-13** | 3.52 | 0.28 | 0.03 | 0.013 | 0.20 | 0.30 | 3.84 |
| **Jun-13** | 4.60 | 0.27 | 0.02 | 0.007 | 0.20 | ND | 4.89 |
| **Jul-13** | 3.95 | 0.29 | 0.03 | 0.008 | 0.20 | ND | 4.27 |
| **Aug-13** | 3.04 | 0.25 | 0.02 | 0.006 | 0.20 | 0.60 | 3.32 |
| **Sep-13** | 3.42 | 0.30 | 0.01 | 0.004 | 0.10 | ND | 3.74 |
| **Oct-13** | 3.24 | 0.24 | 0.02 | 0.005 | 0.30 | ND | 3.51 |
| **Nov-13** | 3.62 | 0.29 | 0.08 | 0.007 | 1.20 | ND | 4.00 |
| **Dec-13** | 4.34 | 0.22 | 0.27 | 0.006 | 1.10 | ND | 4.84 |
| **Jan-14** | 3.89 | 0.24 | 0.16 | 0.007 | 0.40 | ND | 4.31 |
| **Feb-14** | 6.13 | 0.32 | 0.04 | 0.011 | 0.20 | 0.20 | 6.50 |
| **Mar-14** | 5.34 | 0.26 | 0.09 | 0.011 | 0.20 | 0.70 | 5.70 |
| **Significance** | *** | ** | *** | *** | *** | *** | *** |
| **LSD at0.05** | 0.5204 | 0.0511 | 0.02287 | 0.0021 | 0.00009 | 0.00017 | 0.5343 |

ND = Not detected; Significance level (, ** $P \leq 0.01$, *** $P \leq 0.001$); LSD = Least significant difference.

**Table 4. Total heavy metals# (mg/l) in water as affected by fish farms, periods and their interaction**

| Group / Period | G1 | G2 | G3 | G4 | G5 | Mean |
|---|---|---|---|---|---|---|
| **Apr-13** | 7.46 | 3.62 | 3.15 | 3.18 | 0.90 | 3.66 |
| **May-13** | 8.16 | 4.51 | 4.02 | 1.41 | 1.09 | 3.84 |
| **Jun-13** | 13.11 | 3.56 | 5.06 | 1.29 | 1.46 | 4.89 |
| **Jul-13** | 10.46 | 3.84 | 4.21 | 1.61 | 1.26 | 4.27 |
| **Aug-13** | 6.53 | 2.86 | 2.31 | 3.36 | 1.53 | 3.32 |
| **Sep-13** | 7.64 | 3.25 | 2.40 | 3.64 | 1.76 | 3.74 |
| **Oct-13** | 6.18 | 1.55 | 4.12 | 3.18 | 2.50 | 3.51 |
| **Nov-13** | 7.96 | 1.75 | 4.83 | 3.57 | 1.87 | 4.00 |
| **Dec-13** | 10.59 | 2.98 | 4.55 | 3.14 | 2.92 | 4.84 |
| **Jan-14** | 11.44 | 2.35 | 3.19 | 3.41 | 1.16 | 4.31 |
| **Feb-14** | 19.89 | 3.91 | 2.19 | 5.37 | 1.14 | 6.50 |
| **Mar-14** | 17.95 | 2.48 | 2.90 | 3.17 | 2.00 | 5.70 |
| **Annual mean** | 10.61 | 3.06 | 3.58 | 3.03 | 1.63 | 4.38 |
| **LSD at0.05** | Group | Period | | Group × period | | |
| | 0.3449 | 0.5343 | | 1.1966 | | |

