

Bioaccumulation of Pesticides in Aquatic System of Edku Lake, Egypt: An Approach for Risk Associated With Fish Consumption

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Abstract

Monitoring of some organochlorines (OCs) and organophosphorus (OP) pesticide residues in Edku Lake during 2015-2016 have been determined in water, sediment and Tilapia fish to find out the extent of pesticides contamination and bioaccumulation into the lake. Pesticide residues were determined using gas chromatography equipped with appropriate detectors. The mean residues of Σ BHC, Σ DDT, total OCs, and OPs in water samples were 68.43, 14.17, 118.3 and 138.46 ppb, respectively. The corresponding residues in sediments were 8343.26, 5307.59, 21402.83 and 267.66 ppb, respectively. In fish muscles, the mean residues of Σ BHC, Σ DDT, methoxychlor and total OCs were 2513.56, 1916.85, 46175.05, and 57592.40 ppb, respectively. The corresponding values in fish gills were 3565.44, 16014.96, 13182.44, 35645.15 and 3318.10 ppb, respectively. Sum of BHC and DDT were the mostly detected in muscle samples accounting for 1593.60 and 916.53 ppb, respectively. Regarding bioaccumulation of examined pesticides, bioconcentration factor (BCF) was estimated to be in range 7.96-40701.50 for water/muscle ratio of OCs. In case of BCF for water/gills, the values ranged from 16.72 to 237090.17. BCF values obtained from ratio sediment/muscle or sediment/gills not exceeded than 100. These concepts indicate that OCs induced bioaccumulation in fish tissues may attributed to predicted risks associated with this kind of consumption. All findings represent concept that, Edku Lake represents reservoir of all pollutants coming from north governorates e.g. El-Behira.

Keywords: Pesticide residues; Edku lake; Bioaccumulation; Tilapia fish.



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1. Introduction

The excessive use of pesticides in agriculture is harmful to ecosystem and they contaminate soil, surface and ground water resources. Pesticide residue problems in the fish tissues are serious, as reflected by the high pesticides concentrations recorded in the water and sediment [1]. Studies on pesticide residues in lake's water, sediments and fish have been a major environmental focus especially during the last decade. Sediments are important sinks for various pesticides and also play a significant role in the remobilization of contaminants in aquatic systems under favourable conditions and in interactions between water and sediment. Organochlorine compounds (OCs) are classified as persistent organic pollutants (POPs). They had been extensively studied for long-term depending on their persistence, bioaccumulation, long-range transport, toxicity and adverse effects on wildlife and human. For these reasons, most countries had restricted or banded their use [2, 3]. Depending on their persistent and lipophilic properties, POPs can be easily accumulated in biota from surrounding environment [4] and induce multi-adverse effects in many organisms [5]. Also, many studies in the world focused on the evaluation of OPs residues in fish.

In aquatic media, there are different types of organisms. Recently, fish is considered valuable bioindicator in POPs monitoring studies, because its detoxication enzymes (e.g. mono-oxygenase) have lower activity than those in mammals and allows toxicants to accumulate. Moreover, fish able to concentrate the pollutants *via* gills directly from water and food ingestion ending to risk in human *via* sea food consumption [6-8].

The pesticide residues in closed lakes mostly come from agricultural runoff and domestic discharge. Many studies had been carried out to monitor the occurrence of pesticides in lakes in different countries, including southern Lake Victoria, Tanzania Henry and Kishimba [9], in Bosomtwi and Weija Lakes, Ghana Darko, *et al.* [10], Kumi, *et al.* [11], in Victoria Lake, Wasswa, *et al.* [12], Taihu Lake, China Wang, *et al.* [13] and Lake Nokue and Cotonou Lagoon, Benin Pazou, *et al.* [14]. Regarding regional investigation, different studies focused on pesticides and other pollutants residues in Egyptian environment [15-21].

The present study was carried out to monitor the residue levels of pesticides and their bioaccumulation in the aquatic environment of some contaminated sites of Edku Lake, Egypt during the period from 2015 to 2016 as implication for risk imposed from fish consumption.

