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Overview of Levels of Organochlorine Pesticides in Surface Water and Food Items in Nigeria

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Abstract
Consumption of contaminated food is one of the main routes of human exposure to pesticides. Also, surface water plays an important role in long range transport of pesticides. Persistent organic pesticides are categories under Persistent Organic Pollutants (POPs) which are organic compounds that are resistant to environmental degradation and as a result of their persistence, bioaccumulate with potential significant impacts on human health and the environment. The persistent organochlorine pesticides (OCPs) have been listed by Stockholm Convention for elimination globally. Despite the ban, some OCPs are still used illegally in developing countries. Also, from other sources, OCPs find their way into water bodies. This review therefore investigates the current levels of OCPs in surface water and food items in Nigeria and environmental/human health implications. The methodology was mainly by review of available literatures. The results were discussed in the context of criteria that designate a substance as POP, as well as in the context of allowed limit levels. Levels reported from several studies in Nigeria exceeded the water-quality criteria for surface water and maximum residue limit for food. The illegal use may be the likely sources of these pollutants in the Nigerian environment. Aquatic organisms stand the risk of acute or chronic toxicity while human health is at risk of adverse effect through consumption of contaminated food or use of polluted surface water for domestic activities. There is need for enforcement of appropriate policy to safeguard the environment and human health.
Keywords: organochlorine pesticides, persistent organic pollutants, surface water, food items

1. Introduction

Pesticides are any substance or mixture of substances intended for preventing, destroying or controlling any pest, including vectors of human or animal disease, unwanted species of plants or animals causing harm during or otherwise interfering with the production, processing, storage or marketing of food, agricultural commodities, wood and wood products or animal food stuffs or which may be administered to animals for the control of insects, arachnids or other pests in or on their bodies (Hashmi and Khan, 2011). One category of pesticides is organochlorine pesticides (OCPs) which are toxic, persistent, bioaccumulative and have potentials for long-range atmospheric transport (Kumar et al., 2012).

Applications of synthetic pesticides in Nigeria started in 1950s (Adeyeye and Osibanjo, 1990). In addition to broad applications of synthetic pesticides for control of disease vectors like tsetse flies and mosquitoes, farmers in Nigeria have been using them for control of weeds; weevils of cotton, beans and cereals; borers of plant stalks and yams (Ogunfowokan et al., 2012). There are indications that the banned pesticides are still in use in the country. And if not checked, there may be contamination of water and food which may result in human poisoning.

Globally, approximately three million people are poisoned and 200,000 died each year from pesticide poisoning, and a majority of them belongs to the developing countries (Sarkar et al., 2008). Among others, environmental/health concerns are exposure during pregnancy, transport across the placenta, gestational weight gain and new born head circumference, cardiovascular disease and cancer, obesity and diabetes (Wikipedia, 2016a).

However, despite the potential environmental/health hazard, government efforts and legal instruments in place, activities involving the use of banned POPs, especially the OCPs, still continue in the country. There is therefore the need for broader assessment of banned OCPs in developing countries, Nigeria in particular. This will provide the scope of exposure and extent of human and environmental health risks. This review therefore aims at assessing the levels of organochlorine pesticides in food and surface water in Nigeria.

2. Methodology

The methodology was mainly by review of available literatures. The results were discussed in the context of criteria that designate a substance as POP, as well as in the context of allowed limit levels (Tables 1 and 2).

Table 1. EPA ambient water-quality criteria for aquatic organisms

Pesticide/Metabolite	Freshwater		Saltwater	
	Acute, µg/l	Chronic, µg/l	Acute, µg/l	Chronic, µg/l
Chlordane	2.4	0.0043	0.09	0.004
p,p′-DDT	1.1	0.001	0.13	0.001
Dieldrin	0.3595	0.0651	0.6594	0.1194
Endosulfan	0.22	0.0056	0.034	0.0087
α-Endosulfan	0.22	0.056	0.034	0.0087
β-Endosulfan	0.22	0.056	0.034	0.0087
Endrin	0.19	0.061	0.033	0.011
Heptachlor	0.52	0.0038	0.053	0.0036
Heptachlor epoxide	0.52	0.0038	0.053	0.0036
Hexachlorobenzene	6	3.68	-	-
Lindane	2	0.08	0.16	-
*Aldrin	3		1.3	