# = Sum (Fe, Mn, Zn, Cu, Cd and Pb) ; LSD = Least significant difference.

**Table 5. Two-factors analysis of variance (ANOVA) for heavy metals analysis of water**

| Item | | Source of variation | | | | |
|---|---|---|---|---|---|---|
| | | Replication | Farm | Period | Farm × Period | Error |
| Degrees of freedom | | 2 | 4 | 11 | 44 | 118 |
| Fe | Sign | NS | *** | *** | *** | |
| | SS (%) | 0.06 | 69.55 | 5.53 | 22.49 | 2.38 |
| Mn | Sign | NS | *** | ** | *** | |
| | SS (%) | 0.67 | 20.70 | 3.87 | 57.91 | 16.85 |
| Zn | Sign | * | *** | *** | *** | |
| | SS (%) | 0.13 | 10.85 | 32.78 | 54.21 | 2.02 |
| Cu | Sign | NS | *** | *** | *** | |
| | SS (%) | 0.83 | 50.00 | 16.67 | 25.00 | 8.33 |
| Cd | Sign | NS | *** | *** | *** | |
| | SS (%) | 0.12 | 29.23 | 15.52 | 53.70 | 1.40 |
| Pb | Sign | NS | *** | *** | *** | |
| | SS (%) | 0.11 | 14.30 | 34.30 | 46.94 | 4.36 |
| Total | Sign | NS | *** | *** | *** | |
| | SS (%) | 0.08 | 68.80 | 5.65 | 23.04 | 2.43 |

Significance level (NS = Not significant, * $P \leq 0.05$, ** $P \leq 0.01$, *** $P \leq 0.001$); SS = sums of squares.

**Table 6. Heavy metals content of sediments as affected by fish farms**

| Item / Group | Fe (g/kg) | Mn (mg/kg) | Zn (mg/kg) | Cu (mg/kg) | Cd (mg/kg) | Pb (mg/kg) | Total (g/kg) |
|---|---|---|---|---|---|---|---|
| G1 | 22.41 | 422.37 | 31.89 | 19.16 | 0.43 | 2.12 | 22.89 |
| G2 | 33.05 | 514.57 | 45.39 | 26.14 | 0.64 | 1.74 | 33.64 |
| G3 | 37.37 | 660.60 | 49.70 | 29.31 | 0.44 | 1.58 | 38.11 |
| G4 | 45.96 | 561.11 | 64.08 | 31.55 | 0.44 | 4.95 | 46.62 |
| G5 | 58.30 | 683.13 | 69.06 | 43.36 | 0.50 | 3.21 | 59.10 |
| AR# | - | 460-1110 | 120-820 | 16-110 | 0.6-10 | 31-250 | |
| Significance | *** | *** | *** | *** | *** | *** | *** |
| LSD at0.05 | 1.733 | 39.014 | 2.635 | 2.041 | 0.078 | 0.900 | 1.739 |

Significance level ***$P \leq 0.001$; LSD = Least significant difference.
# Acceptable ranges according to Persaud *et al.* (1990).

is rich with phosphate fertilizer (Mason, 2002). The application of phosphate fertilizers leads to increase the cadmium content in sediments (Piscator, 1985). On the other hand, G1 had the lowest (22.89 g/kg) annual mean value of total heavy metals; Fe (22.41 g/kg), Mn (422.37 mg/kg), Zn (31.89 mg/kg), Cu (19.16 mg/kg), and Cd (0.43 mg/kg), while G3 had lowest annual mean value of Pb (1.58 mg/kg).

From the previous data, it is evident that there were a very highly significant ($P \leq 0.001$) differences in annual mean values of metals among the different fish farms. A mean value of Mn concentration (722.06 mg/kg) was detected in sediments of fish farms located at Al-Abbassa, Sharkia Governorate by Al-Nagaawy and Saeed (2012).

Generally, the order of the annual mean values of total heavy metals concentration in sediments of different fish farms was as follows: G5 > G4> G3> G2> G1. The highest heavy metals concentration at G5 may be due to the high content of clay and organic matter. The pollutants concentration in sediments increased with decreasing the particle size of sediments. Sediments have certain limited capacity to absorb different ions from waters percolating through it. This capacity is lowest for carbonate-sandy fractions of sediments and highest for clayey organic matter rich sediments (Sin *et al*., 1991). Fine sediments associated with high load of organic matter have a larger surface area, which allows heavy metals and other contaminants to be adsorbed easily (Nguyen *et al*., 2005). Most of the heavy metals become bound to particles in sediment, but a small quantity becomes dissolved in the water and can spread widely in the food chains (Khadr, 2005).