2. Material and Methods

2.1. Chemicals

A standard mixture of organochlorine compounds α , β , γ BHC isomers, HCB, heptachlor, aldrin, heptachlor epoxide, γ -chlordane, *P*, *P'*-DDE, *P*, *P'*-DDD, *P*, *P'*-DDT, endrin and methoxychlor and another one of organophosphorus compounds; ethoprophos, phorate, diazinon, dimethoate, primiphos-methyl, chlorpyrifos, fenitrothion, quinalphos, prothiophos, fenamiphos, ethion and triazophos were obtained from the Central Agricultural Pesticides Laboratory (CAPL), ARC-Giza, Egypt.

The solvents such as acetone, cyclohexane, ethyl acetate, ethanol, petroleum ether (b.p 40-60 and 60-80 °C), methylene chloride, and *n*-hexane were obtained from ADWIC lab, Egypt. Acetonitrile was obtained from BDH chemical Ltd. Sodium chloride (NaCl), anhydrous sodium sulfate (Na₂SO₄) and Magnesium sulfates (MgSO₄) were obtained also from ADWIC Lab, Egypt. Acids such as glacial acetic acid was supplied by BDH chemical Ltd. Silica gel (100-120 mesh), sodium citrate and sodium hydrogen citrate were also supplied by BDH chemical Ltd. Paraffin oil was obtained from J. T. Baker Chem. Co. Primary secondary amine (PSA)-bulk sorbent was supplied by Agilent Technologies, USA.

2.2. Study Area

Edku Lake is one of five coastal north lakes that are connected to the Mediterranean Sea in Egypt. It locates about 40 km eastern of Alexandria and 18 km western of Rosetta branch of the Nile River. Between Longitude, 30° 8' 30" & 30° 23' 00" E and Latitude, 31° 10' 00" & 31° 18' 00" N. The lake is connected to the Abu Qir Bay through the opening lied at the west of delta (Boughaz El Maadeya). It is considered a brackish lake, where water depth varies from 60 to 150 cm with an average of 1m. The lake's area decreased from 12.4×10³ to about 3.5×10³ hectares as a result of agricultural reclamation. The lake can be divided into three compartments; eastern, central and western.

Two main drains discharge their water into the lake; the first drain is namely Kom Belag receives its water from three sub drains; Bosily, Edku and El-Khairy and discharges the water at the eastern part of the lake. Another is Bersik drain which outlets its water at the southern central part of this lake. Figure (1) represents the selected sites for the study as follows: El-Maadeya Strait (S1), near the international Road (S2), the middle of the Lake (S3), Bersik zone (S4) and Kom Belag zone (S5), respectively.

2.3. Sampling Procedures

Environmental samples were collected periodically once time every season during 2015-2016, where fish samples, *Tilapia sp* weighed 100–250 g were caught from the selected sites as marked in the geographic map (Figure 1). They were packed into polyethylene bag and labeled. In addition, sediment sample were taken by using simplified equipment (auger) at a depth of 5 cm of sedimentation surface. The water was removed from the sediments before packed in a labeled polyethylene bag. Water samples (two liters) were collected in glass bottles from each site. The bottles were covered with aluminum foil, acidified to pH 2.5-5 with concentrated hydrochloric acid to inhibit the biological activity of organisms and stored in ice box. In addition, all samples were preserved in an icebox during transfer.

2.4. Analytical Procedures

2.4.1. Fish Samples

Quick, Easy, Cheap, Effective, Rugged and Safe technique (QuEChERS) [22] was used as follows: five g of fish tissues were mixed with 10 ml of acidic acetonitrile (1% glacial acetic acid), homogenized using a polytron homogenizer (Janke and KunKel, Gmb Hu Co KG) and shaken for 1 min. One g of NaCl and 3 g of MgSO₄ were added, vortexed immediately for 1 min and centrifuged at 4000 rpm for 5 min. An aliquot (1 ml) was placed into a micro centrifuge tube (2 ml) containing 150 mg primary-secondary amine (PSA) and 200 mg MgSO₄, vortexed for 1 min and re-centrifuged as described above. The supernatant was checked on gas chromatographic instrument.

2.4.2. Sediment Samples

Ten g of sieved dried sediments were added to 20 ml of acidic acetonitrile in 50 ml centrifuge tube. Next, 4 g of MgSO₄, 1 g NaCl, 1 g sodium citrate and 0.5 g sodium hydrogen citrate were added. The mixture was then shaken for 30 sec, sonicated for 5 min (ultrasonic bath at 50/60Hz and 100W, Barcelona, Spain) and centrifuged at 4000 rpm for 8 min. Ten ml of the supernatant were added to 1.5 g MgSO₄ and 250 mg of PSA into 15 ml centrifuge tube. The mixture was done as described before. The solvent was evaporated to dryness, dissolved in 1ml of cyclohexane and filtered on polytetrafluorethylene filters [23].

