Organochlorine pesticide residues in farmed fish in Machakos and Kiambu counties, Kenya

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Abstract: This study was conducted to evaluate occurrence of organochlorine pesticide residues in Oreochromis niloticus fish reared by aquaculture in Kiambu and Machakos Counties. A total of 213 fish organ samples were analyzed for organochlorine pesticide residues from Kiambu and Machakos Counties in Kenya using gas–liquid chromatography. Overall, beta-hexachlorocyclohexane (BHC) group, the cyclodiens, aldrin, heptachlor, dieldrin, endrin and the Dichlorodiphenyltrichloroethane (DDT) group of compounds were detected in fish samples. p,p′-DDT and its metabolite p,p′-DDD were detected in the muscle, liver and gonad and their concentration ranged between not detectable (ND) to 0.916 μg kg⁻¹ for p,p′-DDT and ND to 1.684 μg kg⁻¹ for p,p′-DDD. Brain had the highest concentration of DDT metabolites o,p′-DDT (2.098 ± 4.097 μg kg⁻¹) and p′-p′-DDD (1.684 ± 3.666 μg kg⁻¹). Organochlorine pesticide residues were generally higher in Kiambu County compared to Machakos County but there was no significant difference. The residue levels of organochlorines in all fish samples analyzed were lower than the benchmark levels set by FAO, FDA, and NAS/NAE.

Subjects: Bioscience; Environmental & Ecological Toxicology; Toxicology

Keywords: organochlorines; residues; farmed fish; gas liquid chromatography

ABOUT THE AUTHORS
The authors’ key research activities include research in general toxicology, environmental toxicology and ecotoxicology. The authors also have interest in toxicological characterization for chemicals and agents of public health concern, especially those that gain entry into the body through oral route hence posing a challenge to food safety. Other areas include pharmacology and ethnopharmacology.

The current paper contributes to findings recorded in the field of environmental toxicology, especially pesticides and heavy metal toxicology in aquatic environment and their possible effects on both the target (bio indicator) organism and their possible consequences to public health.

PUBLIC INTEREST STATEMENT
Our diet determines our health, quality, and length of life. Fish have long been known as a cheap source of proteins for most of the global population and particularly in developing countries in contrast to the more expensive meat, poultry, and eggs. Apart from being a good source of digestible protein, vitamins, minerals, and polyunsaturated fatty acids, fish are also a source of environmental contaminants like pesticides. This study was conducted to evaluate occurrence of organochlorine pesticide residues in Oreochromis niloticus fish reared by aquaculture in Kiambu and Machakos Counties, Kenya. It shows that organochlorine pesticides, although present in small concentrations do not pose a health hazard to fish consumers in both counties since they are lower than the benchmark levels. The study also indicates that some farmers could still be using some banned or restricted organochlorines like lindane and DDT illegally.
1. Introduction

Aquaculture is one of the fastest growing food production activities in the world (FAO, 1997). Production volumes continue to increase in developing countries, and the number of countries involved as well as the variety of species under culture continues to expand (FAO, 1997). In Kenya, the aquaculture sector has been prioritized by the government to benefit from the economic stimulus program in order to contribute to economic recovery and attainment of vision 2030. Although inland fish is fast becoming established in Kenya, there is little information regarding the safety of the end product and hence potential hazard to humans. Several chemical contaminants enter the aquatic ecosystem through run-offs from agricultural fields, ponds, streams, and rivers that eventually drain into lakes. Previous studies in Kenya had shown cases of organochlorine pesticide residue in fish from Kenyan lakes (Koeman, 1972; Lincer, Zalkind, Brown, & Hopcraft, 1981; Mugachia, Kanja, & Gitau, 1992; Mwangi, 2003; Wandiga, Yugi, Barasa, Jumba, & Lalah, 2002).