Source: Adapted from IUPAC (2003); *EPA (2016a)

Table 2. Maximum residue limits (mg/kg) for organochlorine pesticides in food

Food	Aldrin	Dieldrin	DDT	Endosulfan	Endrin	Heptachlor	Lindane	Chlordane	BHC
Cereal grains	0.02[b]	0.02[b]	0.1[b]	0.05[c]	0.01[c]	0.02[b]	0.01[b]	0.1[a]	0.05[a]
Onion leaf	0.05[b]	0.05[b]	0.05[c]	0.05[c]	0.05[a]	0.01[c]	0.01[c]	0.1[a]	0.05[a]
Cabbage leaf	0.05[b]	0.05[b]	0.05[c]	0.05[c]	0.05[a]	0.01[c]	0.01[c]		
lettuce leaf	0.05[b]	0.05[b]	0.05[c]	0.05[c]	0.05[a]	0.05[a]	0.01[c]	0.1[a]	0.05[a]
Pulses	0.05[b]	0.05[b]	0.05[c]	0.05[c]	0.01[c]	0.05[a]	0.5[a]	0.1[a]	0.05[a]
Fish	0.3[a]	0.3[a]				0.3[a]		0.3[a]	
Cucurbits	0.1[b]	0.1[b]	0.05[c]	0.05[c]	0.05[b]	0.01[c]	0.01[c]		0.05[a]
Carrot	0.1[a]	0.1[a]	0.2[b]	0.05[c]	0.01[c]	0.01[c]	0.5[a]	0.1[a]	0.3a
Cucumber	0.1[a]	0.1[a]	0.05[c]	1[b]	0.01[c]	0.05[a]	0.01[c]	0.1[a]	
Melons	0.1[a]	0.1[a]	0.05[c]	2[b]	0.01[c]	0.05[a]	0.01[c]	0.1[a]	0.01[d]
Potato	0.1[a]	0.1[a]	0.05[c]	0.05[b]	0.01[c]	0.01[c]	0.01[c]	0.1[a]	0.01[d]
Soya bean			0.05[c]	1[b]	0.01[c]	0.02[b]	0.01[c]		

Source: Adapted from US FDA (2016)[a], Codex (2016)[b], GSO (2013)[c]

3. Discussion

3.1 Aldrin

The following were the levels of aldrin reported for some surface water bodies in Nigeria: River Benue at Katsina-Ala and Buruku, ND-16 µg/l (Ogah et al., 2015); Ogbese River Edo State, 0.21±0.08 µg/l (Ezemonye et al., 2015a); fish pond in Osogbo Osun State, ND-78.82 µg/l (Ogunfowokan et al., 2012); Biu Dam Reservoir Borno State, 183±3 µg/l (Shinggu et al., 2015); Lagos Lagoon, 0.080-0.790 µg/l (Adeyemi et al., 2011); Tarkwa Bay Lagos Lagoon, 6.0±3.3 µg/l (Williams, 2013a); River Benue Yola Adamawa State, 3.75±0.01 mg/l (Akan et al., 2015a); Ogbese River Ekiti State, ND-0.85 µg/l (Ibigbami et al., 2015); Agboyi Creek Lagos, 3±1.4 µg/l (Williams (2013c).

For acute toxicity, EPA ambient water quality criteria for freshwater is 3 µg/l and for saltwater is 1.3 µg/l. Many surface water bodies reported in this review have levels far above this limit, implying detrimental effects on aquatic organisms. The sources of pollution therefore need to be checked.

In addition to sources from wastewater and effluents, some rivers and ponds in the country receive runoffs from agricultural lands (Ogunfowokan et al., 2012) where there might have been considerable application of pesticides for various purposes. Checking these sources is necessary because of several human activities that have direct bearing with surface water.

These water bodies are sources of water for direct drinking, cooking and other activities in some rural areas. The EU allowed limit level for aldrin in drinking water is 0.10 µg/l (Wikipedia, 2016b) which is far lower than these levels reported. Human population around these surface water sources may be exposed to aldrin. Furthermore, fishing activities are prevailent in these polluted water bodies.

Levels of aldrin reported for fish and other food items are shown in Table 3. Maximum residue limit (MRL) for aldrin in fish is 0.3 mg/kg (Table 2). Levels for some fish reported here are above the MRL. However, these reports are too scanty to draw a conclusion.