2.4.3. Water Samples

Samples (one liter each) were mixed with 10 ml of saturated NaCl solution and partitioned with 2×50 ml of methylene chloride. The organic layer was taken, combined, dried over anhydrous sodium sulphate (10 g) and then rotary evaporated at 30 °C to dryness. The residue was dissolved in 1 ml of *n*-hexane+methylene chloride (1:1 v/v). Sample fractionation and clean up procedure was carried out according to the methods of EPA, (1982) with slight modifications, where samples were loaded on 20 % deactivated silica gel column (1 g) prewashed with 10 ml of *n*-hexane. The column was eluted with the following systems: 10 ml of *n*-hexane, 15 ml of petroleum ether (b.p 60–80 °C): *n*-hexane (60:40 v/v), 15 ml of acetonitrile: petroleum ether (b.p 60–80 °C)(5:95 v/v), and 15 ml of acetone:

ethyl acetate (25:75 v/v), respectively. The fractions were dried under a stream of nitrogen by using N-evaporator, and then dissolved in 0.3 ml of *n*-hexane.

Recoveries were carried out by addition of internal standards of OCs or OPs. All fortified samples were extracted either and cleaned up as described above. Methods and instruments were fully validated as part of a laboratory quality assurance system [24]. The codex committee's criteria for quality assurance were followed to determine the performance of the multi-residue method. Recovery, accuracy and limit of detection (LOD) were determined for every compound.

2.4.4. Chromatographic Analysis

The residues were determined on gas liquid chromatography. Organophosphorus compounds were performed on an Agilent GC Model - 6890 series equipped with flame photometric detector (FPD). The analysis was conducted on a PAS-1701 (Agilent, GC Model 6890) fused silica capillary column (30 m length × 0.32 mm i.d. and 0.25 μm film thickness). The oven temperature was programmed from an initial temperature 160 °C for 1 min, then hold to 260 °C for 15 min at a rate of 5 °C/min. Nitrogen was used as a carrier gas at a flow rate of 3 ml/min. The hydrogen and air were used at flow rates 75 and 100 ml/min, respectively. Peaks were identified by comparison of sample retention time values with those of the corresponding of pure standards. Among OCs, the samples were examined on gas liquid chromatography equipped with electron capture detector (ECD). The analysis was conducted on a PAS-5 analytical capillary column (30 m length × 0.32 mm i.d. and 0.25 μm film thickness). The oven temperature was programmed from an initial temperature 160 °C for 2 min, then hold to 280 °C for 15 min at a rate of 5 °C/min. Nitrogen was used as a carrier gas at a flow rate of 4 ml/min. The data were calculated in a computer program to final values in ppm. Peaks were identified as described before.

GC-MS analysis (Agilent 6890 with an Agilent mass spectrometric detector) was used to confirm GC results. The used column was silica capillary column PAS-5 (30 mm × 0.25 μm film thickness). The samples were injected under the following conditions: Helium was used as carrier gas at a flow rate approximately of 1 ml/min pulsed splitless mode. The solvent delay was 3 min and the injection size was 1.0 μl. The mass spectrophotometric detector was operated in electron impact ionization mode at ionic energy of 70 e.v and scanning from 50 to 500 m/z. The ion source temperature was 230 °C and the quadrupole temperature was 150 °C. The electron multiplier voltage (EM voltage) was maintained 1250v. The instrument was manually tuned using perfluorotributyl amine (PFTBA). The GC temperature program was started at 60 °C, elevated to 280 °C at a rate of 8 °C/min and 10 min hold at 280 °C. The detector and injector temperature were set at 280 and 250 °C, respectively. Data was used in the identification of the separated peaks. OCs compounds were injected into GC-MS and confirmed at scan mode.

Bioconcentration factor (BCF) is defined as the ratio between the chemical concentration in organism ($C_{org.}$) to the respective concentration in the surrounding media (C_{media}) [25].

$$BCF = C_{org.}/C_{media}$$

2.5. Statistical Analysis

Analysis of variance was used to compare means among treatments by using student-Newman-Kelas test Sokel and Rohlf [26].