The order of metals concentrations in sediments at the five fish farms was as follows: Fe > Mn > Zn > Cu > Pb > Cd and follow the same trend of water. The percentage of iron (Fe) from total heavy metals in sediments represented 98% at G1, G2, and G3, while at G4 and G5 it represented 99%, followed by manganese (2%) at G1, G2, and G3 and 1% at G4 and G5. Percentage of zinc, copper, cadmium and lead $\simeq$ 0% at all farms. In this respect, iron concentration in sediments from the studied locations was the highest, while Cd conc. was the lowest one. As Fe is one of the most common elements in the earth's crust (Usero *et al*., 2003), its concentrations might simply be abundant in both natural and constructed wetland sediments. Lead may be strongly adsorbed on sediments particles (Elith and Garwood 2001), while cadmium ions can be directly absorbed by water and it is known to be most mobile among the other metals (Kabata-Pendias and Pendias, 2001).

It is also cleared from data presented in Table 6 that, concentrations of all studied metals were within acceptable ranges according to Persaud *et al*. (1990).

**Effect of periods**

Data recorded in Table 7 show that, the highest value of total heavy metals (44.79 g/Kg) was observed in April, while the lowest value (35.97 g/kg) was detected in February. The highest value of Fe (44.10 g/kg) was reported in April, while the lowest value (35.40 g/kg) was recorded in February. The highest value (635.27 mg/kg) of Mn was measured in June, while the lowest value (493.18 mg/kg) was observed in January. The highest value (56.48 mg/kg) of Zn was detected in October, while the lowest value (48.66 mg/ kg) was observed in February. The highest (31.97 mg/kg) and lowest (27.48 mg/kg) values of Cu were recorded in October and July, respectively. The highest value (0.60 mg/Kg) of Cd was observed in May, while the lowest value (0.36 mg/kg) was measured in January. The highest value (3.45 mg/kg) of Pb was detected in April, while the lowest value (2.22 mg/kg) was observed in February and March. Statistical analysis of the obtained results showed that there were very highly significant ($P \leq 0.001$) differences among months concerning metals concentration.

Concerning the interaction effect between fish farms and periods, data in Table 8 show that, the highest value (66.33 g/kg) of heavy metals was recorded at G5 in April and October, while the lowest value (19.58 g/kg) was reported at G1 in June. From the previous results and data in Table 9, it is evident that, there were very highly significant ($P \leq 0.001$) differences in values of total heavy metals according to the interaction effect between fish farms and periods. Data in Table 9 show that, the highest source of variation in total heavy

**Table 7. Heavy metals content of sediments as affected by periods**

| Item / Period | Fe (g/kg) | Mn (mg/kg) | Zn (mg/kg) | Cu (mg/kg) | Cd (mg/kg) | Pb (mg/kg) | Total (g/kg) |
|---|---|---|---|---|---|---|---|
| **Apr-13** | 44.10 | 598.66 | 54.52 | 30.70 | 0.38 | 3.45 | 44.79 |
| **May-13** | 41.88 | 614.05 | 53.74 | 30.40 | 0.60 | 3.08 | 42.58 |
| **Jun-13** | 39.86 | 635.27 | 51.68 | 28.32 | 0.52 | 2.60 | 40.58 |
| **Jul-13** | 38.44 | 596.55 | 50.92 | 27.48 | 0.45 | 2.47 | 39.12 |
| **Aug-13** | 36.50 | 612.40 | 50.23 | 27.77 | 0.53 | 2.89 | 37.20 |
| **Sep-13** | 40.90 | 561.85 | 50.93 | 30.77 | 0.48 | 3.15 | 41.55 |
| **Oct-13** | 42.98 | 626.54 | 56.48 | 31.97 | 0.49 | 2.50 | 43.70 |
| **Nov-13** | 38.68 | 535.62 | 51.58 | 29.62 | 0.74 | 2.46 | 39.30 |
| **Dec-13** | 39.18 | 556.13 | 52.57 | 31.76 | 0.50 | 2.80 | 39.82 |
| **Jan-14** | 38.10 | 493.18 | 49.87 | 30.16 | 0.36 | 2.78 | 38.68 |
| **Feb-14** | 35.40 | 493.48 | 48.66 | 29.11 | 0.40 | 2.22 | 35.97 |
| **Mar-14** | 36.99 | 496.56 | 53.08 | 30.80 | 0.42 | 2.22 | 37.58 |
| **Significance** | *** | *** | * | *** | *** | ** | *** |
| **LSD at0.05** | 2.685 | 60.440 | 4.082 | 0.000 | 0.121 | 0.405 | 2.695 |

