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# POND MANAGEMENT, WATER SOURCES AND ITS IMPACT ON THE ACCUMULATION OF HEAVY METALS AND CONTAMINANTS OF MICROBIAL CONTENT IN WATER, SOIL AND FISH IN POLYCULTURE

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***Abstract***

Heavy metal pollution is one of the most serious environmental issues globally. The present study aimed to evaluate some heavy metal concentration and bacterial load in water, soil depth and some organs of Nile tilapia (*Oreochromis niloticus*) and mullet (*mugil cephulus*) reared in earthen ponds with different water sources and pond managements. The study was conducted at six fish farms distributes in three governorates in Egypt, namely as; Kafer el-Sheikh, Ismailia and Port Said, two farms each. At each governorate one farm received artificial feed and other use organic and mineral fertilization. Each farm has four ponds with an area of about two feddans and a depth of 1.25 m. The first fish farm used organic and mineral fertilizers only during the first three months and then adding the artificial feed until harvest. The second fish farm used artificial feed 25% protein only during the whole study period.

The results showed significantly increase in heavy metal levels and microbial content in water, soil and fish organs in Port Said fish farms. Also heavy metals increase in mullet (*Mugil Cephulus*) than tilapia (*Oreochromis niloticus*). Concerning fish organs, liver showed significantly increase of heavy metal levels than gills and muscles. This study concluded that water source and management processes play an important role in heavy metal accumulation in soil and fish organ and the microbial content in each different fish pond component. So, a great attention should be when use sewage wastewater to prevent the transmission of pathogenic bacteria and heavy metals from fish to humans.

**Key words:** pond management, water source, heavy metals, microbial content, tilapia, mullet, water, soil

## INTRODUCTION

Fisheries and aquaculture in Egypt are important components of the agricultural sector that serve as a great source of animal protein. Aquaculture is a real tool in increasing fish production, which is achieved through higher fish stocking density and the application of organic and inorganic fertilization and artificial. Unfortunately, the cost of feed is enormous and therefore many farmers use low cost materials such as animal manure.

Fish pond manuring is often used in fish farming for the intensification of fish production by balancing the ratio between carbon and other nutrients. The manure is directly decomposing and release nutrients that support the growth of photosynthetic organisms (phytoplankton) (Little and Edwards, 1999). Additionally, the manures were applied to produce some necessary plant nutrients which serve as a soil fertilizer by adding the organic matter (Sloan *et al.,* 2003).

Fishes have been used for many years to indicate the pollution status of water, and are thus regarded as excellent biomarkers of metals in aquatic ecosystems (Rashed, 2001a&b). The presence of toxic materials in ecosystems is presently related to increase concentration of heavy-metal ions, which enter water sources with wastewater. Heavy metals are transferred through food chains and accumulate in fish organs and by this way, they reach human.

Significant quantities of heavy metals are discharged into aquatic systems which can be strongly accumulated and biomagnified along water, sediment, and aquatic food chain, resulting in devastating effects on the ecological balance of the recipient environment and on a variety of aquatic organisms (Ben Ameur *et al.,* 2012).

Among the aquatic species, fish are the major targets of metals and bacteriological contamination. Fish are largely being used for the assessment of the quality of aquatic environment and can serve as bioindicators of environmental pollution. The accumulation of heavy metals in fish due to anthropogenic activities has become internationally an important issue, not only because of the threat to fish but also due to the health risks associated with fish consumption (Rahman *et al.*, 2012).

Bacterial load plays an important role in biological chains of fresh water pond ecosystem, and the structural diversity of the bacterial community is relevant to the prevailing conditions in this ecosystem. Fish are intimately in contact with a complex and dynamic microbial organisms. A large fraction of microorganisms adheres to fish and colonize epithelial surface. Microorganisms may cause diseases directly by damaging or traversing epithelial layers and indirectly by inducing tissue-damaging inflammatory responses (Gómez and Balcázar, 2008).

Li *et al* (2016) concluded that the special structure diversity of the bacterial community in a seawater and fresh water culture pond system. These changes suggest that attention must be paid to prevent latent disease. The microbial communities may be affected by input and circulation of nutrients and human activities. Consequently, this system requires more detailed study.

Therefore, this study aimed to evaluate the inducing impacts of pond managements and water source on heavy metals accumulation and microbial load in water, soil depth and some organs of tilapia (*Oreochromis niloticus*) and mullet (*mugil cephulus*).

## MATRIALS AND METHODS

### Experimental design:

This study was conducted in three fish farms located in Kafer el-Sheikh, Ismailia and Port Said governorates in Egypt. The first two farms located in Kafer el-Sheikh governorate and received agriculture drainage water, while the second one located in Ismailia governorate and its feed water from Ismailia Canal. The third farm group has its water supply from Baher El Bakar drains which is a mixture of agriculture drainage water (Hadous and Ramsise drainage), Sewage and industrial waste water.

Each farm has four ponds with an area of about two feddans and 1.25 m as an average water depth. The two fish farms in three governorates undergo different pond management systems. The first farm used chicken litter and mineral fertilizers' during the first three months and artificial feed 25% protein five days/week until harvest. While the second farm used artificial feed 25% only during the whole study period. The two system had been stocked with two fish species, Nile tilapia (*Oreochromis niloticus*) 16000 fish/feddan and mullet (*mugil cephulus*) 4000 fish/feddan with an initial weight 2 and 30g respectively. The experimental period was 150 days. The feed fish farm (KF) and fertilizer fish farm (KM) located in Kafr El-Sheikh governorate, the feed fish farm (IF) and fertilizer fish farm (IM) in Ismailia governorate located in El Tal El Kabeer. The feed fish farm (PF) and fertilizer fish farm (PM) in Port Said governorate located in Shader Azam area.

**Sampling and analyses:**

Water samples were taken monthly by vertical water sampler from five spot at each pond and mixed in a plastic bucket and a sample of 1 liter was placed in a polyethylene bottle, kept refrigerated and transferred cold to the laboratory for heavy metals analysis.

Surface Soil samples (0-10cm) and subsurface (10-20cm) soil samples were collected using core sampler as described in (Boyd and Tucker, 1998), then kept in cleaned plastic bags and chilled on ice box for transport to the laboratory for heavy metals determination. The soil samples were taken before the experiment as initial and after harvest of fish. In the laboratory, the soil samples were dried at 105 ºC, grinding, sieving and about (1.0 g) of the finest dried grains were digested with a mixture of conc. $H_2O_2$, HCl and $HNO_3$ as the method described in Page *et al.* (1982) and preserved in a refrigerator till analysis.