3. Result

The results of pesticide residues analysis in aquatic media of the Lake are presented in Table 2. In water samples, the mean values of measured compounds were lower than their detection limits. However, methoxychlor reached the highest mean value (25.71 ppb). Moreover, β-BHC, heptachlor, *P, P'*-DDE and *P, P'*-DDD were the mostly detected during all seasons with values; 66.75, 6.53, 6.51 and 7.61 ppb, respectively, compared with other compounds. The mean values of Σ-BHC and Σ-DDT reached the highest concentration in summer and spring season and reached the lowest values in winter season with the mean values; 156.19, 44.25 and 5.99 ppb for Σ-BHC and 20.50, 20.92 and 1.09 ppb for Σ-DDT (Figure 2). Regarding OPs, diazinon, chlorpyrifos and fentrithion were the only detected in water samples accounting for mean values: 8.95, 20.66 and 92.69 ppb, respectively.

In case of muscles and gills of Tilapia fish, most of the examined compounds were detected in all analyzed samples. The levels of pesticide residues in gills were greater than those in muscle tissues. Sum of BHC and DDT were the mostly detected in muscle samples. They exhibited 1593.60 and 916.53 ppb, respectively (Figure 2). Methoxychlor was found with highest level (46175.05 ppb) followed by aldrin (2279.45 ppb). The lowest level was recorded for *P, P'*-DDT (286.35 ppb). Regarding gills samples, *P, P'*-DDT revealed the highest level (13277.05 ppb) followed by methoxychlor (13182.44 ppb). However, HCB exhibited the least level (44.75 ppb). Diazinon and chlorpyrifos were the only detected in all samples with mean values; 2972.47 and 345.36 ppb.

In case of sediment samples, all examined OCs were positively detected except γ-BHC, γ-Chlordane and methoxychlor. The mean values of OCs ranged from 24.37 to 5551.18 ppb. The highest level was recorded for β-BHC (5551.18 ppb), while the lowest one was 24.37 ppb for *P, P'*-DDE. In addition, the mean value of aldrin was found to be 5025.24 ppb followed by *P, P'*-DDT (3945.17 ppb), α-BHC (2758.74 ppb), endrin (1343.92 ppb), *P, P'*-DDD (1338.05 ppb), heptachlor (879.61 ppb) and heptachlor epoxide (392.92 ppb), respectively. Examined OP compounds were not detected, except diazinon which exhibited mean value (267.66 ppb). GC-MS analysis was used to confirm the gas chromatographic results. Retention times, detection limits and recovery percentages for fortified samples were carried out as described previously. The residue data were calculated and corrected for recovery percentages for sediment and tissues samples, but considered as 100% in case of water samples.

The bioaccumulation of the examined compounds was estimated as a ratio of their concentration in both muscles and gills to the respective concentration in the media (water and sediments) as presented in Table 2. Between water and muscle tissues, positively residue levels of OCs showed BCF ranged from 7.96 to 40701.50. In fact, HCB, γ -BHC, γ -Chlordane, *P*, *P'*-DDT, methoxychlor and aldrin exhibited BCF values >1000. However, other OCs were found in range lower than 1000. Moreover, BCF for β -BHC, heptachlor, *P*, *P'*-DDE did not exceed 100 with values; 7.96, 74.37 and 80.42, respectively. In case of BCF for water/gills, the values ranged from 16.72 to 237090.17. γ -BHC, γ -Chlordane, *P*, *P'*-DDT and aldrin were the only OCs compounds exhibiting BCF values >1000. Other OCs maintained values ranged from 16.72 to 895.00.

In case of BCF obtained from ratio sed./muscle or sed./gills, all values of examined compounds did not exceed than 100. BCF values of sed./muscle exhibited the highest number (21.48) for *P*, *P'*-DDE, followed by HCB (18.46) and heptachlor epoxide (1.06), respectively. BCF of other compounds did not exceed 1.

The measured residues in edible parts of tilapia fish (muscle) exceeded than permissible limits of most international authorities as reported in Table (3). For example, lindane was found in a mean value (1982.36 ppb) upper the permissible level (1000 ppb). On the other hand, γ -Chlordane exhibited mean value 647.06 ppb upper the rough of all authorities legal levels (5.0-300.0 ppb).