Organochlorine (OC) pesticides like DDT, dieldrin, aldrin, and lindane (used between 1940’s until late 1970’s and are now banned for use in Kenya) were desirable due to their availability at low cost, broad spectrum, long residue effect, and low toxicity. Due to their chemical characteristics, the uses of these chemicals have led to environmental pollution where they are known to exert detrimental effects in non-target organisms through sub lethal exposure and chronic toxicity (Sankar, Zynudheen, Anandan, & Viswanathan Nair, 2006). Organochlorines are now classified as persistent organic pollutants and bioaccumulate in the food chain, thus posing the highest risk on the animals at the top of the food chain (Sankar et al., 2006). Though many persistent OCs are restricted or banned in developed countries, they are still produced and used in many developing countries (Sankar et al., 2006).

The use of chemical pesticide is still indispensable in Kenya due to the hot and humid tropical environmental conditions that are conducive to the development of pests, weeds, and disease vectors. The public health sector in Kenya also depends heavily on pesticides to control vector—borne diseases such as malaria, sleeping sickness, bilharziasis, and filariasis through pesticide spray program aimed at controlling disease vectors such as mosquitoes, tsetse flies, and water snails. Studies have reported that only 5% of the sprayed chemicals actually reach the targeted organisms, with the remaining 95% drifting to surrounding areas and eventually becoming environmental contaminants (Panagiotis & Wei, 2008).

Despite the benefits accrued, pesticides have harmful effects; they can cause injury to human health as well as to the environment. The range of these adverse health effects includes acute and persistent injury to the nervous system, lung damage, injury to the reproductive organs, dysfunction of the immune and endocrine systems, birth defects, and cancer (Mansour & Sidky, 2004). The pesticides mainly exert their detrimental effects on non-target organisms through chronic toxicity and sub-lethal exposure. DDT and its metabolites cause microsomal enzyme induction, egg-shell thinning in birds and tumor induction. DDT also reduces the reproductive success of birds and fish. Aldrin and dieldrin are potentially carcinogenic, while lindane and other hexachlorohexane (HCH) isomers produce liver tumors in mice (Mugachia, Kanja, & Maito, 1992).

This study sought to determine pesticide residue concentration in edible fish samples collected from ponds in Machakos and Kiambu Counties in Kenya and compare them with the WHO guidelines so as to assess potential health hazard. The study was also aimed at assessing environmental pollution due to organochlorines.

2. Materials and methods

2.1. Study area

This study was carried out in Kiambu and Machakos counties in Kenya. Kiambu county is in the central province of Kenya, where fish farming and consumption are not traditional practices (Figure 1). The area borders Nairobi city where there is a lucrative market for fish. The county covers an area of
1,323.9 km². It borders Nairobi city and Kajiado district to the south, Nakuru district to the west, Nyandarua district to the northwest and Thika to the east. The county lies between latitudes 0°75′ and 1°20′ South of equator and longitudes 36°54′ and 36°85′ East.

Machakos is in a semi-arid agro-ecological zone with no history of fish farming or consumption (Figure 2). Since water is scarce, its cost is higher than that in Kiambu county. The county borders Nairobi city and Thika district to the northwest, Kitui and Mwingi districts to the east, Kajiado district to the west, Makueni county to the south, Maragwa district to the north and Mbeere district to the northeast. It stretches from latitudes 0°45′ South to 1°31′ South and longitudes 36°45′ East to 37°45′ East. The two counties were among the counties that were allocated funds from the economic stimulus package which aimed at construction of 200 fish ponds in each constituency. The analysis was conducted at the Department of Public Health, Pharmacology and Toxicology, University of Nairobi.

2.2. Fish sampling
A total of 213 Tilapia (Oreochromis niloticus) fish samples were obtained from 60 fish ponds in study areas in September 2011. The fish were caught by gill nets. In Kiambu County, 125 fish were sampled from 30 fish ponds, while 88 fish were sampled from Machakos county and a sample of muscle, liver,
brain, and gonads were taken from each fish. Size of fish ranged from 6.5 to 28.3 cm in length. Organ samples from the same pond that weighed below 3.0 g were pooled together for analysis.