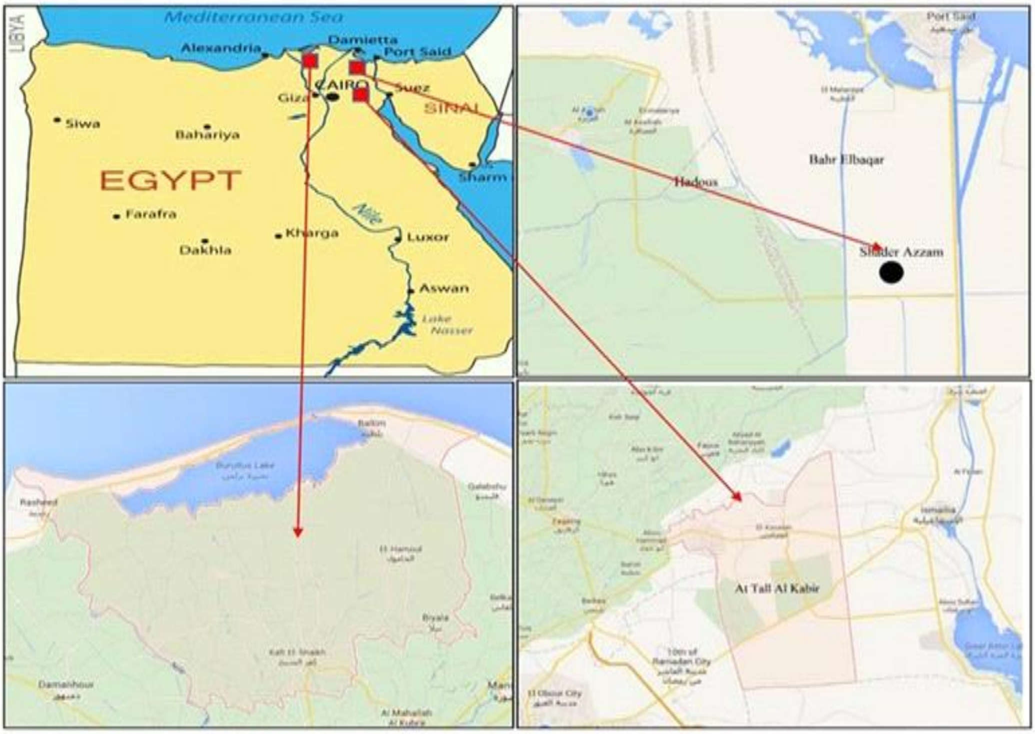


**Fig. 1.** A map showing of different fish farms in Kafr El-Sheikh; El Tal El Kabeer in Ismailia and Shader Azam in Port Saied governorates.

Heavy metals in water samples were extracted with conc. HCl and preserved in a refrigerator till analysis for $Fe^{3+}$, $Mn^{2+}$, $Zn^{2+}$, $Cu^{2+}$, $Pb^{2+}$ and $Cd^{2+}$ (Parker, 1972).

Fish samples Nile Tilapia (*Oreochromis niloticus*) and mullet (*Mugel cephalus*) after harvest were collected for heavy metals analysis. The collected fish were washed with distilled water, put in cleaned plastic bags and stored frozen until analysis carried out. About 0.5 g from wet organs (liver, gills and muscles) was dried, ignited and digested with concentrated $HNO_3$ and HCl according to procedures recommended by AOAC (2005).

Heavy metals concentrations (mg/l) in water, soil depth and fish organs were determined by atomic absorption spectrophotometer according to (Thermo

ELECTRON CORPORATION S SERIES AA Spectrometer with Gravities furnace, UK,) instrument was used to detect the heavy metals APHA (2000).

**Microbiological examination:**

For microbiological examination, the suitable number of each bacteria was reached, three different tenfold dilutions prepared from each sample are used for the enumeration of each bacteria. For total viable count, poured plate method was used according to APHA (2000). For enumeration of coli form group and E. coli, MacConkey agar was used while, Thiosulphate-Citrate-Bile-Sucrose agar (T.C.B.S) was used for vibrio cholera selective media.

**Statistical analyses:**

Two-way ANOVA was used to evaluate the significant differences of the concentration of different items studied with respect to fish farms and pond managements. A probability at level of 0.05 or less was considered significant. Standard errors were also estimated. All statistics were run on the computer, using the SAS program (SAS, 2000).

## RESULS AND DISSCIONS

Environmental pollution by toxicants has become one of the most important problems in the world (Chandran *et al.*, 2005). The heavy metal and pesticide contamination of aquatic system has attracted the attention of researchers all over the world (Dutta and Dalal, 2008) and has increased in the last decades due to extensive use of them in agricultural, chemical, and industrial processes that are becoming threats to living organisms. Fish are more frequently exposed to these pollutants because it is believed that regardless of where the pollution occurs, it will eventually end up in the aquatic environment.

Data in Table (1) and fig (2), show the average and monthly concentration of heavy metals in water during the experiment period in different fish farms under different pond management. we note that the concentration of elements increases with the study period. Also, we found that the iron concentration was higher than other elements. Port Said farm showed significantly increase in elements concentrations in waters than other locations. Also, we noted increase in the concentration of heavy metals in water of artificial feeding system than in the fertilization system. These results may be due to increase of phytoplankton in fertilizers system that led to accumulation of heavy metals. These results are in agreement with those obtained by Shaker *et al*. (2016) who reported that the phytoplankton has the ability to collect pollutants from the water and thereby reduce the concentration in water.

**Table 1.** Average values of some heavy metals ions (mg/l) in water in different fish farms during the experiment period.

| Fish farm / Metals | Kafer El-Sheik | | El Tal El Kabeer | | Shader Azam | |
|---|---|---|---|---|---|---|
| | Fertilizer fish farm | Feed fish farm | Fertilizer fish farm | Feed fish farm | Fertilizer fish farm | Feed fish farm |
| $Fe^{3+}$ | 0.4257 ±0.035$^{d}$ | 0.4830 ±0.024$^{c}$ | 0.2048 ±0.012$^{e}$ | 0.2270 ±0.011$^{e}$ | 0.6048 ±0.013$^{b}$ | 0.6420 ±0.022$^{a}$ |
| $Mn^{2+}$ | 0.0572 ±0.001$^{d}$ | 0.0660 ±0.027$^{c}$ | 0.0170 ±0.0031$^{f}$ | 0.0210 ±0.002$^{e}$ | 0.0868 ±0.0022$^{b}$ | 0.1051 ±0.0023$^{a}$ |
| $Zn^{2+}$ | 0.0605 ±0.002$^{d}$ | 0.0693 ±0.019$^{c}$ | 0.0143 ±0.0021$^{f}$ | 0.0260 ±0.0011$^{e}$ | 0.0943 ±0.0022$^{b}$ | 0.1243 ±0.014$^{a}$ |
| $Cu^{2+}$ | 0.0371 ±0.002$^{d}$ | 0.0463 ±0.017$^{c}$ | 0.0150 ±0.0014$^{f}$ | 0.0224 ±0.0011$^{e}$ | 0.0652 ±0.0031$^{b}$ | 0.0783 ±0.0023$^{a}$ |
| $Pb^{2+}$ | 0.0042 ±0.001$^{d}$ | 0.0047 ±0.0002$^{c}$ | 0.0017 ±0.0001$^{f}$ | 0.0023 ±0.0001$^{e}$ | 0.0057 ±0.0002$^{b}$ | 0.0064 ±0.0002$^{a}$ |
| $Cd^{2+}$ | 0.0027 ±0.001$^{d}$ | 0.0031 ±0.0002$^{c}$ | 0.0007 ±0.00002$^{f}$ | 0.0013 ±0.0001$^{e}$ | 0.0037 ±0.0002$^{b}$ | 0.0043 ±0.0002$^{a}$ |

Letters (a to f) show horizontal differences among fish farms under different managements. Data shown with different letters are statistically different at ($P < 0.05$) level.

The average concentrations of iron in feed system were 0.642; 0.483 and 0.227ppm in Port Said; Kafr el-Sheikh and Ismailia respectively. In fertilizer system, these values were 0.6048; 0.4257 and 0.2048ppm for the same locations respectively. The concentrations order of heavy metals were as follows: $Fe^{3+} > Zn^{2+} > Mn^{2+} > Cu^{2+} > Pb^{2+} > Cd^{2+}$.