Significance level (***** $P \leq 0.05$, ****** $P \leq 0.01$, ******* $P \leq 0.001$); LSD = Least significant difference.

**Table 8. Total heavy metals# concentration (g/kg) in sediments as affected by fish farms, periods and their interactions**

| Group / Period | G1 | G2 | G3 | G4 | G5 | Mean |
|---|---|---|---|---|---|---|
| **Apr-13** | 22.93 | 54.48 | 30.41 | 49.78 | 66.33 | **44.79** |
| **May-13** | 22.54 | 56.59 | 33.95 | 42.72 | 57.11 | **42.58** |
| **Jun-13** | 19.58 | 46.38 | 38.57 | 44.19 | 54.19 | **40.58** |
| **Jul-13** | 20.24 | 46.82 | 33.72 | 43.61 | 51.22 | **39.12** |
| **Aug-13** | 22.54 | 40.62 | 31.93 | 47.45 | 43.46 | **37.20** |
| **Sep-13** | 22.86 | 20.30 | 48.93 | 57.24 | 58.41 | **41.55** |
| **Oct-13** | 24.46 | 24.41 | 46.12 | 57.19 | 66.33 | **43.70** |
| **Nov-13** | 21.87 | 26.53 | 38.77 | 48.01 | 61.32 | **39.30** |
| **Dec-13** | 24.34 | 22.47 | 43.83 | 47.37 | 61.10 | **39.82** |
| **Jan-14** | 21.01 | 26.43 | 40.37 | 42.59 | 62.97 | **38.67** |
| **Feb-14** | 25.86 | 18.99 | 33.92 | 38.68 | 62.42 | **35.97** |
| **Mar-14** | 26.39 | 19.69 | 36.84 | 40.62 | 64.34 | **37.58** |
| **Annual mean** | **22.89** | **33.64** | **38.11** | **46.62** | **59.10** | **40.07** |
| **LSD at0.05** | **group** | **period** | | **Group × period** | | |
| | 1.739 | 2.695 | | 6.025 | | |

# = Sum (Fe, Mn, Zn, Cu, Cd and Pb) ; LSD = Least significant difference.

**Table 9. Two-factor analysis of variance (ANOVA) for heavy metals analysis of sediment**

| Item | | Source of variation | | | | |
|---|---|---|---|---|---|---|
| | | Replication | Farm | Period | Farm × Period | Error |
| **Degrees of freedom** | | 2 | 4 | 11 | 44 | 118 |
| **Fe** | **Sign** | NS | *** | *** | *** | |
| | **SS (%)** | 0.10 | 68.56 | 2.99 | 24.14 | 4.21 |
| **Mn** | **Sign** | NS | *** | *** | *** | |
| | **SS (%)** | 0.31 | 27.85 | 7.90 | 50.10 | 13.83 |
| **Zn** | **Sign** | NS | *** | *** | *** | |
| | **SS (%)** | 0.18 | 59.90 | 1.47 | 31.45 | 7.00 |
| **Cu** | **Sign** | * | *** | NS | *** | |
| | **SS (%)** | 0.56 | 50.63 | 1.60 | 37.13 | 10.08 |
| **Cd** | **Sign** | ** | *** | *** | *** | |
| | **SS (%)** | 0.46 | 49.10 | 10.94 | 28.55 | 10.94 |
| **Pb** | **Sign** | ** | *** | ** | *** | |
| | **SS (%)** | 0.50 | 54.57 | 5.04 | 23.28 | 16.61 |
| **Total** | **Sign** | *** | *** | *** | *** | |
| | **SS (%)** | 0.10 | 68.53 | 3.02 | 24.18 | 4.17 |

Significance level (NS = Not significant, * P ≤ 0.05, ** P ≤ 0.01, *** P ≤ 0.001); SS = sums of squares.

metals; Fe, Zn, Cu,Cd and Pb (68.56, 59.90, 50.63, 49.10 and 45.57%, respectively) were referred to the farms effect, while the highest source of variation in Mn (50.10%) was referred to the interaction effect between farms and periods.