The tissues were weighed, wrapped in aluminum foil and immediately transported on ice to the Department of Public Health, Pharmacology and Toxicology, University of Nairobi for analysis. For long term storage the tissues were weighed and frozen at −20°C. A structured questionnaire was administered during sampling to capture details on the previous land use and the nature of the ponds.

2.2.1. Sample analysis
Extraction clean-up and analysis of organochlorine pesticide residues of the solid tissues (liver, brain, muscle and gonads) was done according to Kanja, Skåre, Nafstad, and Maitai (1986). Briefly, 3.0 g of each sample was ground together with 4.4 g of acid washed sea sand and 4.5 g of anhydrous sodium sulfate (Na₂SO₄). The pesticide in 4 g of the homogenate was extracted through a glass column with diethyl ether (15 ml) into a weighed centrifuge tube. The eluent was evaporated in a sand bath at 50°C.

The fat was weighed and redissolved in hexane (0.05 g fat/ml). Two aliquots of the different hexane extracts were subjected to acid and base cleanup using concentrated sulfuric acid and methanolic potassium hydroxide, respectively. About 1 μl of the analyte was injected into a GC- 2014 Shimadzu Gas Chromatograph fitted with a 30 m long Zebron ZB – 170 IP analytical column with an internal diameter of 0.25 mm × 0.25 μm. Oven program used was 100–200°C at 25°C/min and then to 240°C at 6°C/min and then finally to 265°C @ 20°C/min for 5 min.

Nitrogen gas was used as the carrier gas at a flow rate of 1.6 ml/min and the compounds were detected by Electron capture detector ECD 63Ni at a temperature of 300°C. About 1 μl of the chlorinated pesticide mixture (CPM) No.T796066 ©1997 Sigma-Aldrich company) was used as the standard which is a mixture of 13 organochlorines (OC). Injection of the standard was repeated for replicability. The organochlorine compounds were identified by analyses of both acid and alkali treated hexane fractions on GC columns, and their retention times compared to those of the standards. Analytical quality assurance was done to check on the efficiency of the analytical method and reproducibility of the results by carrying out recovery tests. Fish samples were fortified with known quantities of the pesticides under investigation. The limit of pesticide residue was 0.001 mg/kg calculated on wet weight basis.

Percentage recoveries were calculated and evaluated according to UNEP/WHO criteria for evaluation of pesticide recovery results (1980). High recovery rates were obtained using solvent–solvent extraction method. The average recovery rates for the analyzed pesticides were α-HCH 95.55%, β-HCH 94.23%, γ-HCH 96.62%, p,p′-DDT 97.53%, α,p′-DDE 97.21%, p,p′-DDD 98.32%, aldrin 88.62%, and dieldrin 97.23%. These were good recoveries in relation to the recommended rate that ranges between 70 and 120%.

External standard calibration was used to determine peak areas from the samples. Quality control and quality assurance procedures included replicate sampling, extraction, and analysis for all the samples.

Data from the two counties was subjected to descriptive statistics and analysis of variance (ANOVA) to test levels of significance at 95% confidence limit using Statistical Analysis Software (SAS) 9.0 version (SAS Institute Inc, Carolina).

3. Results
The recoveries obtained ranged from 80 to 104% and this was found to be within the acceptable range for pesticide residue analysis according to UNEP/WHO criteria for evaluation of pesticide recovery results (1980).
3.1. Levels of organochlorine pesticides in fish from Kiambu county

One hundred and twenty-five (125) organ samples from Kiambu County were analyzed for organochloride pesticides. 30 (24%) were muscle, 31 (24.8%) liver, 33 (26.4%) samples, and 31 (24.8%) brain samples.

\(p, p'-\text{DDT}\) and its metabolite \(p, p'-\text{DDD}\) were the only compounds detected in all the four tissues, i.e. muscle, liver, gonad and brain. They ranged between ND (limit of detection = 0.001 \(\mu\)g kg\(^{-1}\)) to 0.916 \(\mu\)g kg\(^{-1}\) for \(pp'-\text{DDT}\) and ND to 1.684 \(\mu\)g kg\(^{-1}\) for \(p, p'-\text{DDD}\). The other compounds were found in one, two, or three of the tissues analyzed.