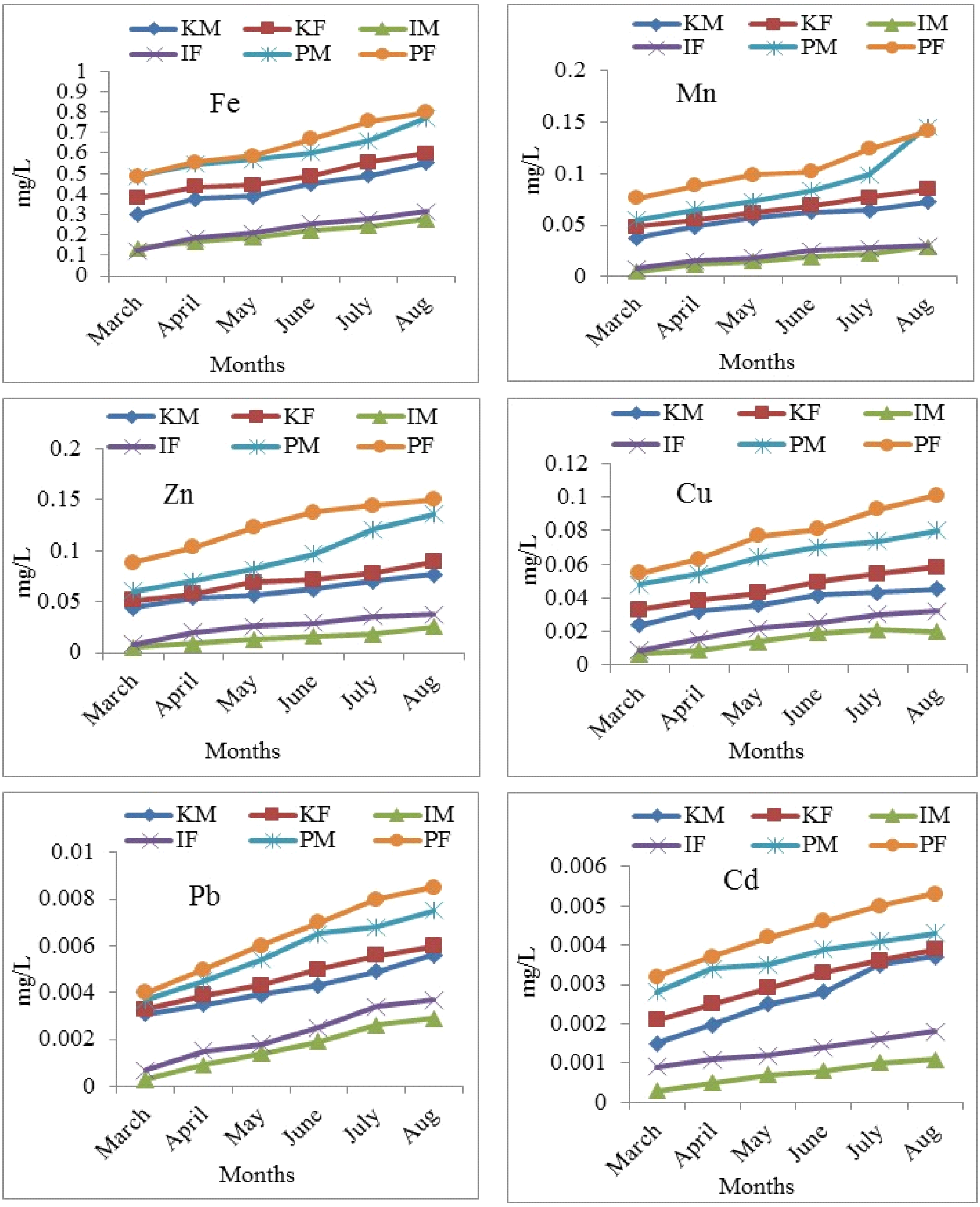


**Fig. 2.** Monthly fluctuations in some heavy metals ions concentration in three fish farms water under different pond managements during the experimental period.

Water pollution has become one of the most serious problems in Egypt, especially in Kafr El-Sheikh and Port Said, as most of the industries, untreated waste agriculture drainage and untreated sewage waste water discharge in canals. The river acts as a source of drinking water, fishing and other domestic uses for the inhabitants. In view of the activities of these industries, which discharge their untreated waste products into the river, it is necessary to investigate the level of pollution in the river.

Total heavy metals concentration in water samples from fish ponds followed the order $Fe^{3+} > Zn^{2+} > Mn^{2+} > Cu^{2+} > Pb^{2+} > Cd^{2+}$. The pollution of water in Port Said fish farms may be due to the water source of is Baher El-Bakar drain which mainly depends on sewage waste water and Ramses, Hadous drain which mainly depends on agriculture drainage water plus sewage wastewater, on the other hands Kafr El Sheikh fish farms that the primary source is agricultural agriculture drainage water mixed with sewage waste water and Ismailia fish farm depends on fresh water source from Ismailia Canal, branches from Nile River.

Table (2) shows the average concentrations of heavy metals in surface and subsurface of soil in different fish farms before and after experiment period.

Iron is generally the most abundant metal in all of the reservoirs because it is one of the most common elements in the earth's crust (Usero *et al.*, 2003). In aquatic systems, metals are transported either in solution or on the surface of suspended sediments. Due to their strong affinity for particles, metals tend to be accumulated by suspended matter or trapped immediately by bottom sediments. The heavy metals may be percolated in sediment through indirect or direct discharge of agriculture drainage and sewage waste water to the drains or from atmospheric deposition at the power plant (Demirak *et al.*, 2006).

From the results in Table (2), we find increase in the heavy metals concentration in soil in each fish farm after the experimental period. The highest accumulation of heavy metals recorded in surface layer of soil in Port Said. The accumulation of heavy metals in surface layer after the experimental period had significantly ($P<0.05$) increased than in subsurface layer of soil. Also, the accumulation of heavy metals in soil had significantly ($P<0.05$) increased in fertilizer treatments ponds than artificial feeding ponds.

The accumulation of contaminants in the soil takes the opposite trend to the concentration of pollutants in the water due to increased growth phytoplankton in fertilizer ponds. The accumulation of dead and decaying algae on the surface soil layers, leading to increase concentration of heavy elements. Increase the accumulation of heavy metals in the soil in Port Said farms than other farms result from the fact that Port Said water more polluted than water in Kafr El-Sheikh and Ismailia.

Iron had highest concentration of heavy metals in soil followed by copper, manganese, zinc, while lead and cadmium had the lowest values. Also we found that the accumulation of heavy metals in the soil increases with increasing organic matter as a result of the organic matter is working on the composition of chelating compounds with these elements. These results are in good agreement with those obtained by Shaker *et al*. (2016).

The soil can be used as an indicator of the quality of water used in fish farming in terms of the amount of pollutants as it is the main component store different of pollutants. The study suggests the accumulation of heavy metals in the soil rate as a contamination factors need more study.

Fish which lay at the top of food chain, are widely used to evaluate the health of aquatic ecosystems because pollutants build up in the food chain and reach human through fish (Farkas *et al*., 2002). The studies carried out on various fishes in both tissues and in blood have shown that heavy metals may alter the physiological activities and biochemical parameters (Alikunhi *et al*., 2016).