Table 3. Levels of Aldrin residues in food

Location	Food	Levels (µg/g)	Source
Lagos	Beans	0.0098	Ogah *et al*. (2012)
Alau Dam Agricultural site, Borno State	Onion leaf	41.73±1.54	Akan *et al*. (2014)
Alau Dam Agricultural site, Borno State	Cabbage leaf	23.45±3.45	Akan *et al*. (2014)
Alau Dam Agricultural site, Borno State	lettuce leaf	20.56±1.43	Akan *et al*. (2014)
Ogbese River, Edo State	Fish	0.63±0.19	Ezemonye *et al*. (2015a)
Biu Dam Reservoir, Borno State	Fish	1.464±0.001	Shinggu *et al*. (2015)
Markets in Ile-Ife, Osun State	Cowpea grains	0.043–0.509	Olufade *et al*.(2014)
Markets in Ile-Ife, Osun State	Dried yam chips	0.067–4. 682	Olufade *et al*.(2014)
Nasarawa State	Millet	0.13±0.02	Anzene *et al*. (2014)
Nasarawa State	Guinea corn	0.03±0.10	Anzene *et al*. (2014)
Nasarawa State	Maize	0.03±0.02	Anzene *et al*. (2014)
Alau Dam, Borno State	Fish	0.22 ± 0.01	Akan *et al*. (2013)
Ogbese River, Ekiti State	Fish	0.0065-0.00212	Ibigbami *et al*. (2015)
Ilishi, Ogbese and Owan rivers in Edo State	Fish	ND-0.7	Ezemonye *et al*. (2015b)
Lagos Lagoon	Fish	0.0535±0.00671	Williams (2013b)
Borno State	Beans	0.17	Gwary *et al*. (2012)
Gashua, Yobe State	Watermelon	0.20±0.04	Akan *et al*. (2015b)

For all the other food items mentioned in Table 3, MRL range between 0.02 and 0.1 mg/kg; whereas the levels reported here are far higher than this range. These food items are commonly consumed in Nigeria. A greater population may then be at risk. The hazardous levels suggest direct application of aldrin to control pest on the food items like onion, cabage leaf and lettuce.

Aldrin is classified as an extremely hazardous substance in the United States and considered as a potential occupational carcinogen by the Occupational Safety and Health Administration and the National Institute for Occupational Safety and Health (Wikipedia, 2016c). It has an LC50 of 0.006 – 0.01 mg/kg for trout and bluegill (Robert, 2002). These high levels reported therefore is of serious environmental/human health concern.

3.2 Dieldrin

The levels reported for surface water in some parts of Nigeria are: Lagos Lagoon, 0.015-0.996 µg/l (Adeyemi et al., 2011); River Benue Yola, Adamawa State, 5.24±0.23 mg/l (Akan et al., 2015a); Tarkwa Bay Lagos Lagoon, 0.8±0.3 µg/l (Williams, 2013a); Agboyi Creek Lagos, 0.6±0.3 µg/l (Williams, 2013c); fish pond in Osogbo Osun State, 2.14-99.57 µg/l (Ogunfowokan et al., 2012); Ogbese River Ekiti State, ND-0.23 µg/l (Ibigbami et al., 2015); River Benue at Katsina-Ala and Buruku, 15-21 µg/l (Ogah et al., 2015); Ogbese River Edo State, 0.14±0.05 µg/l (Ezemonye et al., 2015a). The limit for acute toxicity in freshwater is 0.3595 µg/l and for saltwater is 0.6594 µg/l; while the limits for chronic toxicity are 0.0651 and 0.1194 µg/l for freshwater and saltwater respectively (Table 1). From the available few reports in the country, dieldrin is present at levels far above (and some were below) the limit. But a larger data is required to make a meaningful conclusion. However, the available reports indicate pollution. In particular, chronic toxicity to aquatic organisms seems inevitable. Also, the data show that these water bodies are unsuitable for any domestic activities involving direct human consumption. The EU allowed limit for dieldrin in drinking water is 0.10 µg/l (Wikipedia, 2016b).