\(o, p'-\text{DDD}\) had the highest concentration of 2.098 ± 4.097 \(\mu\)g kg\(^{-1}\) in the brain followed by \(p, p'-\text{DDD}\) 1.684 ± 3.666 \(\mu\)g kg\(^{-1}\) in the brain tissue (Table 1).

### Table 1. Mean concentration of organochlorine pesticide levels (\(\mu\)g kg\(^{-1}\)) ± SD in various fish organs in Kiambu county

| Organochlorine | Muscle       | Liver          | Gonad         | Brain          |
|----------------|--------------|----------------|---------------|----------------|
| \(\alpha\)-HCH | ND           | 0.236 ± 0.266  | 0.383 ± 0.15  | 0.025 ± 0.024  |
| \(\gamma\)-HCH | 0.072 ± 0.011| 0.013 ± 0.033  | 0.169 ± 0.45  | 0.022 ± 0.046  |
| \(\beta\)-HCH  | ND           | ND             | ND            | ND             |
| Heptachlor     | 0.067 ± 0.080| ND             | ND            | ND             |
| Aldrin         | ND           | ND             | ND            | 0.172 ± 0.241  |
| Heptachlor epoxide | ND     | 0.018 ± 0.025  | 0.003 ± 0.002 | 0.038 ± 0.068  |
| \(pp'-\text{DDE}\) | 0.001       | ND             | 0.017 ± 0.016 | 0.028 ± 0.034  |
| Dieldrin       | 0.071 ± 0.075| 0.086 ± 0.089  | 0.012 ± 0.073 | 0.028 ± 0.034  |
| \(op'-\text{DDD}\) | 0.032 ± 0.043| 0.015          | 0.016 ± 0.015 | ND             |
| Endrin         | 0.04 ± 0.050 | ND             | ND            | ND             |
| \(op'-\text{DDT}\) | ND         | 0.02 ± 0.024   | 0.116 ± 0.254 | 2.098 ± 4.097  |
| \(pp'-\text{DDD}\) | 0.916 ± 1.287| 0.151 ± 0.314  | 0.116 ± 0.254 | 1.684 ± 3.666  |
| \(pp'-\text{DDT}\) | 0.916 ± 1.916| 0.151 ± 0.314  | 0.274 ± 0.648 | 0.122 ± 0.220  |

Note: ND: Not detected/below detection limit.

### Table 2. Concentration of organochlorine pesticide (\(\mu\)g kg\(^{-1}\)) ± SD levels in various fish organs in Machakos county

| Organochlorine | Muscle       | Liver          | Gonad         | Brain          |
|----------------|--------------|----------------|---------------|----------------|
| \(\alpha\)-HCH | ND           | ND             | 0.013 ± 0.19  | 0.011          |
| \(\gamma\)-HCH | 0.013 ± 0.008| 0.073 ± 0.01   | 0.017 ± 0.029 | 0.029 ± 0.041  |
| \(\beta\)-HCH  | ND           | ND             | ND            | ND             |
| Heptachlor     | ND           | 0.014 ± 0.016  | ND            | ND             |
| Aldrin         | ND           | ND             | ND            | 0.035          |
| Heptachlor epoxide | ND     | 0.02 ± 0.005   | ND            | 0.05           |
| \(pp'-\text{DDE}\) | 0.004       | 0.035 ± 0.018  | 0.037         | 0.014 ± 0.150  |
| Dieldrin       | 0.057 ± 0.081| ND             | ND            | 0.009          |
| \(op'-\text{DDD}\) | 0.051 ± 0.056| 0.132          | 0.046 ± 0.015 | ND             |
| Endrin         | ND           | ND             | ND            | ND             |
| \(op'-\text{DDT}\) | ND         | 0.016 ± 0.016  | 0.033 ± 0.016 | 0.029          |
| \(pp'-\text{DDD}\) | 0.003 ± 0.004| 0.034 ± 0.009  | 0.032 ± 0.016 | 0.097 ± 0.012  |
| \(pp'-\text{DDT}\) | 0.005       | 0.158 ± 0.183  | 0.025 ± 0.019 | 0.024 ± 0.033  |