**Table 2.** Concentrations of some heavy metals (mg/100 g) in soil surface and sub-surface layers before and after the study period in different fish farms.

| Metals | Fe | | Mn | | Zn | | Cu | | Pb | | Cd | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Farms** | **Before** | **after** | **before** | **after** | **before** | **After** | **before** | **after** | **before** | **after** | **Before** | **After** |
| | | | | | | **Surface layers 0-10cm** | | | | | | |
| **KM** | 387.4± 22.2$^{Be}$ | 410.3± 17.6$^{Ac}$ | 17.9± 1.1$^{Bd}$ | 20.1± 1.1$^{Ac}$ | 10.93± 0.2$^{Bd}$ | 13.85± 0.3$^{Ad}$ | 28.99± 1.2$^{Bd}$ | 32.11± 1.4$^{Ad}$ | 2.34± 0.04$^{Bc}$ | 3.33± 0.03$^{Ac}$ | 1.58± 0.01$^{Bc}$ | 1.48± 0.03$^{Ac}$ |
| **IM** | 351.2± 15.3$^{Bg}$ | 373.1± 21.12$^{Ad}$ | 11.1± 0.65$^{Bf}$ | 13.3± 0.77$^{Af}$ | 8.42± 0.65$^{Be}$ | 9.18± 0.66$^{Af}$ | 15.5± 1.02$^{Bf}$ | 16.4± 1.02$^{Af}$ | 1.56± 0.03$^{Ad}$ | 1.65± 0.05$^{Ae}$ | 1.35± 0.04$^{Ac}$ | 1.42± 0.02$^{Ac}$ |
| **PF** | 785.1± 35.75$^{Bc}$ | 862.3± 38.18$^{Aa}$ | 27.5± 1.11$^{Bb}$ | 36.2± 1.36$^{Aa}$ | 19.8± 1.02$^{Bb}$ | 26.3± 1.42$^{Ab}$ | 44.5± 1.88$^{Ba}$ | 51.6± 2.37$^{Aa}$ | 5.1± 0.09$^{Ba}$ | 5.8± 0.08$^{Aa}$ | 3.7± 0.02$^{Ba}$ | 4.1± 0.05$^{Aa}$ |
| **KF** | 377.9± 11.1$^{Bf}$ | 398.8± 15.5$^{Ac}$ | 18.3± 1.2$^{Bd}$ | 19.2± 1.2$^{Ac}$ | 11.7± 0.1$^{Bd}$ | 12.4± 0.2$^{Ad}$ | 25.4± 1.5$^{Be}$ | 29.2± 1.6$^{Ad}$ | 2.55± 0.04$^{Bc}$ | 2.79± 0.03$^{Ad}$ | 1.14± 0.02$^{Bd}$ | 1.28± 0.01$^{Ad}$ |
| **IF** | 355.4± 14.02$^{Bg}$ | 363.4± 5.55$^{Ad}$ | 28.2± 1.04$^{Ba}$ | 30.1± 1.22$^{Ab}$ | 18.7± 1.04$^{Bc}$ | 21.2± 0.88$^{Ac}$ | 40.5± 2.12$^{Bc}$ | 43.1± 2.15$^{Ac}$ | 2.55± 0.03Ac | 2.62± 0.03$^{Ad}$ | 1.2± 0.01$^{Ad}$ | 1.26± 0.01$^{Ad}$ |
| **PF** | 776.4± 26.88$^{Bd}$ | 815.6± 25.55$^{Ab}$ | 27.1± 1.22$^{Bc}$ | 30.5± 1.26$^{Ab}$ | 20.3± 0.77$^{Bb}$ | 22.5± 0.75$^{Ac}$ | 45.1± 2.25$^{Ba}$ | 47.7± 2.25$^{Ab}$ | 4.9± 0.05$^{Ba}$ | 5.2± 0.06Ab | 3.7± 0.05$^{Aa}$ | 3.8± 0.04$^{Ab}$ |
| | | | | | | **Sub surface layers 10-20cm** | | | | | | |
| **KM** | 377.2± 11.3$^{bf}$ | 391.3± 15.1$^{Ac}$ | 17.2± 1.2$^{Bd}$ | 18.7± 1.2$^{Ad}$ | 10.3± 0.1$^{Bd}$ | 11.4± 0.1$^{Ae}$ | 27.5± 1.2$^{Bd}$ | 29.8± 1.3$^{Ad}$ | 2.35± 0.03$^{Bc}$ | 2.77± 0.02$^{Ad}$ | 1.17± 0.01$^{Bd}$ | 1.35± 0.02$^{Ac}$ |
| **IM** | 352.6± 13.26$^{Bg}$ | 369.2± 18.7$^{Ad}$ | 11.2± 0.44$^{Bf}$ | 13.1± 0.35$^{Af}$ | 8.1± 0.12$^{Bf}$ | 8.75± 0.13$^{Af}$ | 14.9± 0.77$^{Bf}$ | 15.5± 0.67$^{Af}$ | 1.42± 0.02$^{Bd}$ | 1.55± 0.02$^{Ae}$ | 3.65± 0.03$^{Ba}$ | 4.15± 0.04$^{Aa}$ |
| **PM** | 801± 3.22$^{Bb}$ | 857.2± 35.48$^{Aa}$ | 27.1± 1.12$^{Bc}$ | 35.5± 2.11$^{Aa}$ | 21.2± 1.04$^{Ba}$ | 28.5± 1.72$^{Aa}$ | 42.8± 2.45$^{Bb}$ | 47.7± 2.36$^{Ab}$ | 4.9± 0.04$^{Ba}$ | 5.2± 0.04$^{Ab}$ | 3.65± 0.02$^{Ba}$ | 4.2± 0.03$^{Aa}$ |
| **KF** | 371.1± 10.5$^{bf}$ | 283.4± 12.2$^{Af}$ | 16.3± 1.1$^{Be}$ | 17.7± 1.1$^{Ad}$ | 9.7± 0.1B$^{e}$ | 10.3± 0.1$^{Ae}$ | 25.3± 1.5$^{Be}$ | 26.5 ± 1.3$^{Ae}$ | 2.33± 0.02$^{Bc}$ | 2.47± 0.02$^{Ad}$ | 1.1± 0.01$^{Bd}$ | 1.25± 0.01$^{Ad}$ |
| **IF** | 345.5± 12.25$^{Bh}$ | 354.2± 1.22Ae | 10.4± 0.08$^{Bf}$ | 11.1± 0.06$^{Af}$ | 7.9± 0.06$^{Bf}$ | 8.23± 0.11$^{Af}$ | 13.3± 0.11$^{Ag}$ | 13.8± 0.12$^{Ag}$ | 1.35± 0.02$^{Ad}$ | 1.42± 0.02$^{Ae}$ | 3.55± 0.03$^{Ab}$ | 3.62± 0.04$^{Ab}$ |
| **PF** | 814± 15.75$^{Ba}$ | 837± 26.78$^{Ab}$ | 27.7± 1.02$^{Bb}$ | 30.3± 1.1$^{Ab}$ | 20.9± 0.88$^{Ba}$ | 23.2± 1.04$^{Ac}$ | 43.4± 2.23$^{Bb}$ | 45.1± 2.25$^{Ac}$ | 4.75± 0.03$^{Ab}$ | 4.88± 0.04$^{Ab}$ | 3.75± 0.04$^{Aa}$ | 3.85± 0.04$^{Ab}$ |

Letters (a to h) show vertical differences among fish farms under different managements in the same metal. Data shown with different letters are statistically different at ($P < 0.05$) level.