Table 4. Levels of Dieldrin residues in food

Location	Food	Levels (µg/g)	Source
Lagos	Beans	0.0058	Ogah *et al*. (2012)
Alau Dam Agricultural site, Borno State	Onion leaf	58.34±1.77	Akan *et al*. (2014)
Alau Dam Agricultural site, Borno State	Cabbage leaf	59.87±1.34	Akan *et al*. (2014)
Alau Dam Agricultural site, Borno State	lettuce leaf	46.75±2.08	Akan *et al*. (2014)
Ogbese River, Edo State	Fish	0.53±0.21	Ezemonye *et al*. (2015a)
Biu Dam Reservoir, Borno State	Fish	0.044±0.00	Shinggu *et al*. (2015)
Markets in Ile-Ife, Osun State	Cowpea grains	0.007 – 0.098	Olufade *et al*.(2014)
Markets in Ile-Ife, Osun State	dried yam chips	N D – 0. 084	Olufade *et al*.(2014)
Lagos Lagoon	Fish	0.02-1.78	Adeyemi *et al*. (2008)
Nasarawa State	Millet	0.02±0.03	Anzene *et al*. (2014)
Nasarawa State	Guinea corn	0.02±0.01	Anzene *et al*. (2014)
Nasarawa State	Maize	0.018±0.01	Anzene *et al*. (2014)
Alau Dam, Borno State	Fish	2.88 ± 0.15	Akan *et al*. (2013)
Ogbese River, Ekiti State	Fish	0.0103-0.0385	Ibigbami *et al*. (2015)
Ilishi, Ogbese and Owan rivers in Edo State	Fish	ND-0.80	Ezemonye *et al*. (2015b)
Lagos Lagoon	Fish	0.095±0.00529	Williams (2013b)
Gashua, Yobe State	Watermelon	0.28±0.06	Akan *et al*. (2015b)

Levels reported for food items are shown in Table 4. Maximum residue limit for dieldrin in food ranges from 0.02 to 0.1 mg/kg. Levels reported for many food items here far exceed this limit. It implies a greater exposure in the country since the items are traded beyond the localities of these studies.

Dieldrin exhibits biomagnification along the food chain and has been linked to health problems such as Parkinson's, breast cancer, and immune, reproductive, and nervous system damage (Wikipedia, 2016d). It causes convulsions in humans at high concentrations (Honeycutt and Shirley, 2014).

3.3 Endrin

Studies revealed the following levels in some surface water bodies in the country: fish pond in Osogbo Osun State, 3.60-49.12 µg/l (Ogunfowokan et al., 2012); River Benue at Katsina-Ala and Buruku, 2-28 µg/l (Ogah et al., 2015); Ogbese River Edo State, 0.06±0.04 µg/l (Ezemonye et al., 2015a); Tarkwa Bay Lagos Lagoon, 1.0±0.2 µg/l (Williams, 2013a); Agboyi Creek Lagos, 0.9±0.2 µg/l (Williams, 2013c).

EPA ambient water-quality criteria for aquatic organisms show limits of 0.19 and 0.033 µg/l for acute toxicity, and 0.061 and 0.011 µg/l for chronic toxicity for freshwater and saltwater respectively. Levels reported from studies in the country exceeded this limit, implying potential hazardous exposure for aquatic organisms and humans. For citizens that engage in activities that involve direct drinking of the water; or if the surface water bodies are sources of public water supply without adequate treatment, this may pose greater potential hazards, since EU allowed limit for endrin in drinking water is 0.10 µg/l (Wikipedia, 2016b).

Reported levels of endrin in food items are shown in Table 5. Maximum residue limits for these food items ranges between 0.01 and 0.05 mg/kg. Levels, especially in fish exceeded this limit considerably. Consumption of fish from these sources may result in detrimental human exposure.

Table 5. Levels of Endrin residues in food

Location	Food	Levels (µg/g)	Source
Lagos	Beans	0.0078	Ogah *et al*. (2012)
Ogbese River, Edo State	Fish	0.45±0.27	Ezemonye *et al*. (2015a)
Biu Dam Reservoir, Borno State	Fish	14.758±0.001	Shinggu *et al*. (2015)
Markets in Ile-Ife, Osun State	Cowpea grains	0.042 – 0.243	Olufade *et al*.(2014)
Markets in Ile-Ife, Osun State	Dried yam chips	0.085 – 0. 501	Olufade *et al*.(2014)
Nasarawa State	Millet	0.03±0.04	Anzene *et al*. (2014)
Nasarawa State	Guinea corn	0.03±0.03	Anzene *et al*. (2014)
Nasarawa State	Maize	0.0003±0.10	Anzene *et al*. (2014)
Ogbese River, Ekiti State	Fish	0.00854-0.0477	Ibigbami *et al*. (2015)
Ilishi, Ogbese and Owan rivers in Edo State	Fish	ND-0.60	Ezemonye *et al*. (2015b)
Lagos Lagoon	Fish	0.133±0.0318	Williams (2013b)
Borno State	Beans	2.46	Gwary *et al*. (2012)