Note: ND: Not Detected/below limit of detection.
Lindane had the highest frequency of occurrence and was detected in 36 samples (16.9%) with a mean concentration of 0.723 ± 0.011, 0.013 ± 0.033, 0.169 ± 0.45, and 0.022 ± 0.046 in muscle, liver, gonad, and brain, respectively.

3.2. Levels of organochlorine pesticides in fish organs from Machakos county

Out of the eighty-eight (88) samples analyzed from Machakos County; 22 (25%) were muscle, 22 (25%) liver, 21 (23.9%) gonad, and 23 (26.1%) brain samples.

Lindane, pp-DDE, pp-DDD and pp-DDT were the only residues detected in all the four samples, i.e. muscle, liver, gonad, and brain. p, p’-DDT had the highest concentration and ranged between ND (detection limit = 0.001 µg kg⁻¹) to 0.158 µg kg⁻¹ (Table 2).

4. Discussion

p, p’-DDT and its metabolite p, p’-DDD were the only compounds detected in all the four tissues, i.e. muscle, liver, gonad, and brain in Kiambu county. They ranged between not detectable (limit of detection = 0.001 µg kg⁻¹) to 0.916 µg kg⁻¹ for p, p’-DDT and not detectable to 1.684 µg kg⁻¹ for p, p’-DDD. The other compounds were found in one, two, or three of the tissues analyzed.

Lindane had the highest frequency of occurrence and was detected in 36 samples (16.9%) with a mean concentration of 0.723 ± 0.011, 0.013 ± 0.033, 0.169 ± 0.45, and 0.022 ± 0.046 in muscle, liver, gonad and brain, respectively, in Kiambu county. This was followed by α, p’-DDT 25 (11.74%), dieldrin in 24 (11.27%), α-BHC was detected in 19 samples (8.92%), α, p’-DDD was detected in 16 samples (7.51%) heptachlor was in 11 samples (5.16%), heptachlor epoxide was detected in 11 samples (5.16%), p, p’-DDE was in 10 samples (4.69%), aldrin was detected in 3 samples (1.41%).

In Machakos county lindane, p, p’-DDE, p, p’-DDD, and p, p’-DDT were the only samples detected in all the four organ samples, i.e. muscle, liver, gonad, and brain. The other compounds were found in one, two or three of the tissues analyzed. Lindane had the highest frequency of occurrence (16.9%) followed by p, p’-DDT (13.15%), p, p’-DDD (12.68%), α, p’-DDT (11.74%), dieldrin (11.27%), α-BHC (8.92%), heptachlor epoxide (5.63%), heptachlor (5.16%), p, p’-DDE (4.69%), aldrin (1.41%), and endrin (0.94%) in that order.

Based on the objectives of this study, comparison with previous studies was constrained by the fact that very few studies on organochlorine residues in farmed fish have been reported.

In this study, the organochlorine pesticide residues were generally higher in Kiambu County compared to Machakos County. This could be due to the fact that Kiambu County is a high potential area in agriculture and there is a possibility of OC use in the past. Another reason could be leaching and surface run-off since 68% of the ponds in Kiambu County were earth ponds as compared to 45% in Machakos County (Figure 3). Further, 89.3% of land on which ponds were constructed in Kiambu County was previously used for growing crops compared to 86% in Machakos County (Figure 4).
High residue levels were detected in brain tissues in both counties followed by the gonads, liver, and muscle. This could be attributed to the lipid content of the organs since organochlorine pesticides are lipophilic and tend to accumulate in tissues with high fat content that are characterized by low turn-over rates (Borrell & Aguilar, 2007).

