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| Title            | Estimation of organochlorine pesticides and heavy metal residues in two species of mostly consumed fish in Sharkia Governorate, Egypt |
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| Citation         | Japanese Journal of Veterinary Research, 64(Supplement 2), S233-S241                                                                  |
| Issue Date       | 2016-04                                                                                                                               |
| Doc URL          | <a href="https://hdl.handle.net/2115/61999">https://hdl.handle.net/2115/61999</a>                                                     |
| Type             | departmental bulletin paper                                                                                                           |
| File Information | S233-241 Amany Abdel-Rahman Mohame.pdf                                                                                                |



# Estimation of organochlorine pesticides and heavy metal residues in two species of mostly consumed fish in Sharkia Governorate, Egypt

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## Abstract

The current study aimed to afford baseline information on the level of twenty one organochlorine pesticides (OCPs) and four heavy metals in muscles of *Oreochromis niloticus* and *Mugil cephalus*. This will help elucidating the present status as chemical contaminants in the fish species. A total number of thirty fish from each species were collected to set up this study. *Nile tilapia (Oreochromis niloticus)*, was noticed to contain higher levels of most estimated types of  $\Sigma$  HCH in (40% of *Tilapia*) and  $\Sigma$  CHLRs. While Mullet (*Mugil cephalus*) was higher only in DDTs. Meanwhile,  $\Sigma$  HCB,  $\Sigma$  DRINs and  $\Sigma$  HPTs were the lowest. The recorded results demonstrated that organochlorines were within the permissible limit according to FAO except for the CHLRs, it exceeds the permissible limit in 100% (N=30) of tested samples of *Nile tilapia* for all isomer. The analytical data obtained from such study declared that the level of Cd, Zn and Cu were significantly ( $p \leq 0.05$ ) higher in Mullet than *Tilapia* but vice versa for Pb. It was evident, that all the detected metals were within the permissible limits according to FAO and WHO. Except for Zn, It exceeded the permissible limits in 50% of the analyzed samples in Mullet.

Key words: Organochlorine pesticide, Heavy metals, Residue, Fish, Egypt.

## Introduction

Fish is a desirable and highly nutritive food. It is considered as a rich source of calcium, phosphorous and vitamins, long-chain omega-3 polyunsaturated fatty acids DHA (Docosaheptaenoic acid) and Eicosapentaenoic acid which are associated with many health benefits<sup>23</sup>. The pollution of water with a broad range of pollutants has become a great matter of concern in the last few decades<sup>29</sup>.

Water pollution referred to the contamination of water by any excess of foreign material which is harmful to human, animals and fish<sup>28</sup>. Organochlorine pesticides (OCPs) are of immense concern as environmental contaminants owing to their bioaccumulation, potential for magnification in food chain and adverse effects on human and wild life<sup>20</sup>. They are widely used in control of pests and diseases since 1940s causing wide spread contamination of the environment<sup>24</sup>. In

developed countries the production and use of most compounds was banned since 1970s. However they are still used in developing countries and represent an environmental issue of concern, these compounds are bio-accumulated through food chain and reach a significant level in the top predators. Organochlorines have several forms of toxic effects; including effects on liver, immune, reproductive performance and nervous system viability in addition to skin irritation signs and cancer. They are accused of mimicking the function of hormones and of disrupting the endocrine system<sup>18)</sup>

Heavy metals usually enter the aquatic ecosystem from natural and anthropogenic sources. Anthropogenic impacts including domestic sewage, industrial sources such as galvanizing, electrical conductors, batteries, cement, pigments and minning activities. This resulting in exposure of the aquatic animals and fish to elevated levels of heavy metals. These elements continuously enter the aquatic ecosystem and pose serious threat due to bioaccumulation in food chain and being permanent addition to the aquatic environment and their different organisms<sup>2)</sup>. These metals cannot be destroyed by heat treatment so the potential to reach human was highly expected<sup>28)</sup>. This study aimed to establish definite data borders about the level of twenty one OCPs and four heavy metals (Cd, Pb, Cu and Zn) in muscles of two species of mostly consumed fish, *Oreochromis niloticus* and *Mugil cephalus*, this will in turns help elucidating the status of chemical contaminants and bioaccumulation of OCPs and heavy metals.