## Correlation Among Heavy Metals of Sediments

The relationships among heavy metals in sediments, as a whole in this study, were tested by computing the value of the correlation coefficient (r) as shown in Table 10 and Fig. 1. The results showed that there were very high positive significant (P≤0.001) correlations between each of Fe, Mn, Zn and Cu. Also there were high positive significant (P≤0.01) correlations between Pb and each of Fe and Zn. The results also revealed that there were a very highly positive significant (P≤0.001) correlations between each of heavy metals and all studied metals except Cd where there was no significant (P > 0.05) correlation. Also there were no significant correlations between Cd and each of Fe and Cu of sediments.

## Relationship Between Heavy Metals in Water and Sediments

The relationships between heavy metals in water and sediments, as a whole in this study, were tested by computing the value of the correlation coefficient (r) as shown in Table 11 and Figs. 2, 3 and 4. The results showed that there were negative correlations between water and sediment in concentration of all studied metals (Fe, Mn, Cu, Zn, Cd, Pb and total metals).

**Table 10. Correlation coefficient matrix (*r*) between heavy metals in sediments**

| Metal | Fe | Mn | Zn | Cu | Cd | Pb | Total |
|---|---|---|---|---|---|---|---|
| **Fe** | 1 | | | | | | |
| **Mn** | 0.5892*** | 1 | | | | | |
| **Zn** | 0.9140*** | 0.6331*** | 1 | | | | |
| **Cu** | 0.9158*** | 0.6098*** | 0.8996*** | 1 | | | |
| **Cd** | -0.0123 | 0.0497 | 0.0094 | -0.1058 | 1 | | |
| **Pb** | 0.3343** | 0.0877 | 0.4058** | 0.1973 | 0.0955 | 1 | |
| **total** | 0.9999*** | 0.5969*** | 0.9154*** | 0.9168*** | -0.012 | 0.3332*** | 1 |

Significance level (****P ≤ 0.01, ***** P ≤ 0.001)