Endrin can be stored in body fats and can act as a neurotoxin on the central nervous system, which can cause convulsions, seizures, or even death; the symptoms of poisoning including headache, dizziness, nervousness, confusion, nausea and vomiting (Wikipedia, 2016e).

3.4 *Chlordane*

The few available reports showed levels in fish pond in Osogbo Osun State, ND-39.72 µg/l (Ogunfowokan et al., 2012); Lagos Lagoon, 0.006-0.950 µg/L (Adeyemi et al., 2011); Tarkwa Bay Lagos Lagoon, 0.7±0.4 µg/l (Williams, 2013a); Agboyi Creek Lagos, 0.8±0.3 µg/l (Williams, 2013c). And for food items, studies revealed levels in cowpea grains and dried yam chips at markets in Ile-Ife Osun State, 0.047 – 0.364 and 0.035 – 0.158 µg/g respectively (Olufade et al., 2014); fish from Lagos lagoon, 0.0793±0.00843 µg/g (Williams, 2013b).

For acute and chronic toxicity, EPA ambient water-quality criteria for aquatic organisms reports 2.4 and 0.0043 µg/l, 0.09 and 0.004 µg/l for freshwater and saltwater respectively. Since the levels reported in the country are higher than the limits, pollution of these water sources is implied. Also, the levels exceeded 0.10 µg/l EU Limit in drinking water: water from these sources would require adequate treatment before supply for public consumption.

Maximum residue limits for chlordane in food range between 0.1 and 0.3 mg/kg. Paucity of available data may not allow categorical conclusion here as the levels reported fall within these limits. Similar studies in other countries reported 0.027–0.045 ppb in fish from Lake Tashk in Iran (Kafilzadeh, 2015).

The acute effects of chlordane in humans include gastrointestinal distress and neurological symptoms, such as tremors and convulsions while chronic inhalation exposure of humans to chlordane results in effects on the nervous system (EPA, 2016b).

3.5 *Heptachlor*

Levels reported for surface water in Nigeria were Ogbese River Edo State, 0.14±0.03 µg/l (Ezemonye et al., 2015a); Ogbese River Ekiti State, ND-0.35 µg/l (Ibigbami et al., 2015); fish pond in Osogbo Osun State, ND-63.29 µg/l (Ogunfowokan et al., 2012); Tarkwa Bay Lagos Lagoon, 23.0±3.2 µg/l (Williams, 2013a); River Benue at Katsina-Ala and Buruku, 1-21 µg/l (Ogah et al., 2015); Lagos Lagoon, ND-0.067 µg/l (Adeyemi et al., 2011); Agboyi Creek Lagos, 5.0±2.2 µg/l (Williams, 2013c). These exceeded the limits, especially for chronic toxicity to aquatic organisms. The EPA ambient water-quality criteria for acute and chronic toxicity are 0.52 and 0.0038 µg/l, 0.053 and 0.0036 µg/l for freshwater and saltwater respectively. These levels are also higher when compared with EU allowed limit for drinking water (0.10 µg/l). However, larger data is needed to make a better categorical conclusion.

For residues in fish, reports revealed fish from Lagos lagoon, 0.0698±0.00652 µg/g (Williams, 2013b); Ilishi Ogbese and Owan rivers in Edo State, ND-6.00 µg/g (Ezemonye et al., 2015b); Ogbese River Ekiti State, 0.0053-0.0423 µg/g (Ibigbami et al., 2015); Ogbese River Edo State, 0.43±0.19 µg/g (Ezemonye et al., 2015a); while levels in other food items like cowpea grains and dried yam chips from markets in Ile-Ife, Osun State, were 0.147 – 0.760 and 0.151 – 0.606 µg/g respectively (Olufade et al., 2014). Maximum residue limits range from 0.01 to 0.3 mg/kg. Generally, the few available reports showed levels within this limit. However, further assessment is necessary. Reports from other countries showed similar levels of 0.037–0.049 ppb in fish from Lake Tashk in Iran (Kafilzadeh, 2015).