## Material and Methods

### Sampling:

A total number of sixty fish (30 fish of each specie). Nile Tilapia (*O. niloticus*) ranged from (200-250 g) and about 10 cm length while Mullet (*Mugil cephalus*) ranged from (350-400 g) and (18-20 cm) in length. The sample collection was done

during June and July 2014, from the local market in Zagazig city. The samples were immediately washed with distilled water then, the edible portion of the meat was taken, enclosed with clean and dry plastic film, then aluminum foil and stored frozen in -80 °C in liquid nitrogen tanks for analysis.

### Detection of organochlorine compounds

#### Extraction and preparation of samples:

The organic solvents used in detection of organochlorine compounds (hexane, acetone, dichloromethane, and n-decane) were of HPLC grade. Fish muscle samples were processed and analyzed using a method described by Yohannes et al.<sup>32)</sup>. The aliquot of 20% of the extract was for clean-up process after solvent. Clean-up was carried out on a glass column packed with about 6 g of the activated florisil material. Then it was concentrated to 2 ml elute on rotatory evaporator, dried under gentle nitrogen flow. The extract was re-dissolved in 100  $\mu$ L n-decane and transferred to gas-chromatography (GC) vials for analysis.

#### Determination of OCPs residual concentrations:

It was carried out with a gas-chromatography equipped with Ni electron capture detector (GC-ECD: Shimadzu GC-2014, Kyoto, Japan). An ENV-8MS capillary column (30 m  $\times$  0.25 mm i.d., 0.25  $\mu$ m film thickness) with splitless insertion or injection was used to separate the OCPs. One  $\mu$ l of each sample was instilled. The oven temperature of column was initially set at 100 °C for one minute, increased to 180 °C at 20 °C/min and then to 260 °C at 4 °C/min, and was held for only five minutes. The injector was 250 °C and of detector 310 °C. Helium used as carrier gas at a flow rate of 1.0 ml/min and nitrogen at flow rate of 45 ml/min was used as make-up gas.

#### Heavy metal analysis:

Muscle tissues of fish were subjected to digestion according to the method illustrated by<sup>27)</sup>. The blank solution was prepared according to the method described by<sup>25)</sup>. The quantitative determination of lead, cadmium, zinc and copper residues was conducted by using Thermo Jarrell

Ash Atomic Absorption Spectrophotometer, in Central Laboratory in Zagazig University.

Concentration of metal in samples =  $AXB \div W$ , where A = metal concentration (ppm) in the prepared samples from the digital scale reading of Atomic Absorption Spectrophotometer, B = the final volume of the prepared samples, W = weight of samples in gram<sup>26)</sup>.

#### Statistical analysis:

All values are expressed as mean  $\pm$  SE, statistical significance was evaluated by the Tukey-Kamer (HSD test) (JMP statistical package; SAS Institute Inc., Cary, NC)

## Results and Discussion

### Organochlorine compounds

Organochlorine pesticides have become large scale concern owing to their chronic toxicity, tendency to accumulate and persist in biota and potential ruinous impacts on humans and wildlife<sup>34)</sup>. They are broad-spectrum, persistent toxicants which accumulate in the food chain with high risks to the ecosystem and human health<sup>29)</sup>.

Polychlorinated biphenyl residues which investigated in two fish species, Hexachlorocyclohexanes (HCHs) which detected 40% of the tested samples of tilapia (Table 1) were exceeding the permissible limit of 13 and significantly ( $p \leq 0.05$ ) higher than Mullet. This result is much higher than that recorded in a study on tilapia (37.215 ng/g wet weights) in a shallow lagoon, Egypt by<sup>22)</sup>, in mullet,  $\Sigma$  HCH (Table 1) was within the safe value. The result of this study were higher than that found by Ferreira et al., in Douro Estuary of Portugal who found the concentration in Mullet 0.321- 0.562  $\mu\text{g g}^{-1}$  wet weight by<sup>16)</sup>. This may be attributed to the illegal use of HCH as an insecticide although its use was banned in Canada and USA since 1970s, it still applied in some developing countries. It may reach to fish through contamination of surface water that may occur as a result of surface run-off from

agricultural or land especially because it is highly soluble in water.