Data in Table (3), show average the values of heavy metals concentrations (mg/g dry wt) in different tissues of Nile tilapia and Mullet at different fish farms. Heavy metals are among the most hazardous metals that could be bio-accumulated in a habitat. The fact that they increase in values by passing from lower to higher organisms, is even more disturbing. The liver is the center of the compilation of pollutants followed by gills in each fish species in this experiment. Also, mullet accumulates higher levels of heavy elements than the Nile tilapia. The accumulations of heavy metals in fish under fertilization system were significantly higher than artificial feeding system. The average vales of $Fe^{3+}$ in liver of Tilapia were 834; 747; 284; 197; 914 and 832 mg/g dry wt for KM; KF; IM; IF; PM and PF respectively, while the average vales of $Fe^{3+}$ in mullet liver were 2355; 1890; 425; 227; 2892 and 2214 mg/g dry wt for the same fish farms respectively. These results clear that the highest accumulation of $Fe^{3+}$ in liver of Mullet and Tilapia recorded in Port Said farms followed by Kafr el-Sheikh farms and Ismailia farms respectively. Also, the accumulation of $Fe^{3+}$ in liver of Mullet and Tilapia were significantly ($P < 0.05$) increased in fertilizer system than in artificial feed.

$Fe^{3+}$ concentrations were significantly ($P<0.05$) increased than others metal at all fish farms. The average concentrations of heavy metals were gradually increased with increasing period at the farms during the experimental period (fig.2).

The accumulation of heavy metals ions in liver and gills had significantly ($P<0.05$) increase that of muscles. The accumulation of heavy metals in fertilizers fish ponds had significantly ($P<0.05$) increase that of artificial feeding ponds. These results are in good agreement with those obtained by Shaker *et al.* (2015; 2016). Overall, we noted that the concentration of heavy metals in different fish species were lie within the permissible limits.

Vinodhini and Narayanan (2008) reported that the liver accumulates relatively higher amounts of heavy metal ions. Muscles are one of the ultimate parts for heavy metal ions accumulation. The heavy metal ions were uniformly spread over the body muscles. Hence, the observed values were relatively lower than the other potential organs.

**Table 3.** Average values (mean ± SE) of some heavy metal ions concentrations (mg/g dry wt) in different tissues of Nile tilapia and Mullet at different fish farms.

| Manag. | Fish species | Fish organs | $Fe^{3+}$ | $Mn^{2+}$ | $Zn^{2+}$ | $Cu^{2+}$ | $Pb^{2+}$ | $Cd^{2+}$ |
|---|---|---|---|---|---|---|---|---|
| KM | Tilapia | Liver | 834±57[c] | 33.5±0.9[c] | 97.9±5.5[c] | 77.2±3.6[c] | 3.45±0.013[c] | 2.34±0.003[c] |
| | | Gilles | 636±34[c] | 27.9±1.3[c] | 73.5±4.8[d] | 62.3±.1.7[c] | 2.74±0.002[d] | 1.65±0.003[d] |
| | | Muscles | 101±6[d] | 14.4±0.4[e] | 20.8±1.3[e] | 19.5±1.1[e] | 0.66±0.001[e] | 0.45±0.001[e] |
| | Mullet | Liver | 2355±126[a] | 44.8±1.7a | 133.6±5.3[d] | 119.9±3.5[a] | 5.4±0.014[a] | 3.72±0.004[a] |
| | | Gilles | 1445±56[b] | 36.1±1.2[b] | 120.2±5.4[b] | 91.3±2.3[b] | 4.3±0.011[b] | 2.97±0.004[a] |
| | | Muscles | 174±13[d] | 17.7±0.7 [d] | 27.4±0.63e | 30.2±1.3e | 0.87±0.001[e] | 0.59±0.001[e] |
| KF | Tilapia | Liver | 747±44[c] | 23.7±0.5[d] | 80.4 ±4.5[d] | 68.8±3.5[c] | 2.88±0.003[c] | 2.02±0.003[c] |
| | | Gilles | 569±31[c] | 19.9±0.6[e] | 63.7± 3.3[d] | 52.7±3.7[d] | 2.1±0.002[d] | 1.21± 0.01[d] |
| | | Muscles | 81±5[d] | 10.1± 0.2[e] | 15.5 ± 0.5[e] | 14.5±0.6[e] | 0.37±0.001[e] | 0.29± 0.001 |
| | Mullet | Liver | 1890±113[a] | 36.9±2.5[b] | 117.5±7.5[b] | 98.7±1.2[a] | 4.92 ± 0.35[a] | 3.33 ± 0.02[a] |
| | | Gilles | 1202±47[b] | 29.5±1.1[bc] | 97.3±4.3[c] | 79.4±1.1[c] | 3.77±0.017[b] | 2.41 ±0.11[b] |
| | | Muscles | 129.5±10 | 13.3±0.4[e] | 21.1 ± 0.6[e] | 22.6±0.7[e] | 0.55±0.001[e] | 0.37±0.001[e] |
| IM | Tilapia | Liver | 284±0.01[e] | 21.1±0.01[e] | 27.7±0.01[e] | 31.1±0.01[e] | 1.77±0.001[e] | 1.13±0.001[e] |
| | | Gilles | 171±0.01[e] | 17.5±0.01[e] | 23.8±0.01[e] | 26.5±0.01[e] | 1.37±0.001[e] | 0.87±0.001[e] |
| | | Muscles | 41.5±0.01[e] | 9.2±0.01[e] | 14.4±0.01[e] | 17.1±0.01[e] | 0.38±0.001[e] | 0.25±0.001[e] |
| | Mullet | Liver | 425±0.01[e] | 29.9±0.01[e] | 36.2±0.01[e] | 39.1±0.01[e] | 2.81±0.001[e] | 1.56±0.001[e] |
| | | Gilles | 261±0.01[e] | 20.3±0.01[e] | 27.1±0.01[e] | 29.8±0.01[e] | 1.65±0.001[e] | 1.02±0.001[e] |
| | | Muscles | 59.2±0.01[e] | 10.7±0.01[e] | 16.3±0.01[e] | 18.9±0.01[e] | 0.47±0.001[e] | 0.33±0.001[e] |
| IF | Tilapia | Liver | 197±0.01[e] | 17.5±0.01[e] | 21.8±0.01[e] | 24.5±0.01[e] | 1.55±0.001[e] | 0.94±0.001[e] |
| | | Gilles | 114±0.01[e] | 13.7±0.01[e] | 18.4±0.01[e] | 20.9±0.01[e] | 1.07±0.001[e] | 0.71±0.001[e] |
| | | Muscles | 28.5±0.01[e] | 7.7±0.01[e] | 11.3±0.01[e] | 13.7±0.01[e] | 0.28±0.001[e] | 0.21±0.001[e] |
| | Mullet | Liver | 227±0.01[e] | 21.5±0.01[e] | 25.6±0.01[e] | 28.1±0.01[e] | 2.27±0.001[e] | 1.13±0.001[e] |
| | | Gilles | 143±0.01[e] | 15.6±0.01[e] | 19.4±0.01[e] | 21.8±0.01[e] | 1.09±0.001[e] | 0.78±0.001[e] |
| | | Muscles | 40.4±0.01[e] | 8.9±0.01[e] | 13.2±0.01[e] | 15.7±0.01[e] | 0.36±0.001[e] | 0.21±0.001[e] |
| PM | Tilapia | Liver | 914±57[c] | 44.3±1.4[c] | 97.9±5.5[c] | 77.2±3.6[c] | 3.45±0.013[c] | 2.34±0.003[c] |
| | | Gilles | 7011±34[c] | 32.1±1.2[c] | 73.5±4.8[d] | 62.3±.1.7[c] | 2.74±0.002[d] | 1.65±0.003[d] |
| | | Muscles | 127±6[d] | 20.6±0.8[e] | 20.8±1.3[e] | 19.5±1.1[e] | 0.66±0.001[e] | 0.45±0.001[e] |
| | Mullet | Liver | 2892±126[a] | 57.9±1.9a | 133.6±5.3[d] | 119.9±3.5[a] | 5.4±0.014[a] | 3.72±0.004[a] |
| | | Gilles | 1755±56[b] | 44.7±2.7[b] | 120.2±5.4[b] | 91.3±2.3[b] | 4.3±0.011[b] | 2.97±0.004[a] |
| | | Muscles | 214±13[d] | 23.4±1.3[d] | 27.4±0.63e | 30.2±1.3e | 0.87±0.001[e] | 0.59±0.001[e] |
| PF | Tilapia | Liver | 832±44[c] | 31.7±1.4[d] | 80.4 ±4.5[d] | 68.8±3.5[c] | 2.88±0.003[c] | 2.02±0.003[c] |
| | | Gilles | 641±31[c] | 26.2±0.9[e] | 63.7± 3.3[d] | 52.7±3.7[d] | 2.1±0.002[d] | 1.21± 0.01[d] |
| | | Muscles | 97.2±5[d] | 15.1± 0.4[e] | 15.5 ± 0.5[e] | 14.5±0.6[e] | 0.37±0.001[e] | 0.29± 0.001 |
| | Mullet | Liver | 2214±113[a] | 34.8±2.1[b] | 117.5±7.5[b] | 98.7±1.2[a] | 4.92 ± 0.35[a] | 3.33 ± 0.02[a] |
| | | Gilles | 1407±47[b] | 27.1±1.7[bc] | 97.3±4.3[c] | 79.4±1.1[c] | 3.77±0.017[b] | 2.41 ± 0.11[b] |
| | | Muscles | 173.1±10 | 15.2±0.7[e] | 21.1 ± 0.6[e] | 22.6±0.7[e] | 0.55±0.001[e] | 0.37±0.001[e] |