Lindane (BHC isomers) and DDT and its metabolites had the highest frequency of detection in all samples analyzed. This may be an indication that some farmers might be illegally using DDT and lindane or persistence from previous application. Lindane was initially used for seed dressing to protect crops against termites and livestock as a cattle dip. However, its agricultural use has been banned in the country due to persistence and toxicity to the untargeted organisms.

DDT and its metabolites were the second highest in frequency although we can attribute this to recent input from anthropogenic sources since the concentration of \( p, p'-\text{DDD} \) was lower than the original compound \( p, p'-\text{DDT} \). With a half-life of 10–20 years in temperate regions, (Sericano, Wade, Atlas, & Brooks, 1990), and about 3 months in the tropics (Wandiga et al., 2002), DDT undergoes degradation to DDE and DDD. The DDE accounts for 50–70% of the DDT burden in the environment (Newsome & Andrews, 1993). In addition, the levels detected in this study were lower than those reported earlier in fish from Lake Victoria (Mugachia et al., 1992; Wandiga et al., 2002).

Dieldrin was detected in 24 (11.27%) samples, while aldrin was detected in 3 samples (1.41%). Aldrin (1,2,3,4,10,10-hexachloro-1,4,4a,5,8a-hexahydro-1, 4-endo-exo-5, 8-dimethanonaphthalene) is metabolized to dieldrin. Aldrin and dieldrin have both been used in the country in the past as insecticides and for termite control on wood, but aldrin has also been used in seed dressing. Based on the detected residues of dieldrin, which were higher than those for aldrin, the occurrence may be attributed to the previous use of aldrin and dieldrin in the two regions. A previous study of pilot lakes in Uganda reported a dieldrin concentration in the whole fish of 5 \( \mu \text{g kg}^{-1} \) (Sserunjogi, 1974), while another in Winam gulf, Lake Victoria reported an average of 0.83 \( \mu \text{g kg}^{-1} \) (Calamari, Akech, & Ochumba, 1995). These levels are higher than the ones in the current study.

Heptachlor has been in use as an insecticide and its metabolite, heptachlor epoxide, is more persistent, and occurs as an impurity in technical grade chlordane, which also has been used as an insecticide. Heptachlor was in 11 samples (5.16%) with a mean concentration (\( \mu \text{g kg}^{-1} \)) of 0.067 ± 0.08 in muscle and a range between not detectable to 0.067 \( \mu \text{g kg}^{-1} \). Heptachlor epoxide was detected in 11 samples (5.16%) and ranged between ND and 0.038 \( \mu \text{g kg}^{-1} \) and a mean concentration (\( \mu \text{g kg}^{-1} \)) of 0.018 ± 0.025, 0.003 ± 0.002, and 0.038 ± 0.068 in liver, gonad, and brain in Kiambu County.

The residue levels reported in this study were lower than those reported in marine environment at the Kenyan coast by Wandiga et al. (2002) and Getenga, Keng’ara, and Wandiga (2004) in Lake Victoria basin. The difference could be attributed to variations in geographical locations, time differences in terms of the period of study and the extent of previous use of these pesticides. DDT has been banned for agricultural use in Kenya, but is now restricted for public health use.
In comparison to studies carried out in other countries reported lower frequencies of organochlorine pesticide residues of \( p,p' \)-DDT (25%); \( p,p' \)-DDE (37%) during dry season, and higher frequencies of \( p,p' \)-DDT (81%); \( p,p' \)-DDE (100%) and \( \gamma \)-HCH (6%) in samples from the coastal area of Dar es Salaam, Tanzania. The concentrations of dieldrin and \( p,p' \)-DDD were notably higher than aldrin and \( p,p' \)-DDT, respectively, in most of the samples. Since the later are their degradation products, this indicated possible transformation process taking place on \( p,p' \)-DDT and aldrin previously in the region. Organochlorines pose potential health hazard and therefore maximum residual limit has been recommended for human consumption by various agencies. FAO recommends a level of 300 \( \mu g \) kg\(^{-1}\) or 300 ng g\(^{-1}\) as maximum acceptable limit for DDT while Canadian limit is 500 \( \mu g \) kg\(^{-1}\) (Mwevura, Othman, & Mhehe, 2002).