4. Discussion

The contamination of the aquatic environment by OCs is a great concern because of the presence of their residues at varying quantities in different compartments of ecosystem [27]. Numerous investigations have reported the occurrence of OCs in water. For example, Lake Mariout El-Sebae and Abu El-Amayem [28], Qarun Lake Mansour, *et al.* [29] and Damietta region Abdel-Halim, *et al.* [30]. In worldwide, several studies demonstrated the occurrence of OCs and others in lakes water. For example, Lake Bosomtwi, Ghana Darko, *et al.* [10] and Lake Manyas, Turkey Erkemen, *et al.* [31]. Organochlorine compounds are characterized for their common physical and chemical properties such as reactivity appreciable volatility at ambient temperature [32]. Adsorption and volatilization were shown to be important factors for the disappearance of these compounds from aquatic system [33]. On the other hand, OPs are quickly degradable in aquatic environment, where the alkaline media accelerate their degradation [20]. Other factors such as microbial and organic matter content in water course effect on their residue levels. In the present study, chlorpyrifos, diazinon, fenitrothion and some pyrethroid pesticides were the mostly detected during summer and spring seasons. This concept is due to higher agricultural activities among El-Behira governorate arising much farmland runoff into Edku Lake.

Despite restrictions on the usage of these compounds in Egypt, the observed high concentration of them in aquatic environment explain either their persistence in the environment or migration from Nile River Basin countries. Locally, most investigators monitored OCs levels in sediments in Egyptian waters. For example, Mariut Lake Abu El-Amayem, *et al.* [34] and Saad, *et al.* [20], Qarun Lake Mansour, *et al.* [29] and Damietta region [30]. In worldwide, several studies demonstrated the occurrence of pesticides in aquatic environment. As mentioned in Lake Bosomtwi, Ghana [10], Oued Souss estuary, Morocco [35] and Lake Manyas, Turkey [31]. Residue levels of OCs were more than OPs. This concept is in agreement with that obtained by Abbassy, *et al.* [36]. They recorded OCs at all seasons in collected samples from Nile River, while dimethioate and malathion were the only detected among 36 organophosphorus pesticides checked. These findings stated that, the lake was still contaminated by OCs and their residues despite bans on the production and usage over a long time. The presence of pesticides and POPs in sediments follows the dynamics of their presence in the water. Also, their highly contents greater than in water explained by the concept that, the sediment can be generally considered as a purifier for the pollutants [37].

The variable concern of pesticide residue levels in tissues of tilapia fish due to changes of drainage effluents contents of chemicals during the study periods. The persistent of OCs in fish tissue referred to effluent outcome in the lake from runoff, sewage water and industrial discharges. Recently, sites 4 and 5 which lye near drains were contaminated more than other sites. In addition, the sedimentation of drainage effluents resulted in decrease of water quality among these sites of Edku Lake ending to accumulate of chemicals into the biota. The highly content of OCs in gills was more than those in flesh tissue may be associated with different factors. In aquatic environments, pesticides can enter into an organism for instance: a fish mainly *via* two pathways; bioconcentration directly through the water environment as showed in gill tissues [38] and or biomagnification through food web ways [39, 40]. Moreover, lipid content [41], depuration rates [38], size and exposure duration of organism Harding, *et al.* [42] as well as the structure of the food web [43] and the concentrations of chemicals are all potential factors influence on pesticides bioaccumulation. All findings obtained that, BCF values of examined pesticides are in range from 1000 to 4.0E04. These concepts indicate that POPs induced bioaccumulation in fish tissue attributing to predicted risk associated with this consumption. According to EU regulation 253/2011 [44], in the context of assessing persistent, bioaccumulative and toxic substances as well as very persistent and very bioaccumulative substances, substances are bioaccumulative with a BCF > 2.000 and very bioaccumulative with BCF > 5.000. Similarly, the Stockholm Convention regarded POPs with BCF > 5.000 as bioaccumulative [45]. On the other hand, the residue levels of most OCs were found upper the tolerance of international authorities. Several studies focused on human health risk associated with fish consumption: U.S [46], Canada [47], China [48], Hong Kong [49], Italy [50] and in Egypt [51]. There has been an increase in public concern that chronic low exposure to pesticide residues in food might pose a serious cancer risks to the general population [52]. While, epidemiological studies have often considered pesticides as causative agents in human cancer [53, 54]. Most of OCs is classified by EPA as B₂ carcinogen, based on the induction of malignant liver tumors in several strains of mice.