Letters (a to f) show vertical differences among fish farms under different managements. Data shown with different letters are statistically different at ($P < 0.05$) level.

Aquatic organisms have been reported to accumulate trace metals in their tissues several times above ambient levels (Canli and Atli, 2003).

Fish is considered a good indicator of the vital water contamination with heavy metals and pathogenic bacteria. Metals transferred through aquatic food webs are of environmental and human health concern. Ingestion of fish, which is one of aquatic products that humans consume, is an obvious means of exposure to metals because they accumulate substantial amounts of them in their tissues, especially in the muscles, and thus they represent a major dietary source of metal for general population (Castro-González and MéndezArmenta, 2008).

The pollution of water in Port Said fish farms increase as Baher El-Bakar drain is the main source of water, which mainly depends on sewage waste water besides Ramses. Hadous drains which mainly depends on agriculture drainage water with sewage wastewater. While, Kafr El Sheikh fish farms that the primary source is agricultural agriculture drainage water mixed with sewage waste water.

Data presented in Table (4) show the average numbers of total bacterial count, coli form group and fecal coliform (*E. coli*) in water and soil depth. While data in Table (5) show the bacterial load in tilapia and mullet from different fish farms under different pond managements. The presented data clear that the average numbers of total bacterial count, coli form group and fecal coliform (*E. coli*) in water, soil and fish species were depending on water sources, pond managements and correlated with the bacterial levels in the aquatic environment. These results are good in agreement with Alikunhi *et al*. (2016).

The primary sources of microbial pathogens in fish are anthropogenic activities that generate point and non-point pollution in coastal waters. Also, there are naturally occurring waterborne pathogens like vibrio that could cause human illness by way of food consumption. Hence, the monitoring of bacterial pathogens potentially provides early warning to safeguard seafood consumers from the threats of contamination.

Bacterial abundance in fish species generally varies based on environmental and biological factors. Some fishes are inherently more prone to contamination depending on the species, feeding pattern, age, size, harvest season, habitat characteristics, and geographical location (Novotny *et al.*, 2004). Hence, studies on bacterial abundance in fish should be made at a larger spatial scale, considering the potential differences in susceptibility to contamination

**Table 4.** Average numbers of total bacterial count, coli form group and fecal coliform (E. coli) in water; surface and subsurface soil at different fish farm.

| Fish farm / Items | KM | KF | IM | IF | SM | SF |
|---|---|---|---|---|---|---|
| **Water** | | | | | | |
| T. count | $477.6\times10^{4}$ ±$14.23^{Cb}$ | $355.3\times10^{4}$ ±$11.36^{Db}$ | $78.3\text{x}10^{4}$ ±$6.55^{Ec}$ | $55.9\text{x}10^{4}$ ±$3.22^{Fb}$ | $338.5\text{x}10^{5}$ ±$2.11^{Ac}$ | $221.3\text{x}10^{5}$ ±$2.45^{Bc}$ |
| fecal coliform | $117\times10^{4}$ ±$3.33^{Bc}$ | $97.1\times10^{4}$ ±$2.21^{Cc}$ | $41.8\text{x}10^{3}$ ±$1.26^{De}$ | $33.9\text{x}10^{3}$ ±$1.14^{Dd}$ | $155.7\text{x}10^{4}$ ±$3.35^{Ae}$ | $115.1\text{x}10^{4}$ ±$2.11^{Be}$ |
| *E. coli* | $67\times10^{3}$ ±$2.16^{Be}$ | $57.5\times10^{3}$ ±$1.23^{Ce}$ | $12.5\text{x}10^{3}$ ±$0.45^{Df}$ | $15.4\text{x}10^{2}$ ±$0.33^{Df}$ | $71.9\text{x}10^{3}$ ±$2.17^{Ag}$ | $66.8\text{x}10^{3}$ ±$1.35^{Bg}$ |
| **Soil Surface 0-10cm** | | | | | | |
| T. count | $137.7\times10^{5}$ ±$7.11^{Ca}$ | $101.4\text{x}10^{5}$ ±$3.99^{Ca}$ | $135\text{x}10^{4}$ ±$3.99^{Da}$ | $99.7\text{x}10^{4}$ ±$4.42^{Da}$ | $525.1\text{x}10^{6}$ ±$11.66^{Aa}$ | $457.1\text{x}10^{6}$ ±$11.16^{Ba}$ |
| fecal coliform | $77\times10^{4}$ ±$2.19^{Cd}$ | $61.3\text{x}10^{4}$ ±1.98Dd | $82.1\text{x}10^{3}$ ±1.88Cd | $56.7\text{x}10^{3}$ ±3.06Dc | $273.4\text{x}10^{4}$ ±7.21Ad | $204.8\text{x}10^{4}$ ±3.44Bd |
| *E. coli* | $67\times10^{3}$ ±$2.28^{Ce}$ | $46.4\text{x}10^{3}$ ±$1.79^{Df}$ | $35\text{x}10^{2}$ ±$0.77^{Eg}$ | $22.4\text{x}10^{2}$ ±$1.09^{Ff}$ | $169\text{x}10^{3}$ ±$12.26^{Af}$ | $153.2\text{x}10^{3}$ ±$4.26^{Bf}$ |
| **Soil Subsurface 10-20cm** | | | | | | |
| T. count | $105.7\times10^{5}$ ±$5.55^{Ca}$ | $86.7\text{x}10^{5}$ ±$2.77^{Da}$ | $103\text{x}10^{4}$ ±$4.17^{Cb}$ | $85.4\text{x}10^{4}$ ±$2.19^{Da}$ | $421.3\text{x}10^{5}$ ±$13.33^{Ab}$ | $371.3\text{x}10^{5}$ ±$7.13^{Bb}$ |
| fecal coliform | $63.2\times10^{4}$ ±$3.33^{Dd}$ | $57.1\text{x}10^{4}$ ±$2.28^{Dd}$ | $78.9\text{x}10^{3}$ ±$3.24^{Cd}$ | $61.1\text{x}10^{3}$ ±$5.32^{Dc}$ | $198.9\text{x}10^{4}$ ±$6.77^{Ae}$ | $141.7\text{x}10^{4}$ ±$3.17^{Be}$ |
| *E. coli* | $53.5\times10^{3}$ ±$2.18^{Ce}$ | $44.9\text{x}10^{3}$ ±$1.02^{Cf}$ | $17.8\text{x}10^{3}$ ±$0.77^{Df}$ | $11.6\text{x}10^{3}$ ±$0.33^{De}$ | $101.4\text{x}10^{3}$ ±$2.11^{Ag}$ | $85.7\text{x}10^{3}$ ±$3.22^{Bg}$ |