Concerning heptachlor, table (1) showed that the maximum value of  $\Sigma$ HPTs was detected in the Nile Tilapia and it is significantly ( $p \leq 0.05$ ) higher than mean concentration in Mullet. The obtained results were higher than that obtained by Farshid et al.,<sup>16)</sup> who found the concentration ranged from 0.24-0.44 in fish muscles in Iran. The result regarding DRINs (aldrin, dieldrin and endrin), the results of two species recorded in table (2) indicating the absence of endrin fraction in both types of fish. The mean of  $\Sigma$ DRINs in Tilapia is higher than that of Mullet. Dieldrin is the epoxide metabolite of aldrin is found to be higher by more than two folds indicating significant increase ( $p \leq 0.05$ ) in *O. niloticus* than *Mugil cephalus*.

Although the total chlordanes were not previously studied in fish tissues from Sharkia Governorate due to the absence of any recommendation concerning their levels. Cis- and trans-chlordane were detected in 80% of Tilapia flesh with exceeding the maximum Austrian level (10  $\mu\text{g/kg}$ ). In Mullet the Cis- and trans-nonachlor and oxychlordane were noticeably prevalent with different levels (Table 2). This may be attributed to the previous historical use of commercial products in which chlordanes are the active compounds in agricultural applications that may be leaked to fish sources through the drainage of excessive water, especially because of the long time bioaccumulation and slow degradation of chlordanes. This type was used for crops like corn or citrus fruits. Moreover, they may be used as fumigating agents in areas near to the collection sites of studied fish, so the droplets were fallen in water and stored in fish muscles. These residues reach human leading to testicular, liver breast, brain, and prostate cancer<sup>7)</sup>.

In this study the obtained value of DDT significantly ( $P \leq 0.05$ ) higher in Mullet Table 3. These values were lower than that found in fish samples caught from the black sea (0.047-0.138 ppm) and from Mediterranean sea coast Tunisia

(0.014-0.016 ppm wet weight)<sup>6)</sup>. The EPA, in 1987, classified DDT as a main cause for human cancer. In 2007 a Canadian study found a positive association between DDE and the disease of non-Hodgkins Lymphoma.

From the previously mentioned results, it was observed that  $\Sigma$ HCH, CHLRs in *Oreochromis niloticus* and  $\Sigma$ DDTs in *Mugil cephalus* were the superior concentrations. While, the values of  $\Sigma$ HCB,  $\Sigma$  HPTs and  $\Sigma$  DRINs recorded the lowest concentrations among the measured organochlorine pesticide residues. These residues explained by their environmental long persistence and / or the illegal using of these pesticide groups. Organochlorine toxicity leads to serious public health troubles as impairment of immune function, disruption of the endocrine system and promotion of cancer<sup>11)</sup>.

## Heavy metal

The natural aquatic system has been extensively polluted with heavy metals released from industrial, domestic, agricultural and the different man-made activities<sup>8)</sup>. Among animal species, fish are the inhabitants which cannot escape from the damaging effects of these pollutants<sup>27)</sup>.

### Cadmium (Cd)

There was considerable variation of cadmium levels among the examined species. The depicted results in table (4) are lower than that of Essa and Rateb<sup>11)</sup> and Ekop<sup>10)</sup> with mean value 0.976 and 0.001 ppm respectively in Tilapia and Mullet. Higher than that obtained from Awassa Lake, Ethiopia<sup>32)</sup>. Lower cadmium residues in mullet fish detected in Gaza Strip Markets by Muzyed<sup>24)</sup>. There was significant difference between the examined fish species ( $p \leq 0.05$ ).