5. Conclusion

In a conclusion, we can summarize a concept employing that, Edku Lake represents reservoir of all pollutants coming from north governorate e.g. El-Behira. The untreated wastewater from examined drains imposed adversely hazardous to aquatic organisms into the lake. In addition, persistent pollutants are considered the main hazardous materials imposed the risk. The selected model, *Tilapia sp* fish is a good sentinel animal for evaluation environmental pollution of pesticides or others into Edku Lake. The residue levels which measured during the study period revealed levels upper regulation limits of international authorities. In addition, BCF provide information for assessing bioaccumulation potential of pesticides. This result may provide concept among adverse risk can be imposed for regional residents associated with consumption of caught fish in accordance with previous studies. So, we recommend to identify risk factors carefully. Additionally, remediation programs especially wastewater treatment must be carried out to minimize the adverse risks in this region.

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Figure-1. Map of Edku Lake represents sampling sites cited from (<http://earth.google.com>)

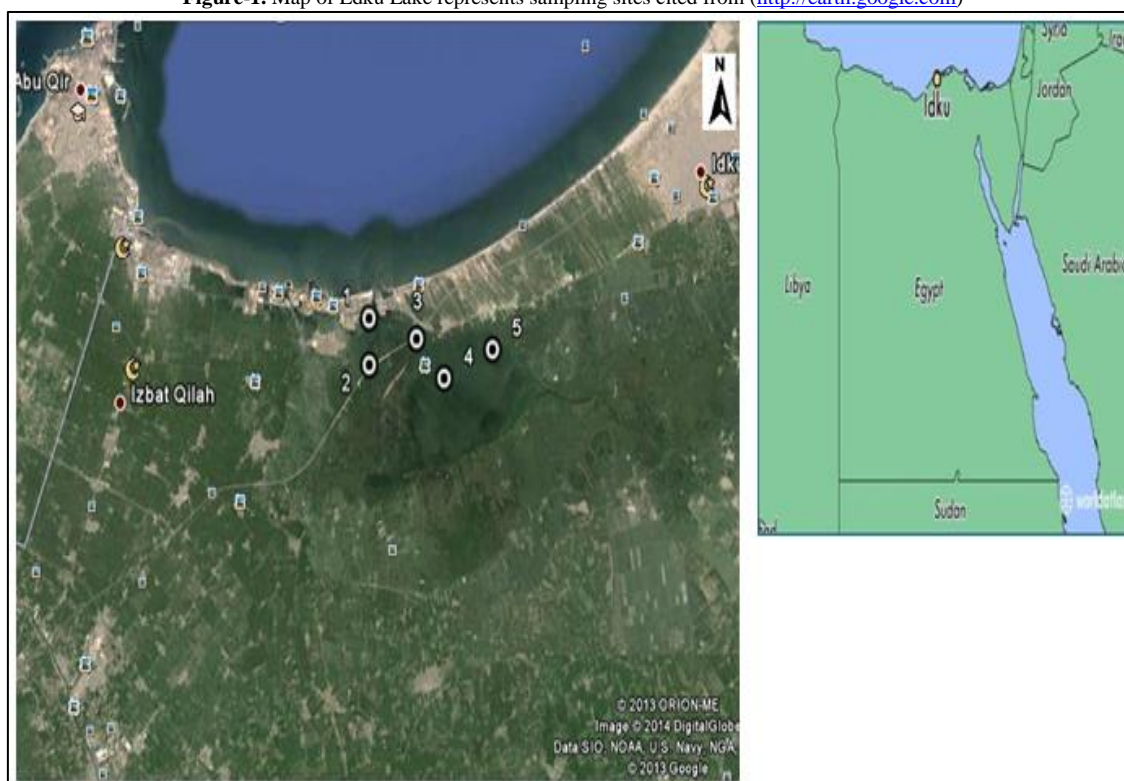


Figure-2. Residue levels of the total amount of Σ BHC, Σ cyclodienes, Σ DDT and Σ OPs in different samples collected from Edku Lake