Due to its highly stable structure, heptachlor can persist in the environment for decades (Wikipedia, 2016f). In addition to being classified as probable human carcinogen, acute inhalation exposure to heptachlor may result in nervous system effects, with oral studies showing gastrointestinal effects; while chronic inhalation and oral exposure by humans may be associated with neurological effects including irritability, salivation, and dizziness (EPA, 2016c).

3.6 *Lindane*

Available reports in the country for levels of lindane in surface water revealed Warri River Delta State, 0.76±0.24 µg/L (Ezemonye et al., 2008); Ogbese River Edo State, 0.22±0.05 µg/L (Ezemonye et al., 2015a); Tarkwa Bay Lagos Lagoon, 38.0±4.3 µg/L (Williams, 2013a); fish pond in Osogbo Osun State, ND-70.44 µg/L (Ogunfowokan et al., 2012); River Benue at Katsina-Ala and Buruku, 1-150 µg/L (Ogah et al., 2015); Ogbese River Ekiti State, ND-3.15 µg/L (Ibigbami et al., 2015); Agboyi Creek Lagos, 13.0±3.3 µg/L (Williams, 2013c).

EPA guidelines for levels of lindane residues in food range between 1 and 7 ppm (U.S. Department of Health and Human Services, 2005). Current levels reported for some food items (especially onion leaf, cabbage and lettuce leaf) (Table 6) in the country exceeded this range. It seems there is illegal application of this banned pesticide on agricultural crops at abnormal doses. It may also be that the pesticide is applied on the farm products during storage. This calls for a serious concern since human health of Nigeria population may be at risk. Lindane is categorized by EPA as a restricted use pesticide and can only be used by licensed and certified applicators (U.S. Department of Health and Human Services, 2005). But in Nigeria, it appears the illegal use still thrives all over the country. This needs to be checked and enforcement of appropriate policy should be put in place.

Lower levels were reported for some other countries: Lake Tashk in Iran, 0.05–0.091 ppb in water and 0.143–0.251 ppb in fish (Kafilzadeh, 2015); Taihu Lake in China,0.001-0.0032 µg/l (Qu et al., 2011); Beijing Guanting reservoir in China, ND-0.057 µg/l (Xue et al., 2006).

Lindane, available as dust, powder, liquid, or concentrate, (also available as a prescription medicine -

lotion, cream, or shampoo - to treat and/or control scabies (mites) and head lice in humans) is a white solid produced and used as an insecticide on fruit, vegetables, and forest crops, and animals and animal premises (U.S. Department of Health and Human Services, 2005). Of all the various kinds of pesticides used by the farmers in some parts of Nigeria, lindane (usually sold under the trade name Gammalin 20) is the most popular and used for controlling pests of kola, for fishing and also used for formulating local insecticides and rodenticides (Ogunfowokan et al., 2012). It is also currently used for seed treatment and in lotions, creams and shampoos for the control of lice and mites (Scabies) in humans (Lawson et al., 2011).

Table 6. Levels of lindane residues in food

Location	Food	Levels (µg/g)	Source
North-Eastern Nigeria	Smoked fish	3.48-9.88	Musa *et al.* (2010)
Alau Dam Agricultural site, Borno State	Onion leaf	18.63±1.02	Akan *et al*. (2014)
Alau Dam Agricultural site, Borno State	Cabbage leaf	26.34±0.37	Akan *et al*. (2014)
Alau Dam Agricultural site, Borno State	Lettuce leaf	55.8±1.73	Akan *et al*. (2014)
Ogbese River, Edo State	Fish	0.66±0.15	Ezemonye *et al*. (2015a)
Warri River, Delta State	Fish	2.5±0.02	Ezemonye *et al*. (2008)
Alau Dam, Borno State	Fish	0.86 ± 0.03	Akan *et al*. (2013)
Ogbese River, Ekiti State	Fish	0.00223-0.0139	Ibigbami *et al*. (2015)
Ilishi, Ogbese and Owan rivers in Edo State	Fish	ND-8.80	Ezemonye *et al*. (2015b)
Lagos Lagoon	Fish	0.0278±0.00864	Williams (2013b)
Borno State	Beans	0.19	Gwary *et al*. (2012)