### Zinc (Zn):

The results of this study indicated that the concentration of zinc in examined species arranged in descending manner as following tilapia then mullet. Higher residues detected in a study by

Amal, M. and Nahed<sup>4)</sup> and the concentration was  $56 \pm 11$  ppm for tilapia muscle tissues while studying accumulation of some heavy metals and the biochemical change in muscles of *O.niloticus* from the River Nile in Upper Egypt. Lower results for mullet than that recorded in the present study, detected by Karadede et al.,<sup>19)</sup> who recorded 7.74mg.kg-1 in Turkey. Furthermore, lower results found in mullet caught in Iskenderun bay in Turkey with means values of zn were 30.44 ppm.<sup>5)</sup>

### Lead (Pb):

Pb concentration in the present study was lower than those found by Essa and Rateb<sup>12)</sup> during assessment of heavy metals in fish tissues, from Assuit city market, Egypt and found the average of lead residue in tilapia nilotica samples 0.125 ppm. Higher residues in Tilapia ( $0.49 \pm 0.33$  ppm) recorded in Taiwan<sup>21)</sup>, while comparable residues obtained in Tilapia from Awassa Lake, Ethiopia when they detect 0.004 ppm<sup>32)</sup>. The examined samples were significantly different ( $p \leq 0.05$ ) between the two tested fish species depending on the habitat of fish in water, the pelagic fish species which present in shallow water in which Pb dissolved more than deep water could accumulate Pb in deep water inhabitant fish<sup>8)</sup>.

### Copper (Cu):

The detected Copper concentration in examined samples (Table 4) were lower than that detected in fish fillets of tilapia (8.926 mg. g-1 fish) from El -Sharkia Governorate by<sup>4,17)</sup> with mean value of 3.5 ppm. But nearly similar to the results of Ling et al.,<sup>21)</sup>. Lower results detected in muscle tissues of Mullet samples by Karadede et al.<sup>19)</sup> with mean values 1.36 ppm and another with mean 0.244, 1.39 and 0.99 ppm caught in Iskenderun bay in different periods<sup>5)</sup>. Collectively from the observed data of heavy metal analysis in table 4 Zn exceeded the permissible limit in *Mugil cephalus* but still in its safe limit in *Oreochromis niloticus*. This variation may be resulted from the different sources of fish according to condition of water, sediment, industrial or agricultural contaminants.

## Conclusion

Based on our analyses of both Nile Tilapia and Mullet marketed in Sharkia governorate, Egypt, it can be concluded that all the estimated organochlorines and heavy metals were mostly

detected in the safe limits admitted by FAO and WHO except for chlordan and Zn. Hence, further investigations about their levels in water, sediment and other types of fish sources in Sharkia governorate should be addressed.

**Table 1:** Levels of HCH and HPTs pesticides in Nile Tilapia (*O.niloticus*) and mullet (*Mugil cephallus*) muscles by ng/g wet weight (ppb). The frequency distribution of HCH and HPTs (n=30). The permissible limits of  $\alpha$ -HCH and  $\gamma$ -HCH and Heptachlor epoxide are 300 ppb<sup>13)</sup>