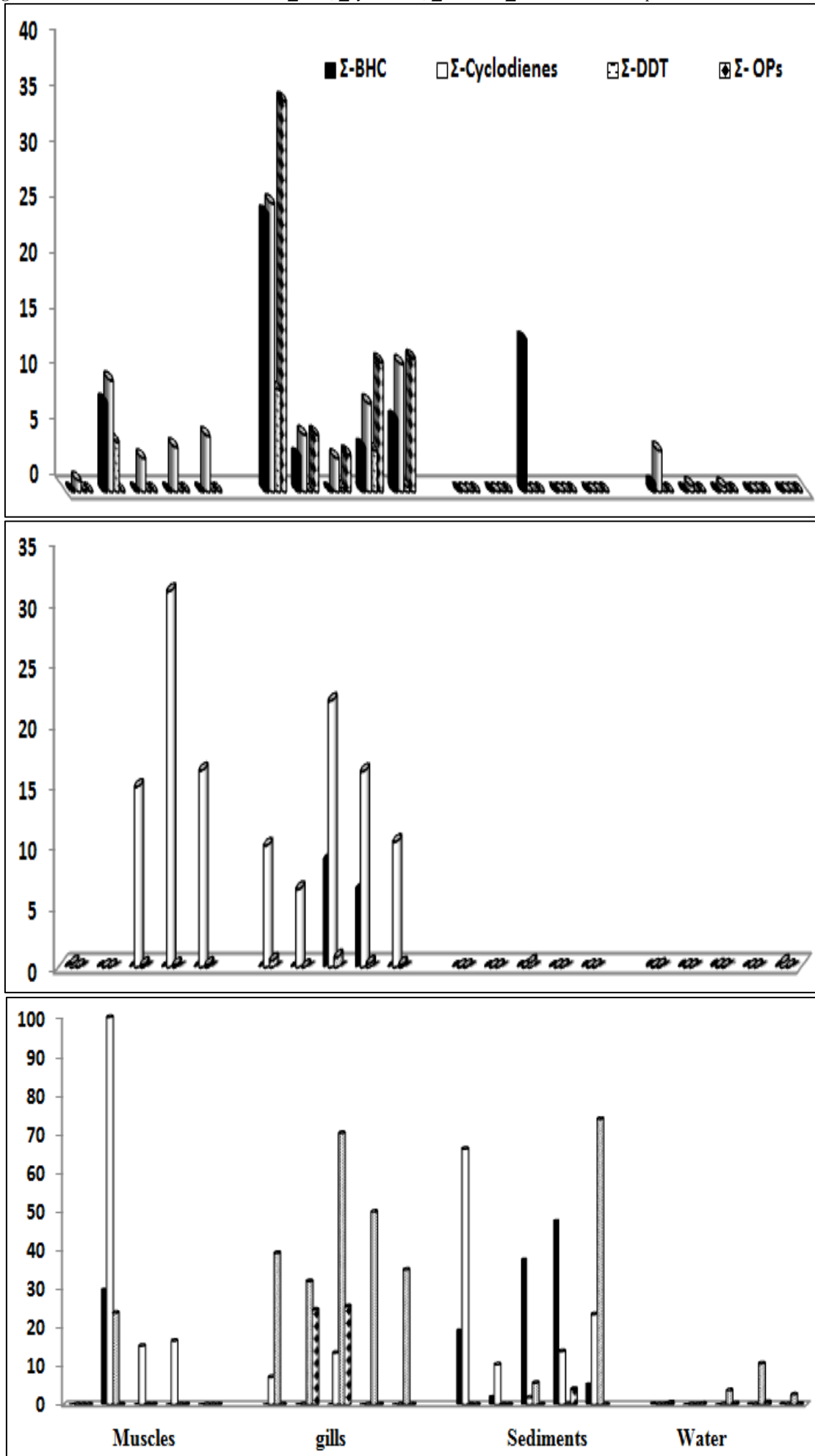


Table-1. Recovery Percentage, limit of detection (LOD) and retention times of measured OCs and OPs pesticides among using QuEChERS method