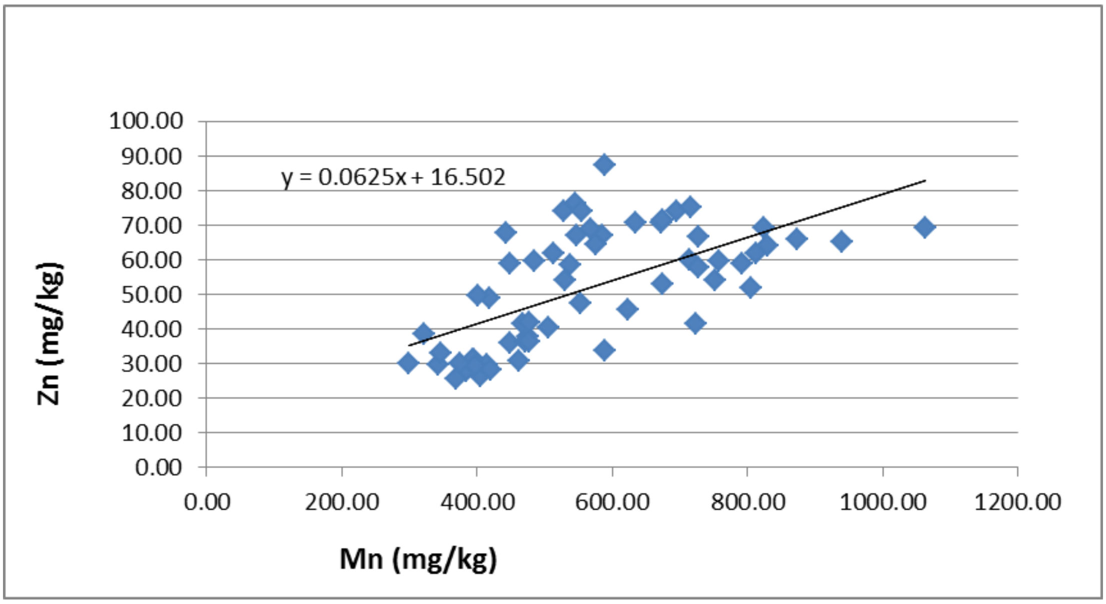


**Fig. 1. Regression analysis between zinc and manganese (mg/kg) in sediments**

**Table 11. The Pearson's correlation coefficient (*r*) between heavy metals in water and sediments**

| Metals water / sediment | Pearson's correlation coefficient (r) |
|---|---|
| **Fe / Fe** | -0.532*** |
| **Mn / Mn** | -0.2786* |
| **Cu / Cu** | -0.2404 |
| **Zn / Zn** | -0.4119** |
| **Cd / Cd** | -0.07 |
| **Pb / Pb** | -0.0694 |
| **Total metals / Total metals** | -0.5336*** |

Significance level (* P ≤ 0.05, ** P ≤ 0.01, *** P ≤ 0.001)

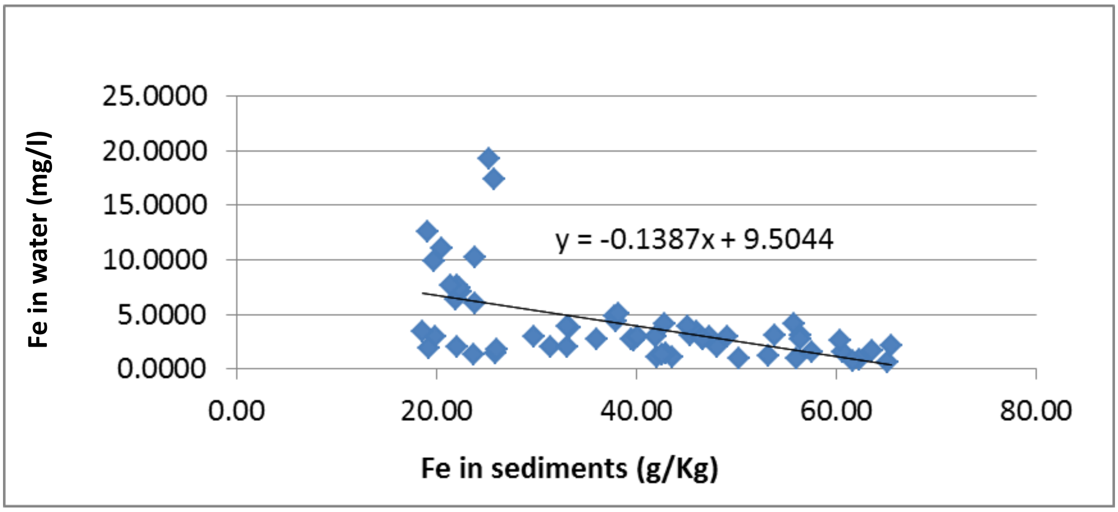


**Fig. 2. Regression analysis of iron in water (mg/l) and sediments (g/kg) according to interaction between farms and periods**