| HCH<br>and<br>HPTs               | Nile Tilapia ( <i>O.niloticus</i> ) |          |                     |      |             |     |             |     |     |
|----------------------------------|-------------------------------------|----------|---------------------|------|-------------|-----|-------------|-----|-----|
|                                  | Min                                 | Max      | Mean $\pm$ SE       | N.D. | Within P.L. |     | Exceed P.L. |     |     |
|                                  |                                     |          |                     | No   | %           | No  | %           | No  | %   |
| $\alpha$ -HCH                    | 37.16                               | 139.15   | 69.22 $\pm$ 15.64   | 0.0  | 0.0         | 30  | 100         | 0.0 | 0.0 |
| $\beta$ -HCH                     | 27.28                               | 82.83    | 56.32 $\pm$ 12.41   | 5    | 16.6        | 25  | 83.4        | 0.0 | 0.0 |
| $\gamma$ -HCH                    | 52.37                               | 75.68    | 66.31 $\pm$ 5.05    | 0.0  | 0.0         | 30  | 100         | 0.0 | 0.0 |
| d-HCH                            | 30.28                               | 81.56    | 61.67 $\pm$ 11.27   | 3    | 10          | 20  | 90          | 0.0 | 0.0 |
| $\Sigma$ HCH                     | 147.09                              | 379.22   | 253.52 $\pm$ 44.37* | 6    | 20          | 12  | 40          | 12  | 40  |
| Heptachlor                       | ND                                  | ND       | ND                  | 30   | 100         | 0.0 | 0.0         | 0.0 | 0.0 |
| cis-Hep-epox                     | 28.92                               | 61.64    | 42.64 $\pm$ 5.79    | 12   | 40          | 18  | 60          | 0.0 | 0.0 |
| trans-Hep-epox                   | 27.46                               | 64.63    | 51.92 $\pm$ 8.68    | 15   | 50          | 15  | 50          | 0.0 | 0.0 |
| $\Sigma$ HPTs                    | 56.37                               | 126.28   | 94.57 $\pm$ 14.48*  | 10   | 33.3        | 20  | 66.7        | 0.0 | 0.0 |
| Mullet ( <i>Mugil cephalus</i> ) |                                     |          |                     |      |             |     |             |     |     |
| $\alpha$ -HCH                    | 6.07                                | 143.0585 | 34.83 $\pm$ 10.65   | 15   | 50          | 15  | 50          | 0.0 | 0.0 |
| $\beta$ -HCH                     | ND                                  | ND       | ND                  | 30   | 100         | 0.0 | 0.0         | 0.0 | 0.0 |
| $\gamma$ -HCH                    | ND                                  | ND       | ND                  | 30   | 100         | 0.0 | 0.0         | 0.0 | 0.0 |
| d-HCH                            | ND                                  | ND       | ND                  | 30   | 100         | 0.0 | 0.0         | 0.0 | 0.0 |
| $\Sigma$ HCH                     | 6.07                                | 143.06   | 34.83 $\pm$ 10.65   | 15   | 50          | 15  | 50          | 0.0 | 0.0 |
| Heptachlor                       | 5.56                                | 44.50    | 15.55 $\pm$ 3.38    | 9    | 30          | 21  | 70          | 0.0 | 0.0 |
| cis-Hep-epox                     | 5.97                                | 29.53    | 15.35 $\pm$ 2.70    | 10   | 33.3        | 20  | 66.7        | 0.0 | 0.0 |
| trans-Hep-epox                   | ND                                  | ND       | ND                  | 30   | 100         | 0.0 | 0.0         | 0.0 | 0.0 |
| $\Sigma$ HPTs                    | 12.14                               | 200.07   | 58.23 $\pm$ 17.75   | 13   | 43.3        | 17  | 56.7        | 0.0 | 0.0 |

n=30 replicates, ND=Non detected and \* Value with superscript significant from the other fish species ( $P \leq 0.05$ )

**Table 2:** Levels of DRINs and CHLRs pesticides in Nile tilapia (*O.niloticus*) and Mullet (*Mugil cephallus*) Muscles by ng/g wet weight The Frequency distribution of DRINs and CHLRs. The permissible limits of DRINs 300 ppb, (FAO 1996). CHLRs is 10 ppb<sup>13)</sup>