Pesticide	Fortified Level (ng)	Recovered level (ng)	% of Recovery	LOD (ng)	Retention time (min)
HCB	2	1.90	92.50	0.003	5.04
α -BHC	2	1.96	97.23	0.002	4.40
β -BHC	16	14.05	88.08	0.005	6.78
γ -BHC	2	1.97	97.30	0.003	5.7
Heptachlor	2	1.98	100.02	0.004	8.31
Aldrin	2	1.97	92.65	0.003	8.83
heptachlor epoxide	2	1.98	100.21	0.002	11.21
γ -Chlordane	4	3.51	86.86	0.005	11.96
Endrin	2	1.76	87.11	0.004	14.36
<i>P, P'</i> -DDE	2	1.98	98.03	0.002	13.16
<i>P, P'</i> -DDD	3	2.81	91.54	0.005	1.19
<i>P, P'</i> -DDT	4	3.74	94.54	0.006	16.23
methoxychlor	4	3.61	89.23	0.005	16.91
Ethoprophos	30	29.77	96.23	0.005	3.72
Phorate	35	30.07	83.90	0.005	4.29
Diazinon	38	37.95	97.87	0.005	5.47
Dimethoate	50	47.05	92.10	0.005	6.55
primiphos methyl	50	98.67	95.34	0.09	8.41
Chlorpyrifos	60	54.27	91.45	0.007	8.99
Fenitrothion	100	81.97	98.99	0.018	9.49
Quinelphos	80	76.28	81.97	0.013	11.56
Prothiophos	90	79.81	95.35	0.003	12.78
Fenamiphos	100	86.90	88.68	0.003	14.48
Ethion	100	87.57	86.90	0.012	15.82
Triazophos	100	87.56	87.56	0.008	18.15

QuEChERS = Quick, Easy, Cheap, Effective, Rugged and Safe technique. LOD= limit of detection

Table-2. Residue levels (ppb) of pesticides in aquatic media of Edku Lake and their bioaccumulation in Tilapia fish tissues

pesticide	Muscle (ppb)	Gills (ppb)	Water (ppb)	BCF Water/muscle	BCF Water/gills	Sediments (ppb)	BCF Sed./muscle	BCF Sed./gills
HCB	2035.08±62.62	44.75	0.050±0.02	40701.50	895.0	110.27±3.18	18.46	0.406
α -BHC	-	1042.04	2.000±0.03	-	521.02	2758.74±125.03	-	0.378
β -BHC	531.20±62.52	2293.80	66.75±1.58	7.96	34.36	5551.18±7.24	0.096	0.413
γ -BHC	1982.36±63.28	229.59	0.052±0.10	37403.1	4331.90	-	-	-
Heptachlor	485.64±4.34	948.84	6.53±0.20	74.37	145.31	879.61±19.45	0.552	1.079
Aldrin	2279.45±63.25	1368.20	-	2279.45	1368.26	5025.24±39.97	0.454	0.272
Hept. Epoxide	416.06±1.48	48.33	0.510±0.09	815.80	94.76	392.92±6.81	1.059	0.123
γ -Chlordane	647.52±1.43	94.22	0.040±0.01	16188.0	2355.50	-	-	-
Endrin	1073.18±175.27	359.92	2.790±0.47	384.65	129.00	1343.92±4.86	0.799	0.268
<i>P, P'</i> -DDE	523.52±52.15	198.56	6.510±0.72	80.42	30.50	24.37±1.37	21.482	8.148
<i>P, P'</i> -DDD	1106.98±7.69	2539.36	7.610±0.17	145.46	333.69	1338.05±5.28	0.827	1.878
<i>P, P'</i> -DDT	286.35±4.51	13277.05	0.056±0.16	5113.39	237090.17	3945.17±30.17	0.073	3.366
Methoxychlor	46175.05±63.25	13182.44	25.710±0.23	1795.99	512.74	-	-	-
Diazinon	-	2972.47	8.950±0.55	-	332.12	267.66±9.12	-	11.113
Chlorpyrifos	-	345.36	20.660±0.44	-	16.72	-	-	-
fentritrion	-	-	92.690±1.39	-	-	-	-	-

-Each value represents the mean of samples collected from five sites during selected seasons±SE

Table-3. Tolerance levels or maximum residue levels ($\mu\text{g}/\text{kg}$) for some pesticides in fish tissues

pesticide	Australia ^c	United States ^a	others	Canada ^b	Codex ^d
Aldrin/dieldrin	100	300	100	-	0.2
Chlordane	5.0	300	-	-	0.05
DDT, DDE, DDD	1000	5000	3000-7000	5000	5.0
heptachlor	5.0	300	-	-	0.2
HCB	100	-	100	-	0.2
Lindane	1000	-	1000	-	0.1
mirex	-	100	-	100	-

^a USFDA [55]; ^b CFIA [56]; ^c FSANZ [57] (extraneous residue limits in Australia) and ^d FAO [58]