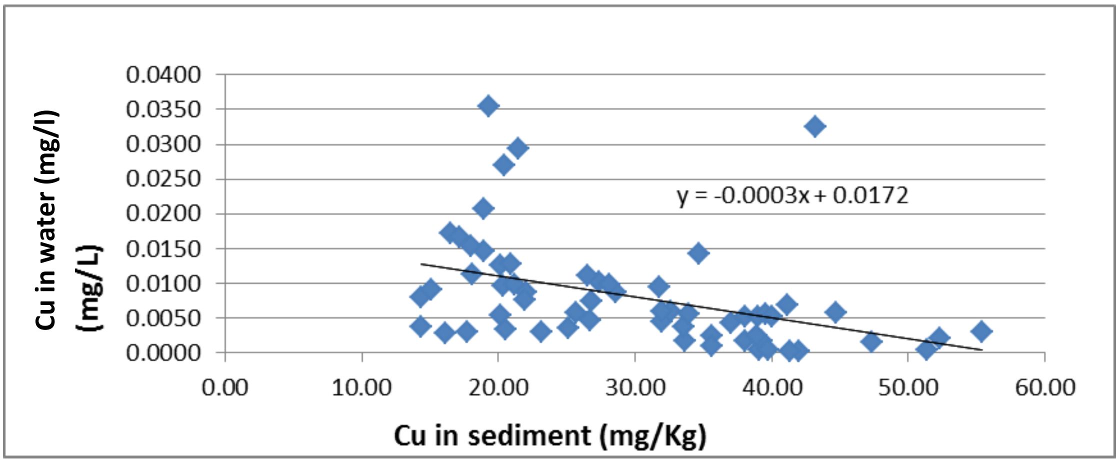


**Fig. 3. Regression analysis of cupper in water (mg/l) and sediments (mg/kg) according to interaction between farms and periods**

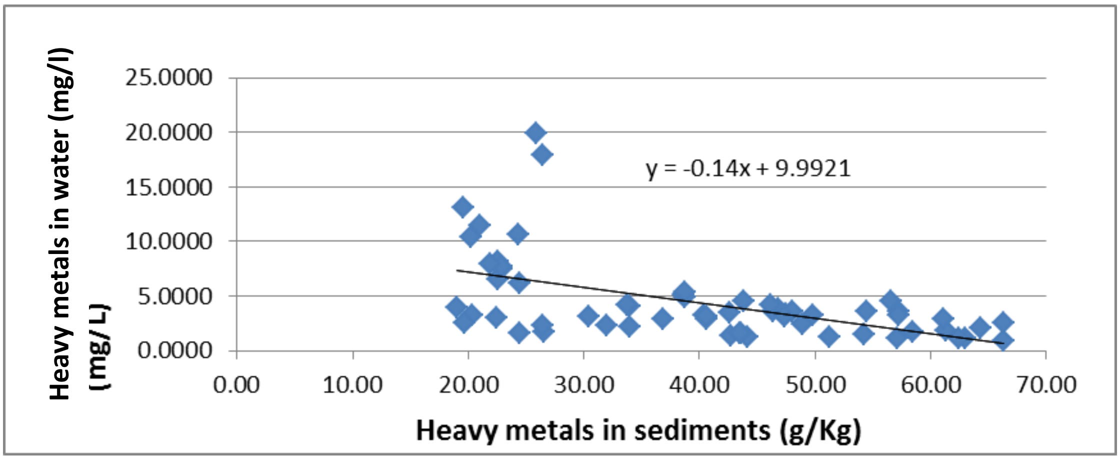


**Fig. 4. Regression analysis between total heavy metals in water (mg/l) and sediments (g/kg) according to interaction between fish farms and periods**

There was a very highly negative significant ($P \leq 0.001$) correlation between heavy metals in water and sediments for total metals. Water and sediments are commonly used as indicators for the state of pollution of aquatic ecosystem (Aremu *et al*., 2007). The negative correlations between some metals concentrations in water and sediments (Table 11) may be reflect the increase of metals in sediments as their concentrations in water decreases, and this may explain how the amount of metal accumulated in sediments related with their water content. In water, most suspended particles tend to bind metals, forming complexes then suspended particles precipitated on the bottom sediments where heavy metals accumulated (Alaoui *et al*., 1994; Yilmaz *et al*., 2007).

## Relationship between Percentage of Clay and Heavy Metals in Water and Sediments

The relationships between heavy metals in water and sediment, as a whole in this study, were tested by computing the value of the correlation coefficient (r) as shown in Table 12. The results showed that there were negative and insignificant correlations ($P > 0.05$) between percentage of clay and all studied metals Fe, Mn, Cu, Zn, Cd, Pb and total heavy metals in water, while there were positive correlations with sediments, except Pb which showed negative correlation.

From this study, it is concluded that all water sources in this study do not pose pollution with heavy metals and could be used in fish culture.

