Kwaghe International
Journal of Sciences and Technology

ISSN : 0000-0000
Index: Harvard, Boston, Sydney University, Dimensions, Lens, ResearchGet Scilit, Semantic, Google Scholar, Base etc

https://doi.org/10.58578/KIJST.v1i1.3576

Preliminary Investigation of the Pollution Status of Kashimbila Dam Takum, Taraba State, North Eastern Nigeria

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Article Info:

Submitted:	Revised:	Accepted:	Published:
Jul 1, 2024	Jul 20, 2024	Jul 27, 2024	Jul 31, 2024

Abstract

Organochlorine pesticides (OCPs) are chemical compounds used to control or eliminate plant and animal pests. Most of these pesticides are non-degradable, leading to residue accumulation in aquatic environments, particularly in sediment and water. This is a significant concern today because aquatic organisms absorb these residues, which can cause serious health risks to humans. The study area, Kashimbila Dam in Takum, Taraba State, is surrounded by uplands where agricultural activities are conducted. Sediment and water samples were collected from Birama, Bibi, and Shingu, all along the Kashimbila Dam. Sample preparation and extraction were performed using analytical-grade chemicals, and OCP concentrations were determined using GC-MS. The study aimed to assess the distribution levels of OCP residues in water. Mirex and Hexachlorobenzene recorded the highest concentration levels, ranging from 0.932±0.036 to 1.712±0.342 mg/kg and from

0.701±0.681 to 1.350±0.002 mg/kg in water, respectively. In sediment, the concentrations ranged from 0.122±0.008 to 2.262±0.050 mg/kg for Mirex and from 0.094±0.008 to 1.176±0.001mg/kg for Hexachlorobenzene. The values obtained for Mirex and Hexachlorobenzene in all samples across the locations were above the WHO and FAO (2014) permissible limits of 0.1 and 0.5 mg/kg, respectively. The distribution levels of other OCPs, such as DDT, Dieldrin, Heptachlor, and Lindane, in all sample locations were also above the WHO and FAO (2009) permissible limits of 0.01 mg/kg for water and 1.00 mg/kg for sediment. The high values of these OCP residues could be attributed to the excessive use of pesticides on agricultural soils and fishing activities. Lindane, a contraband chemical commonly known as Gamalin-20, is used by fishermen to kill fish. The pH values of the three water samples from Kashimbila Dam were 8.32, 9.00, and 9.03 mg/l, indicating that the water body is alkaline or basic. High alkalinity is essential for the well-being of aquatic organisms. The pollution load index (PLI) of OCPs in water and the contamination factor (CF) of OCPs in sediment ranged from 0.110 to 15.050 and from 0.035 to 21.835, respectively, indicating that the pollution status of water and sediment from Kashimbila Dam ranged from moderate to highly polluted levels.

Keywords: Sediment, Water, Organochlorine, Pesticides, Pollution

INTRODUCTION

Water bodies are reservoirs that retain water throughout the year or for extended periods. These include both surface and groundwater sources. Risk assessments related to pesticide residues are relevant to both categories, as they impact the respective ecosystems and humans, given that both surface and groundwater are sources of drinking water. In agricultural regions, surface water can be contaminated by pesticide residues, potentially harming the ecosystem (Staley *et al.,* 2015; Kohler *et al.,* 2013; Cruzeiro *et al.,* 2017). Sediments in marine environments act as sinks for heavy metals and play a crucial role in the transport and storage of potentially hazardous metals (Yebpella et al., 2019). Environmental monitoring of pesticide residues in water typically involves chemical analysis of pesticides and their known metabolites or degradation products. Pesticide pollution of groundwater has been reported in several countries (Malaguerra *et al.,* 2013; Vryzas *et al.,* 2012). Exposure to pesticides, whether occupationally or environmentally, can lead to various health issues. Takum, a significant agricultural province in Taraba State, faces an increased risk of pesticide contamination in both surface and groundwater, which may be linked to diseases and health problems such as cancer or organ damage when found in high concentrations (Seth & Khanna, 2021). This study aims to investigate the pollution status of organochlorine pesticide residues in water and sediment from Kashimbila Dam, Takum, Taraba State.