| DRINs<br>CHLRs                    | Nile tilapia ( <i>O.niloticus</i> ) |        |               |      |      |              |      |               |     |
|-----------------------------------|-------------------------------------|--------|---------------|------|------|--------------|------|---------------|-----|
|                                   | Min                                 | Max    | Mean± SE      | N.D. |      | Within P.L.* |      | Exceed P.L. * |     |
|                                   |                                     |        |               | No   | %    | No           | %    | No            | %   |
| Aldrine                           | 39.12                               | 93.39  | 63.86±11.25   | 3    | 10   | 27           | 90   | 0.0           | 0.0 |
| Dieldrin                          | 40.51                               | 42.52  | 41.51±0.58    | 6    | 20   | 24           | 80   | 0.0           | 0.0 |
| Endrine                           | ND                                  | ND     | ND            | 30   | 100  | 0.0          | 0.0  | 0.0           | 0.0 |
| ΣDRINs                            | 79.62                               | 135.91 | 105.37±11.84* | 3    | 10   | 27           | 90   | 0.0           | 0.0 |
| Oxy-Chlordane                     | 23.09                               | 56.57  | 39.83±9.70    | 0.0  | 0.0  | 0.0          | 0.0  | 30            | 100 |
| trans -chlordane                  | 40.54                               | 171.31 | 76.93±21.90   | 0.0  | 0.0  | 0.0          | 0.0  | 30            | 100 |
| transNonane                       | ND                                  | ND     | ND            | 30   | 100  | 0.0          | 0.0  | 0.0           | 0.0 |
| cis-Chlordane                     | 26.78                               | 63.81  | 48.58±6.20    | 0.0  | 0.0  | 0.0          | 0.0  | 30            | 100 |
| cisNonach                         | ND                                  | ND     | ND            | 30   | 100  | 0.0          | 0.0  | 0.0           | 0.0 |
| Σ CHLRs                           | 90.40                               | 291.69 | 165.34±37.80* | 0.0  | 0.0  | 0.0          | 0.0  | 30            | 100 |
| Mullet ( <i>Mugil cephallus</i> ) |                                     |        |               |      |      |              |      |               |     |
| Aldrine                           | 13.37                               | 134.15 | 41.90±10.09   | 6    | 20   | 24           | 80   | 0.0           | 0.0 |
| Dieldrin                          | 10.24                               | 22.65  | 18.17±1.99    | 13   | 43.3 | 17           | 56.7 | 0.0           | 0.0 |
| Endrine                           | ND                                  | ND     | ND            | 30   | 100  | 0.0          | 0.0  | 0.0           | 0.0 |
| ΣDRINs                            | 23.61                               | 156.80 | 60.07±12.08   | 11   | 36.7 | 19           | 63.3 | 0.0           | 0.0 |
| Oxy-Chlordane                     | 3.16                                | 83.08  | 25.05±7.32    | 0.0  | 0.0  | 0.0          | 0.0  | 30            | 100 |
| transchlordane                    | 5.54                                | 53.93  | 29.73±9.88    | 0.0  | 0.0  | 0.0          | 0.0  | 30            | 100 |
| transNonane                       | 3.77                                | 22.63  | 13.10 ±2.26   | 0.0  | 0.0  | 0.0          | 0.0  | 30            | 100 |
| cis-Chlordane                     | 4.25                                | 18.80  | 12.04±1.74    | 0.0  | 0.0  | 0.0          | 0.0  | 30            | 100 |
| cisNonach                         | 5.04                                | 42.49  | 15.53±3.73    | 0.0  | 0.0  | 0.0          | 0.0  | 30            | 100 |

n=30 replicates and ND=Non detected \* Value with superscript significant from other fish species ( $P \leq 0.05$ )

**Table 3:** Levels of DDTs pesticides in Nile tilapia (*O.niloticus*) and mullet (*Mugil cephallus*) muscles by ng/g wet weight. The Frequency distribution of DDTs. The permissible limits of DDTs 5000 ppb<sup>13)</sup>.