3.7 Endosulfan/isomers

Available literatures reported the levels of endosulfan/isomers in surface water as shown in Table 7. The EPA ambient water-quality criteria for endosulfan, endosulfan I and endosulfan II are 0.034 and 0.0087 µg/l for acute and chronic toxicity in saltwater respectively; while for freshwater, the criteria are 0.22 and 0.056 µg/l for acute and chronic toxicity respectively (endosulfan has chronic toxicity criteria of 0.0056 µg/l). Therefore, these high levels reported may pose adverse effects on humans and the environment. Other countries reported levels of 0.043–0.085 ppb in water and 0.613–0.877 ppb in fish from Lake Tashk in Iran (Kafilzadeh, 2015).

Levels reported for residues in food are shown in Table 8. Maximum residue levels in food range from 0.05 and 2 mg/kg. Levels in onion, cabbage and lettuce exceeded this range. It seems there was heavy application of the pesticide on these crops and may pose adverse health effects on consumers.

Table 7. Levels of endosulfan/isomers in water

Location	Levels (µg/l)	Source
Osogbo, Osun State (Fish pond)	1.22-90.19	Ogunfowokan *et al*. (2012)
River Benue at Katsina-Ala and Buruku	*1.00-105.00 **2.00-39.00	Ogah *et al*. (2015)
Ogbese River, Edo State	*0.22±0.05 **0.08±0.03	Ezemonye *et al*. (2015a)
Lagos Lagoon	0.015-0.996	Adeyemi *et al*. (2011)
Biu Dam Reservoir, Borno State	*0.033±0.001	Shinggu *et al*. (2015)
Tarkwa Bay, Lagos Lagoon	*0.8±0.4 **1.0±0.4	Williams (2013a)
Ogbese River, Ekiti State	**ND-6.17	Ibigbami *et al*. (2015)
Agboyi Creek, Lagos	*0.9±0.2 **2.0±1.2	Williams (2013c)

*Endosulfan I; **Endosulfan II

Table 8. Levels of endosulfan/isomers residues in food

Location	Food	Levels (µg/g)	Source
Lagos	Beans	0.0225	Ogah *et al*. (2012)
Alau Dam Agricultural site, Borno State	Onion leaf	42.41±5.34	Akan *et al*. (2014)
Alau Dam Agricultural site, Borno State	Cabbage leaf	10.44±0.11	Akan *et al*. (2014)
Alau Dam Agricultural site, Borno State	Lettuce	42.34±0.48	Akan *et al*. (2014)
Ogbese River, Edo State	Fish	*0.13±0.10 **0.38±0.30	Ezemonye *et al*. (2015a)
Markets in Ile-Ife, Osun State	Cowpea grains	0.09 – 0.39 8	Olufade *et al*. (2014)
Markets in Ile-Ife, Osun State	Dried yam chips	0.175 – 0. 572	Olufade *et al*. (2014)
Nasarawa State	Millet	0.02±0.01	Anzene *et al*. (2014)
Nasarawa State	Guinea corn	0.02±0.02	Anzene *et al*. (2014)
Nasarawa State	Maize	0.005±0.06	Anzene *et al*. (2014)
Alau Dam, Borno State	Fish	1.75 ± 0.11	Akan *et al*. (2013)
Ogbese River, Ekiti State	Fish	*0.00854-0.066 **0.00755-0.0303	Ibigbami *et al*. (2015)
Ilishi, Ogbese and Owan rivers in Edo State	Fish	*ND-1.40 **ND-0.60	Ezemonye *et al*. (2015b)
Lagos Lagoon	Fish	*0.0751±0.00426 **0.0404±0.00592	Williams (2013b)

*Endosulfan I; **Endosulfan II

3.8 *Dichloro diphenyl trichloroethane (DDT)*

Levels of DDT reported for surface water in Nigeria were River Benue Yola Adamawa State, 660±120 µg/L (Akan et al., 2015); Agboyi Creek Lagos, 4.0±9.5 µg/l (Williams, 2013c); fish pond in Osogbo Osun State, 7.37-66.66 µg/l (Ogunfowokan et al., 2012); River Benue at Katsina-Ala and Buruku, 11-71 µg/l (Ogah et al., 2015); Ogbese River Edo State, 0.12±0.06 µg/l (Ezemonye et al., 2015a); Lagos Lagoon, 0.012-0.910 µg/l (Adeyemi et al., 2011); Tarkwa Bay Lagos Lagoon, 5.0±0.8 µg/l (Williams, 2013a); Ogbese River Ekiti State, 0.61-3.04 µg/l (Ibigbami et al., 2015).