MATERIAL AND METHODS

Description of the Study Area:

The study was carried out in Kashimbila Dam Takum, Taraba State. It is an earth-fill or embankment dam with a reservoir with a water storage capacity of 11,000 skm. Though the Dam's primary purpose is to generate electricity, it became a reservoir of water used for fishing and tourism. Kashimbila is located approximately 143 kilometers (89 mi) south of Wukari town, the nearest large town in Southern Taraba. This is approximately 354 kilometers (220 mi) southwest of Jalingo, the capital of Taraba State The geographical coordinates of Kashimbila Hydroelectric Power Station are: 06°52'27.0"N, 9°45'43.0"E (Latitude:6.874167; Longitude:9.761944).

Sample Collection and Preparation

A total three (3) sampling location were mapped out for each samples (water and sediment). The sampling locations were labelled W_1 (Birama), W_2 (Bibi) and W_3 (Shingu) for water samples while S_1 (Birama), S_2 (Bibi) and S_3 (Shingu) for sediment samples respectively. Stratified sampling technique was applied for sediment sample collection with little modification, likewise Van Veen grab was used for water sample. Each location was broken down to substations and in each individual substation, 10-20 g sediment samples were randomly collected at the depth of 0-15 cm in order to increase precision and accuracy of the estimate over the entire substation. The 10-20 g sample units of approximately equal sizes were pooled together to form composite samples for that location. Similar procedure was repeated for other locations. The sediment samples collected were mixed to obtain a representative samples, samples were manually sorted to remove coarse materials, and then air-dried at room temperature over five days (Yebpella *et al.,* 2019). The Surface water were collected by dipping just below the surface a 1 liter amber glass bottle which was thoroughly cleaned and rinsed with dichloromethane (DCM) and sample were preserved with 2 mL of concentrated hydrochloric acid to render inactive any microorganism that may cause biodegradation of the samples. Bottles containing samples were wrapped with aluminum foil to prevent contamination and was transported to the laboratory and stored at 4 °C (Itodo *et al.,* 2019)

Sediment Sample Preparation

A 10 g sediment sample was weighed into a Teflon bottle, and 5 g of NaSO4 was added. A 2:1 mixture of DCM and n-hexane was then measured and added to the bottle. The sample was placed on a mechanical shaker and shaken for 1 hour and 30 minutes. After standing for 5 minutes, the sample was filtered through a funnel lined with filter paper, cotton wool, and 2 g of NaSO4 into a sample bottle. The filtered sample was stored for further analysis by GC-MS (Oliva and Baba, 2023).

Water Sample Preparation

A 200 mL of water sample was measured into a 250 ml separating funnel then 2:1 mixture of DCM and n-hexane was added to the sample and was shake for 15 minutes. The separating funnel was allowed to stand and the organic layer was separated from the aqueous layer and collected into a vial and stored for further analysis by GC-MS (Itodo *et al.,* 2019).

Contamination Factor (CF) for Sediment/Soil

A contamination factor to describe the contamination of a given toxic metal in water is given by the relation

$$C_f = C_m/B_m)$$

Where Cf = contamination factor of the element of interest;

Bm = background concentration in the study;

Cm = concentration of the element in the sample.

Contamination factor has four categories which include: <1= low contamination factor; 3-6= considerable contamination factor; >6= very high contamination factor. (Omotoso and Ojo, 2015).

Pollution Load Indices

Hu *et al.*, (2013) analyzed the pollution indices to assess environmental pollutants. The pollution level by a given heavy metal, i, is usually evaluated with the single pollution index (PLI), calculated as the ratio between the metal concentration (C_i) in a water sample and its reference value (Si). It is expressed as:

$$PIi = Ci/Si$$

Where Ci is the mean content of metals from at least five samples and Si is the pre-industrial concentration of individual metal or reference value. For the description of the pollution index, the following categories are available; PI<1=Low pollution, 1< PI < 3= Moderate polluted, 3< PI <6 = Considerable pollution, 6 < PI= Very high pollution level (Mohamed *et al.*, 2014).