Letters (A to F) show vertical differences among T.C; C.F and E.C in water; surface and subsurface soil at the same fish farms. (a to g) show horizontal different among different fish farms under different managements. Data shown with different letters are statistically different at $P < 0.05$ level.

**Table 5.** Average numbers of total bacterial count, coliform group and fecal coliform (E. coli) in tilapia and mullet from different fish farm.

| Fish species | Fish organs | Items | KM | KF | IM | IF | PM | PF |
|---|---|---|---|---|---|---|---|---|
| Tilapia | Skin | T. count | 255.3x10$^{6}$ ±10.1$^{Bb}$ | 103x10$^{6}$ ±6.7$^{Bc}$ | 231x10$^{5}$ ±9.7$^{Bd}$ | 91.1x10$^{5}$ ±5.7$^{Ce}$ | 347.1x10$^{6}$ ±14.66$^{Ba}$ | 301.1x10$^{6}$ ±12.16$^{Ba}$ |
| | | fecal coliform | 111.2x10$^{4}$ ±5.4$^{Db}$ | 101x10$^{4}$ ±4.4$^{Db}$ | 57.1x10$^{3}$ ±2.4$^{Dc}$ | 33.3x10$^{3}$ ±1.5$^{Ec}$ | 177.4x10$^{4}$ ±9.21$^{Ea}$ | 113.8x10$^{4}$ ±4.44$^{Ea}$ |
| | | *E. coli* | 57.7x10$^{3}$ ±2.9$^{Ea}$ | 29x10$^{3}$ ±0.1$^{Eb}$ | 11x10$^{3}$ ±0.2$^{Dc}$ | 27.7x10$^{2}$ ±1.8$^{Fb}$ | 84.7x10$^{3}$ ±7.26Fa | 73.2x10$^{3}$ ±6.26Fa |
| | Gills | T. count | 315.2x10$^{6}$ ±12.6$^{Ab}$ | 277x10$^{6}$ ±11.8$^{Ac}$ | 266.5x10$^{5}$ ±10.2$^{Bd}$ | 177.4x10$^{5}$ ±8.8$^{Be}$ | 456.3x10$^{6}$ ±13.66$^{Aa}$ | 411.7x10$^{6}$ ±13.16$^{Aa}$ |
| | | fecal coliform | 141.8x10$^{4}$ ±6.3$^{Da}$ | 117.1x10$^{4}$ ±1.8$^{Db}$ | 55.6x10$^{3}$ ±2.1$^{Dc}$ | 30.3x10$^{3}$ ±2.1$^{Ec}$ | 187.9x10$^{4}$ ±11.21$^{Ea}$ | 157.7x10$^{4}$ ±6.44$^{Ea}$ |
| | | *E. coli* | 55.3x10$^{3}$ ±1.6$^{Eb}$ | 30.1x10$^{3}$ ±0.2$^{Ec}$ | 11.2x10$^{3}$ ±0.4$^{Dd}$ | 33.3x10$^{3}$ ±1.8$^{Ec}$ | 87.02x10$^{3}$ ±5.26$^{Fa}$ | 63.2x10$^{3}$ ±3.03$^{Fb}$ |
| | Muscles | T. count | 77.6x10$^{5}$ ±3.4$^{Cb}$ | 58.4x10$^{5}$ ±1.4$^{Cb}$ | 111.1x10$^{4}$ ±0.9$^{Cc}$ | 77.9x10$^{4}$ ±3.3$^{Dc}$ | 177.7x10$^{5}$ ±11.66$^{Da}$ | 155.9x10$^{5}$ ±9.02$^{Da}$ |
| | | fecal coliform | 102.3x10$^{3}$ ±7.2$^{Eb}$ | 87.9x10$^{3}$ ±2.8$^{Eb}$ | 77.2x10$^{2}$ ±0.6$^{Ec}$ | 66.7x10$^{2}$ ±2.5$^{Fc}$ | 117.9x10$^{4}$ ±7.21$^{Ea}$ | 101.7x10$^{4}$ ±8.04$^{Ea}$ |
| | | *E. coli* | 88.7x10$^{3}$ ±5.7$^{Eb}$ | 71.1x10$^{3}$ ±2.6$^{Ec}$ | 41.1x10$^{2}$ ±0.2$^{Ed}$ | 26.2x10$^{2}$ ±1.1$^{Fe}$ | 111.1x10$^{3}$ ±2.06$^{Fa}$ | 91.5x10$^{3}$ ±1.2$^{Fb}$ |
| Mullet | Skin | T. count | 346.4x10$^{6}$ ±15.9$^{Ab}$ | 299.7x10$^{6}$ ±10.8$^{Ac}$ | 357.1x10$^{5}$ ±16.7$^{Ad}$ | 310.2x10$^{5}$ ±9.7$^{Ae}$ | 477.9x10$^{6}$ ±14.66$^{Aa}$ | 426.3x10$^{6}$ ±12.16$^{Aa}$ |
| | | fecal coliform | 171x10$^{4}$ ±8.9$^{Dc}$ | 151x10$^{4}$ ±5.4$^{Dd}$ | 88.2x10$^{3}$ ±4.4$^{De}$ | 55.7x10$^{3}$ ±2.7$^{Ef}$ | 286.5x10$^{4}$ ±9.21$^{Ea}$ | 203.3x10$^{4}$ ±4.44$^{Eb}$ |
| | | *E. coli* | 71.2x10$^{3}$ ±3.5$^{Ec}$ | 55.4x10$^{3}$ ±1.6$^{Ed}$ | 33.3x10$^{3}$ ±0.3$^{De}$ | 30.5x10$^{2}$ ±1.3$^{Fe}$ | 102.3x10$^{3}$ ±7.26$^{Fa}$ | 89.7x10$^{3}$ ±6.26$^{Fb}$ |
| | Gills | T. count | 387.4x10$^{6}$ ±12.8$^{Ab}$ | 314.2x10$^{6}$ ±12.4$^{Ac}$ | 402.2x10$^{5}$ ±15.7$^{Ad}$ | 319.2x10$^{5}$ ±11.8$^{Ae}$ | 535.3x10$^{6}$ ±14.66$^{Aa}$ | 501.1x10$^{6}$ ±12.16$^{Aa}$ |
| | | fecal coliform | 181.1x10$^{4}$ ±1.1$^{Dc}$ | 165x10$^{4}$ ±8.4$^{Dd}$ | 98.2x10$^{3}$ ±5.6$^{De}$ | 65.7x10$^{3}$ ±3.7$^{Ef}$ | 299.5x10$^{4}$ ±9.21$^{Ea}$ | 217.3x10$^{4}$ ±4.44$^{Eb}$ |
| | | *E. coli* | 77.5x10$^{3}$ ±3.5$^{Ec}$ | 59.5x10$^{3}$ ±1.1$^{Ed}$ | 37.3x10$^{3}$ ±1.4$^{De}$ | 33.3x10$^{2}$ ±1.5$^{Ff}$ | 111.5x10$^{3}$ ±7.26$^{Fa}$ | 92.3x10$^{3}$ ±6.26$^{Fb}$ |
| | Muscles | T. count | 75.1x10$^{5}$ ±4.1$^{Cb}$ | 51.2x10$^{5}$ ±1.3$^{Cc}$ | 99.1x10$^{4}$ ±4.3$^{Cd}$ | 63.9x10$^{4}$ ±3.2$^{De}$ | 147.7x10$^{6}$ ±14.66$^{Ca}$ | 133.3x10$^{6}$ ±9.16$^{Ca}$ |
| | | fecal coliform | 72.7x10$^{3}$ ±4.8$^{Eb}$ | 69.3x10$^{3}$ ±1.9$^{Eb}$ | 51.5x10$^{2}$ ±1.8$^{Ec}$ | 43.4x10$^{2}$ ±2.8$^{Fc}$ | 101.7x10$^{4}$ ±12.21$^{Ea}$ | 97.7x10$^{4}$ ±8.44$^{Ea}$ |
| | | *E. coli* | 61.2x10$^{3}$ ±3.4$^{Eb}$ | 55.3x10$^{3}$ ±3.4$^{Ec}$ | 38.9x10$^{2}$ ±1.4$^{Ed}$ | 26.2x10$^{2}$ ±1.7$^{Fe}$ | 79.5x10$^{3}$ ±5.26$^{Fa}$ | 65.5x10$^{3}$ ±4.26$^{Fb}$ |