EPA ambient water-quality criteria for aquatic organisms for acute and chronic toxicity are 1.1 and 0.001 µg/l, 0.13 and 0.001 µg/l for freshwater and saltwater respectively. Some reported levels in the country were extremely higher than the limit. The same is applicable to residue levels in food (Table 9) compared with the limits of between 0.05 and 0.2 mg/kg. While the high levels in surface water may be explained by the fact that the pesticide is permitted for control of malaria vector, and therefore a potential source of water contamination, the high level in food items may be an indication that the pesticide is still illegally used to control pests on agricultural products.

Lower levels were reported for some other countries. Levels reported in India for Yamuna river showed a range between 0.0001 and 0.354 µg/l (Kumar et al., 2012); Lake Tashk in Iran, 0.018–0.038 ppb in water and 3.751–5.273 ppb in fish (Kafilzadeh, 2015); water from Pearl River estuaries in China, 0.043-0.290 µg/l (Zhang et al., 2002); fish from Lake Ziway in Ethiopia, 0.0009 to 0.0619 µg/g (Yohannes et al., 2014).

Table 9. Levels of DDT residues in food

Location	Food	Levels (µg/g)	Source
North-Eastern Nigeria	Smoked fish	3.82-4.48	Musa *et al.* (2010)
Lagos	Beans	0.0351	Ogah *et al.* (2012)
Alau Dam Agricultural site, Borno State	Onion leaf	51.33±1.23	Akan *et al.* (2014)
Alau Dam Agricultural site, Borno State	Cabbage leaf	33.21±1.45	Akan *et al.* (2014)
Alau Dam Agricultural site, Borno State	Lettuce	24.56±0.05	Akan *et al.* (2014)
Ogbese River, Edo State	Fish	0.04±0.03	Ezemonye *et al.* (2015a)
Lagos Lagoon	Fish	0.02-0.18	Adeyemi *et al.* (2008)
Nasarawa State	Millet	0.04±0.02	Anzene *et al.* (2014)
Nasarawa State	Guinea corn	0.04±0.01	Anzene *et al.* (2014)
Nasarawa State	Maize	0.04±0.01	Anzene *et al.* (2014)
Alau Dam, Borno State	Fish	0.33 ± 0.01	Akan *et al.* (2013)
Ogbese River, Ekiti State	Fish	2.60-10.2 (µg/kg)	Ibigbami *et al.* (2015)
Ilishi, Ogbese and Owan rivers in Edo State	Fish	ND-0.80	Ezemonye *et al.* (2015b)
Lagos Lagoon	Fish	0.0621±0.00543	Williams (2013b)
Borno State	Beans	1.47	Gwary *et al.* (2012)
Gashua, Yobe State	Watermelon	0.04±0.01	Akan *et al.* (2015b)

Dichloro diphenyl trichloroethane, available as dustable powders, aerosols, granules, emulsifiable concentrates and wettable powders, is colourless crystal or white powder with odourless or weak aromatic odour sold under the trade names including anofex, dicophane, genitox, detoxan, pentachlorin, chlorophenothane, neocid, gesarol, cesarex, dinocide, didimac, digmar, guesapon, guesarol, kopsol, and gyron. It is used mainly to control mosquito-borne malaria. It is relatively inert and stable, fat-soluble, and is nearly insoluble in water (Encyclopedia.com, 2016). It is known to be very persistent in the environment, accumulates in fatty tissues, and can travel long distances in the upper atmosphere (EPA, 2015). Human health effects linked to DDT and its breakdown product, DDE, include breast and other cancers, male infertility, miscarriages and low birth weight, developmental delay, nervous system and liver damage (PAN, 2016). It was banned for agricultural uses worldwide by the Stockholm Convention. The only remaining legal use of DDT is to control malaria vector. The World Health Organization has now fully endorsed the use of DDT to fight malaria (Toxipedia, 2013; EPA, 2015).

4. Conclusion

Levels of organochlorine pesticides reported for many surface water bodies in Nigeria exceeded the allowed limits, and may pose hazards to the environment and human health. Sources need to be checked and appropriate policy should be enforced.

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