RESULTS AND DISCUSSION

Table 1: Shows the pH value and temperature Organochlorine pesticide (OCP) in water

SAMPLE SOURCE	pH VALUE	TEMPRETURE (˚C)
W1 (Birama)	8.32± 0.010	27.67±0.002
W2 (Bibi)	9.03± 0.001	20.62±0.004
W3 (Shingu)	9.00± 0.004	25.55±0.006

The pH values of the three water samples were 8.32± 0.010, 9.00± 0.004, and 9.03± 0.001, indicating that the water body is alkaline or basic. High alkalinity is crucial for the well-being of aquatic organisms and can affect essential nutrients. Alkalinity is beneficial for both aquatic organisms and humans.

Water temperature significantly influences aquatic organisms by affecting the toxicity of certain pollutants. Higher temperatures generally accelerate the degradation of pesticides, although they can also increase the bioavailability of pesticides. The temperatures of the different water samples were 20.62±0.004 °C, 25.55± 0.006 °C, and 27.67±0.002 °C respectively.

The results of the mean concentration of organochlorine pesticide residues in sediment are shown in Table 2 below. The results indicate that Heptachlor had the lowest concentration, ranging from 0.002 to 0.003 mg/kg, with a mean value of 0.002±0.001 mg/kg. Dicofol, Endosulfan, and Aldrin had low concentration levels, ranging from 0.010 to 0.342 mg/kg, with mean values of 0.179±0.018 mg/kg, 0.053±0.020 mg/kg, and 0.015±0.001 mg/kg, respectively. The mean concentration of DDT was reported to be 0.133±0.008 mg/kg. The highest concentration was recorded for Mirex, which varied from 0.932 to 1.712 mg/kg, with a mean of 1.456±0.120 mg/kg, followed by Hexachlorobenzene, which ranged from 0.701 to 1.350 mg/kg and had a mean value of 1.125±0.005 mg/kg. Other OCPs with moderately high concentrations included Lindane, Toxaphene, DDD, and Dieldrin, which ranged from 0.333 to 0.710 mg/kg, with mean values of 0.405±0.300 mg/kg, 0.487±0.020 mg/kg, 0.560±0.004 mg/kg, and 0.518±0.010 mg/kg, respectively.

Table 2: Mean concentrations of Organochlorine Pesticide (OCP) in Sediment (mg/kg)

OCP/Sample Location	MF	MWt (g/mol)	**Concentration of OCP**			
			S_1	S_2	S_3	**Mean Values**
DDT	$C_{14}H_9Cl_5$	354.49	0.182	0.142	0.123	0.133± 0.008
DDD	$C_{14}H_{10}Cl_4$	320.0	0.710	0.532	0.439	0.560± 0.004
Aldrin	$C_{12}H_8Cl_6$	364.91	0.011	0.010	0.023	0.015± 0.001
Dieldrin	$C_{12}H_8Cl_6O$	380.91	0.563	0.581	0.410	0.518± 0.010
Endosulfan	$C_9H_6Cl_6O_3S$	406.93	0.018	0.016	0.125	0.053± 0.020
Hexachlorobenzene	C_6Cl_6	284.8	0.701	1.324	1.350	1.125± 0.005
Mirex	C_1OCl_{12}	545.543	0.932	1.723	1.712	1.456± 0.120
Lindane	$C_6H_6Cl_6$	290.83	0.407	0.398	0.409	0.405± 0.300
Heptachlor	$C_{10}H_5Cl_{17}$	373.32	0.003	0.002	0.002	0.002± 0.001
Dicofol	$C_{14}H_9Cl_5O$	370.47	0.011	0.185	0.342	0.179± 0.018
Toxaphene	$C_{10}H_{10}Cl_8$	414	0.691	0.437	0.333	0.487± 0.020
∑OCP						**0.448± 0.001**