**Table 12. The Pearson's correlation coefficient (*r*) between percentage of clay in sediments and heavy metals in water and sediment**

| Metal | Pearson's correlation coefficient (r) | |
|---|---|---|
| | Water | Sediment |
| **Fe** | -0.4122 | 0.6836 |
| **Mn** | -0.4318 | 0.6709 |
| **Zn** | -0.4474 | 0.548 |
| **Cu** | -0.5594 | 0.8112 |
| **Cd** | -0.1519 | 0.196 |
| **Pb** | -0.4331 | -0.1022 |
| **Total** | -0.4235 | 0.6838 |

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# تقييـــم المعـــادن الثقيلـــة فـي ميـــاه ورســـوبيـات خمـس مـزارع سمكية تـروى بمصادر ميـــاه مختلفة

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أجريت هذه الدراسة على مياه ورسوبيات قاع أحواض خمسةً من المزارع السمكية والتى تروى بمصادر مياه مختلفة وهى:المياه الجوفية (المزرعة الأولى)، مياه الصرف الزراعى (المزرعة الثانية)، خليط من المياه الجوفية ومياه النيل (المزرعة الثالثة)، مياه الصرف الصحى من مصرف بحر البقر (المزرعة الرابعة) ومياه بحيرة المنزلة (المزرعة الخامسة) وذلك لتقييم التلوث ببعض المعادن الثقيلة (الحديد والمنجنيز والزنك والنحاس والكادميوم والرصاص) في هذه المزارع. تم تجميع عينات المياه والرسوبيات شهرياً من أبريل ٢٠١٣ حتى مارس ٢٠١٤، أظهرت النتائج أن ترتيب المتوسط السنوى لتركيز المعادن الثقيلة فى مياه المزارع المختلفة كالآتى: الأولى > الثالثة > الثانية > الرابعة > الخامسة بينما فى الرسوبيات كانت الخامسة > الرابعة > الثالثة > الثانية > الأولى، أوضح التحليلَ الإحصائيَ للبياناتِ المتحصل عليها أنّ الإختلافات بين المزارع المختلفة فى تركيز المعادن كانت عالية المعنوية، كان ترتيب تركيز المعادن الثقيلة فى المياه والرسوبيات فى الخمس مزارع السمكية كالأتى: الحديد > المنجنيز > الزنك > النحاس > الرصاص > الكادميوم ماعدا المزرعة الثالثة حيث كان الكادميوم > الرصاص، كان تركيز المعادن الثقيلة في حدود المسموح به في كل من المياه والرسوبيات، أوضح التحليلَ الإحصائيَ للبياناتِ المتحصل عليها أنّ الإختلافات بين الفترات المختلفة لجميع المعادن الثقيلة كانت عالية المعنوية فى المياه والرسوبيات، تم الحصول على أعلى قيمة لتركيز العناصر الثقيلة في المياه فى شهر فبراير بينما أظهر كلاً من شهر أبريل وأكتوبر أعلى تركيز العناصر في الرسوبيات، كان أعلى مصدر للتنوع في مجموع المعادن الثقيلة، الحديد والنحاس في المياه هو تأثير المزارع، بينما في المنجنيز، الزنك، النحاس، الكادميوم والرصاص يرجع إلى تأثير التداخل بين المزارع والفترات، كان أعلى مصدر للتنوع فى مجموع المعادن الثقيلة، الحديد، المنجنيز، الزنك، الكادميوم والرصاص في الرسوبيات هو تأثير المزارع ، بينما فى المنجنيز يرجع إلى تأثير التداخل بين المزارع والفترات، كانت هناك علاقة طردية وعالية المعنوية بين الحديد، المنجنيز والزنك فى الرسوبيات، كانت العلاقة بين المياه والرسوبيات في جميع معادن الدراسة عكسية، أوضحت الدراسة أن كل مصادر المياه المستخدمة فى هذا البحث يمكن استخدامها في عملية الإستزراع السمكي حيث أنها لا تسبب أي تلوث بالمعادن الثقيلة فى المياه وكذلك فى الرسوبيات.

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