Letters (A to F) show vertical differences among T.C; C.F and E.C in water and surface and subsurface soil in the same fish farms. (a to f) show horizontal among differences fish farms under different managements. Data shown with different letters are statistically different at $P < 0.05$ level.

The Average numbers of total bacterial count, coli form group and fecal coliform (*E. coli*) in water, soil, mullet and tilapia were significantly increased ($P<0.05$) at Port Said fish farms than other fish farms. Also, fertilized fish farms significantly increase ($P<0.05$) that of artificial feed fish farm. The average numbers of total bacterial count, coli form group and fecal coliform (*E. coli*) in skin in each fish species were significantly ($P<0.05$) increased than gills and muscles. The lowest number of total bacterial count, coli form group and fecal coliform (*E. coli*) recorded in muscles in each fish species.

Elsaidy *et al.* (2015) found that the TBC and TCC were significantly high in water and fish samples raised at chicken manure ponds followed by fermented chicken manure ponds in comparison with FR. They added that the pathogenic bacteria in water and fish are depending on stocking density and ammonia concentration.

From this study, it appears that the pond water in Port Said were highly contaminated with pathogenic bacteria. The fish samples analyzed thus constitute a health risk for consumers, especially those who eat raw or insufficiently cooked fish. So, fish culture in these pond must be prevented.

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# إدارة الأحواض، مصادر المياه وأثرهما على تراكم المعادن الثقيلة والمحتوى الميكروبي في المياه والتربة والأسماك في الأستزراع المختلط

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*[1،2] المعمل المركزي لبحوث الثروه السمكية- مركز البحوث الزراعية – أبو حماد – شرقيه.*

## الملخـــص العربــــي

أجريت الدراسة في ثلاث محافظات هي كفر الشيخ - الإسماعيلية وبورسعيد وأستخدم في كل منها مزرعتين كل منها أربعة أحواض مساحة الحوض ٢ فدان .المزرعه الأولى تعتمد على التسميد العضوى والمعدني طوال الموسم إلا فى أخر شهر يتم إستخدام الأعلاف الصناعية والمزرعة الثانية تعتمد على العلف الصناعي فقط طوال الموسم و الأعلاف الصناعية المستخدمة ٢٥٪ بروتين. أستمرت الدراسة ١٥٠ يوم. أستزرعت جميع الأحواض بأصبعيات بلطي نيلي وأصبعيات بوري بنفس الحجم. تم تجميع عينات التربة قبل وبعد إنتهاء الدراسة بينما جمعت عينات المياة و الأسماك شهرياً لتقدير تركيزعناصر الثقيلة والمحتوى الميكروبي بها، وكانت أهم النتائج المتحصل عليها :

زيادة معنوية فى تركيز العناصر الثقيلة بالمياة مع زيادة وقت الدراسة من شهر لأخر.

زيادة معنوية فى تركيز العناصر الثقيلة فى المياة فى معاملات التغذية الصناعية عنها فى معاملات التسميد.

زيادة معنوية فى تركيز العناصر الثقيلة فى مزارع بورسعيد المياة والتربة والأسماك عن باقي المزارع.

زيادة معنوية فى تركيز العناصر الثقيلة فى تربة ومياة كفر الشيخ عن الإسماعيلية.

زيادة معنوية فى تركيز العناصر الثقيلة فى تربة وأسماك المزارع التى تعتمد على التسميد عن الأخرى.

زيادة معنوية فى تركيز العناصر الثقيلة فى أسماك البوري عن البلطي وفى الكبد عن الخياشيم واللحم.

زيادة معنوية فى المحتوى الميكروبي للأسماك فى المزارع التى تعتمد على التسميد عن الأخرى.

زيادة معنوية للمحتوى الميكروبي فى المياة والتربة والاسماك فى مزارع بورسعيد عن الأخرى.

زيادة معنوية للمحتوى الميكروبي فى الجلد عن الخياشيم واللحم فى البلطي والبوري.

لا توجد فروق معنوية فى المحتوى الميكروبي بين البلطي والبوري فى نفس المعاملة.

لوحظ أن تركيز العناصر الثقيلة فى المياة و التربة والأسماك وكذلك المحتوى الميكروبي يعتمد بشكل أساسي على مصدر المياة ونظام الإدارة للأحواض.

توصي الدراسة بضرورة توخي الحذر عند إستخدام مياة الصرف الصحي فى الإستزراع السمكي وضرورة إستخدام نظام الإدارة المناسب حتى لا تكون سبباً فى إنتشار و إنتقال الميكروبات المرضية والعناصر الثقيله من الأسماك إلى الإنسان.