The Food and Drug Administration (2001) limits are 5,000 \( \mu g \) g\(^{-1}\) for DDT and 300 \( \mu g \) g\(^{-1}\) for Aldrin, Dieldrin, chlordane, and benzene hexachloride, and heptachlor, heptachlor epoxide in edible portion of fish while National Academy of Sciences and National Academy of Engineering (NAS/NAE, 1972) recommends a limit of 1,000 \( \mu g \) g\(^{-1}\) for dieldrin, endrin, heptachlor, and chlordane. From a public health point of view, residue levels of organochlorines in all fish samples analyzed in this study are considerably lower than these recommended levels and therefore may not pose a health risk to the populace consuming fish from Machakos and Kiambu counties.

5. Conclusion

The concentration levels of organochlorine pesticides found in this study were below the extraneous residue limits set by FDA (2001) and NAS/NAE (1972). Based on these set standards, the fish from inland fish farming (ponds) were found fit for human consumption. Lindane had the highest frequency of occurrence. This is an indication that some farmers might be illegally using lindane. However, the levels were low suggesting rapid degradation of the pesticides in the tropical climate.

The ratio of DDT to that of its metabolite DDE found in this study suggests current use of DDT in the study area hence more strict control measures against the use of these compounds need to be put in place.

Considering the previous and present use of some chlorinated hydrocarbons in agriculture and for vector control in Kenya and East Africa in general, the levels of pesticide residues found in this study were very low. These low levels suggest a high degradation rate of OCs in the tropical environment.

Other researchers have found variations in pesticide dynamics in tropical and subtropical environment compared with temperate environment (Laabs, Amelung, Pinto, Altstaedt, & Zech, 2000; Pandit et al., 2001). However, due to their bioaccumulation and their ubiquitous nature resulting from global transport and redistribution, the use of Organochlorines has global implications making their use unsuitable even in the tropical climate.

Since the levels of organochlorines levels in aquatic environment vary from season to season, we recommend that further research be conducted in both rainy and dry season to establish if there is any significant difference in the concentration of these contaminants in fish and other aquatic organisms in aquaculture.