| DDTs                              | Nile tilapia ( <i>O.niloticus</i> ) |        |               |      |      |              |      |               |     |
|-----------------------------------|-------------------------------------|--------|---------------|------|------|--------------|------|---------------|-----|
|                                   | Min                                 | Max    | Mean± SE      | N.D. |      | Within P.L.* |      | Exceed P.L. * |     |
|                                   |                                     |        |               | No   | %    | No           | %    | No            | %   |
| OP-DDE                            | ND                                  | ND     | ND            | 30   | 100  | 0.0          | 0.0  | 0.0           | 0.0 |
| PP-DDE                            | 39.33                               | 169.66 | 95.55±19.55   | 0.0  | 0.0  | 30           | 100  | 0.0           | 0.0 |
| OP-DDD                            | ND                                  | ND     | ND            | 30   | 100  | 0.0          | 0.0  | 0.0           | 0.0 |
| PP-DDD                            | 39.27                               | 92.70  | 59.92±9.14    | 5    | 16.7 | 25           | 83.4 | 0.0           | 0.0 |
| OP-DDT                            | ND                                  | ND     | ND            | 30   | 100  | 0.0          | 0.0  | 0.0           | 0.0 |
| PP-DDT                            | ND                                  | ND     | ND            | 30   | 100  | 0.0          | 0.0  | 0.0           | 0.0 |
| ΣDDTs                             | 78.60                               | 262.36 | 155.47±28.69  | 0.0  | 0.0  | 30           | 100  | 0.0           | 0.0 |
| Mullet ( <i>Mugil cephallus</i> ) |                                     |        |               |      |      |              |      |               |     |
| DDTs                              | Min                                 | Max    | Mean± SE      | N.D. |      | Within P.L.* |      | Exceed P.L. * |     |
|                                   |                                     |        |               | No   | %    | No           | %    | No            | %   |
| OP-DDE                            | 11.02                               | 29.44  | 21.23±2.71    | 7    | 23.3 | 23           | 76.6 | 0.0           | 0.0 |
| PP-DDE                            | 11.66                               | 48.84  | 26.02±4.07    | 3    | 10   | 27           | 90   | 0.0           | 0.0 |
| OP-DDD                            | 8.09                                | 38.75  | 25.60±4.20    | 6    | 20   | 24           | 80   | 0.0           | 0.0 |
| PP-DDD                            | 16.45                               | 53.70  | 33.27±5.45    | 9    | 30   | 21           | 70   | 0.0           | 0.0 |
| OP-DDT                            | 13.75                               | 59.77  | 30.00±5.26    | 15   | 50   | 15           | 50   | 0.0           | 0.0 |
| PP-DDT                            | 9.88                                | 38.75  | 24.48±4.17    | 2    | 6.7  | 28           | 93.3 | 0.0           | 0.0 |
| ΣDDTs                             | 70.86                               | 269.24 | 160.60±25.86* | 5    | 16.7 | 25           | 83.3 | 0.0           | 0.0 |

n=30 replicates and ND=Non detected\* Value with superscript significant from the other fish species ( $P \leq 0.05$ )

**Table 4:** Concentration of heavy metals in tilapia (*O.niloticus*) and mullet (*Mugil cephallus*) muscles and maximum permissible limit (MPL) of heavy metals in fish muscles<sup>9,13,14</sup>

| Heavy metal (ppm)                 | Tilapia( <i>O.niloticus</i> ) |        |                     |      |     |                         | Reference   |
|-----------------------------------|-------------------------------|--------|---------------------|------|-----|-------------------------|-------------|
|                                   | Min                           | Max    | Mean $\pm$ SE       | N.D. |     | Permissible limit (ppm) |             |
|                                   |                               |        |                     | No   | %   |                         |             |
| <b>Cadmium (cd)</b>               | 0.0005                        | 0.002  | 0.001 $\pm$ 0.00    | 15   | 50  | 0.05<br>0.5             | 13, 9<br>14 |
| <b>Lead(Pb)</b>                   | 0.0056                        | 0.077  | 0.022 $\pm$ 0.01    | 6    | 20  | 0.5<br>0.2              | 14<br>9     |
| <b>Zinc(Zn)</b>                   | 13.255                        | 23.844 | 20.222 $\pm$ 4.05   | 0.0  | 0.0 | 30<br>40                | 13<br>14    |
| <b>Copper(Cu)</b>                 | 0.354                         | 0.720  | 0.539 $\pm$ 0.12    | 3    | 10  | 30<br>30                | 13<br>14    |
| Mullet ( <i>Mugil cephallus</i> ) |                               |        |                     |      |     |                         |             |
| <b>Cadmium (cd)</b>               | 0.0008                        | 0.007  | 0.003 $\pm$ 0.00    | 0.0  | 0.0 | 0.05<br>0.5             | 13,9<br>14  |
| <b>Lead (Pb)</b>                  | 0.0032                        | 0.0214 | 0.011 $\pm$ 0.01    | 0.0  | 0.0 | 0.5<br>0.2              | 14<br>9     |
| <b>Zinc (Zn)</b>                  | 24.505                        | 67.410 | 49.853 $\pm$ 15.74* | 0.0  | 0.0 | 30<br>40                | 13<br>14    |
| <b>Copper (Cu)</b>                | 0.744                         | 4.170  | 1.424 $\pm$ 0.90*   | 6    | 20  | 30<br>30                | 13<br>14    |

n=30 replicates and ND=Non detected.\* Value with superscript significant from the other fish species ( $P \leq 0.05$ )

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