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References
Borrell, A., & Aguilar, A. (2007). Organochlorine concentrations declined during 1987–2002 in western Mediterranean bottlenose dolphins, a coastal top predator. Chemosphere, 66, 347–352. http://dx.doi.org/10.1016/j.chemosphere.2006.04.074
Calamari, D., Akech, M. O., & Ochumba, P. B. (1995). Pollution of Winam Gulf, Lake Victoria, Kenya: A case study for preliminary risk assessment. Lakes and Reservoirs: Research and Management, 1, 89–106. http://dx.doi.org/10.1111/j.1931-133X.1995.1.issue-2
FAO. (1997). Aquaculture production. FAO Year Book of Fishery Statistics, 92, 186. Rome: FAO 2003.
Food and Drug Administration (FDA). (2001). Environmental chemical Contaminant and pesticide tolerances, action levels and guidance levels for fish and fishery products (Compliance Policy Guide Sec.575.100. Pesticide Chemical Residues in Food – Enforcement Criteria, CPG 7141.101).
Getenga, Z. M., Keng’ara, F. O., & Wandiga, S. O. (2004). Determination of organochlorine pesticide residues in soil and water from river Nyando drainage system within Lake Victoria Basin, Kenya. Bulletin of Environmental Contamination and Toxicology, 72, 335–343. http://dx.doi.org/10.1007/s00128-003-9107-3
Kanja, L. W., Sköre, J. U., Nafstad, I., & Maitai, C. K. (1986). Organochlorine pesticides in human milk from different areas of Kenya 1983–1985. Journal of Toxicology and Environmental Health, 19, 449–464. http://dx.doi.org/10.1080/15287398609530944
Koeman, J. H. (1972). A preliminary survey of the possible contamination of Lake Nakuru in Kenya with some metals and chlorinated hydrocarbon pesticides. The Journal of Applied Ecology, 9, 411–416. http://dx.doi.org/10.2307/2402441
Loabs, V., Amelung, W., Pinto, A., Alstooedt, A., & Zech, W. (2000). Leaching and degradation of corn and soybean pesticides in an Oxisol of the Brazilian Cerrados. Chemosphere, 41, 1441–1449. http://dx.doi.org/10.1016/S0045-6535(99)00546-9
Lincer, J. H., Zolkind, D., Brown, L. H., & Hopcraft, J. (1981). Organochlorine residues in Kenya’s Rift valley lakes. The Journal of Applied Ecology, 18, 157–171. http://dx.doi.org/10.2307/2402486
Mansour, S. A., & Sidky, M. M. (2004). Ecotoxicological studies. 3: Heavy metals contaminating water and fish from Fayoum Governorate, Egypt. Food Chemistry, 78, 15–22.
Mugachia, J. C., Kanja, L., & Gitau, F. (1992). Organochlorine pesticide residues in fish from Lake Naivasha and Tana River, Kenya. Bulletin of Environmental Contamination and Toxicology, 49, 207–210. New York, NY: Springer-Verlag.
Mugachia, J. C., Kanja, L., & Maithe, J. (1992). Organochlorine pesticides in Estuarine pesticides in Estuarine fish from the Athi River, Kenya. Bulletin of Environmental Contamination and Toxicology, 49, 199–206.
Mwangi, C. M. (2003). Quality of Lake Victoria Nile Perch (Lates niloticus) at the landing facility as a potential microbiological and organochlorine pesticide residue hazards critical control point (MSc Thesis). University of Nairobi, Nairobi.
Mwevura, H., Othman, O. C., & Mhehe, G. L. (2002). Organochlorine pesticide residues in waters from the coastal area of Dar ES salaam and their effect on aquatic biota. Tanzania Journal of Science, 28, 117–130.
NAS/NAE. (1972). Water quality criteria 1972. Washington, DC: National academy of sciences, national academy of engineering, US environmental inspection agency R3 73 033.
Newsome, W. H., & Andrews, P. (1993). Organochlorine pesticides and polychlorinated biphenyl congeners in commercial fish from the Great Lakes. Journal of AOAC International, 76, 707–710.
Panagiotis, E., & Wei, L. (2008). Biodegradation behavior of agricultural pesticides in anaerobic pesticides in Estuarine fish from the Athi River, Kenya. Bulletin of Environmental Contamination and Toxicology, 49, 199–206.
Pandit, G. G., Mohan Rao, A. M., Jha, S. K., Krishnamoorthy, T. M., Kale, S. P., & Raghu, K. (2001). Monitoring of organochlorine pesticide residues in the Indian marine environment. Chemosphere, 44, 301–305. http://dx.doi.org/10.1016/S0045-6535(00)00179-X
Sencar, T. V., Zynudheen, A. A., Anandan, R., & Viswananthan Noir, P. O. (2006). Distribution of organochlorine pesticides and heavy metal residues in fish and shellfish from Calicut region, Kerala, India. Chemosphere, 65, 583–590. http://dx.doi.org/10.1016/j.chemosphere.2006.02.038
Serciano, J. L., Wade, T. L., Atlas, E. L., & Brooks, J. M. (1990). Historical perspective on the environment availability of DDT and its derivatives to Gulf of Mexico oysters. Environmental Science & Technology, 24, 1541–1548.
Sserunjogi, J. M. (1974). A study of organochlorine insecticide residues in Uganda, with special reference to dieldrin contamination (IAEA Techical Report SM-175).
Vienna: IAEA.
Wandiga, S. O., Yugi, P. O., Bora, M. W., Jumba, I. O., & Lalai, J. O. (2002). The distribution of organochlorine pesticides in marine samples along the Indian Coast of Kenya. Environmental Toxicology, 23, 1235–1246.