Table 3: Mean Concentration of Organochlorine Pesticide (OCP) in Water (mg/l)

OCP Residues	Molecular Formulae	Molecular Wt (g/mol)	**Concentration of OCP**			
			W_1	W_2	W_3	**Mean Values**
DDT	$C_{14}H_9Cl_5$	354.49	0.054	0.039	0.046	0.046± 0.001

DDD	$C_{14}H_{10}Cl_4$	320.0	0.689	0.502	0.037	0.410± 0.002
Aldrin	$C_{12}H_8Cl_6$	364.91	0.013	0.009	0.006	0.010± 0.001
Dieldrin	$C_{12}H_8Cl_6O$	380.91	0.087	0.082	0.015	0.061± 0.010
Endosulfan	$C_9H_6Cl_6O_3S$	406.93	0.021	0.663	0.001	0.228± 0.100
Hexachloro benzene	C_6Cl_6	284.8	1.716	0.248	0.094	0.686± 0.001
Mirex	C_1OCl_{12}	545.543	2.262	0.626	0.122	1.003± 0.001
Lindane	$C_6H_6Cl_6$	290.83	0.029	0.027	0.053	0.036± 0.020
Heptachlor	$C_{10}H_5Cl_{17}$	373.32	0.002	0.002	0.005	0.003± 0.005
Dicofol	$C_{14}H_9Cl_5O$	370.47	0.178	0.188	0.358	0.241± 0.001
Toxaphene	$C_{10}H_{10}Cl_8$	414	0.809	0.581	0.044	0.478± 0.060
∑OCP						**0.291± 0.010**

The results of the mean concentration of organochlorine pesticide residues in water are shown in Table 3 above. The results indicate that Heptachlor had the lowest concentration, ranging from 0.002 to 0.005 mg/l, with a mean value of 0.003±0.005 mg/l. Dicofol, Endosulfan, and Aldrin had low concentration levels, ranging from 0.001 to 0.663 mg/l, with mean values of 0.241±0.001 mg/l, 0.228±0.100 mg/l, and 0.010±0.001 mg/l, respectively. The mean concentration of DDT was reported to be 0.046±0.001 mg/l. The highest concentration was recorded for Mirex, which varied from 0.122 to 2.262 mg/l, with a mean of 1.003±0.001 mg/l, followed by Hexachlorobenzene, which ranged from 0.248 to 1.716 mg/l and had a mean value of 0.686±0.001 mg/l. Other OCPs with moderately high concentrations included Lindane, Toxaphene, DDD, and Dieldrin, which ranged from 0.015 to 0.809 mg/l, with mean values of 0.036±0.020 mg/l, 0.478±0.060 mg/l, 0.410±0.002 mg/l, and 0.061±0.010 mg/l, respectively.

The values obtained for Mirex and Hexachlorobenzene (HCB) in all sample locations were above the WHO and FAO permissible limits of 0.100 mg/kg and 0.500 mg/kg, respectively. Additionally, the values for DDT, Lindane, and Dieldrin in all sample locations exceeded the WHO and FAO permissible limits of 0.01 mg/kg, 0.05 mg/kg, and 0.01 mg/kg, respectively.

The high values of Mirex can be attributed to its high stability and resistance to degradation. This persistence leads to long-term accumulation in soil and sediments. Similarly, HCB's hydrophobic nature and low water solubility cause it to adsorb to soil and sediment particles rather than staying dissolved in water, leading to its accumulation. HCB can also be transported over long distances through the atmosphere and deposited far from its original source, resulting in widespread environmental contamination.

The concentration of Mirex recorded in this study was higher than those reported by Moses *et al.* (2022) in River Donga and well water in Wukari. The concentration of HCB residue aligns with the findings of Barau *et al.* (2023), which indicate that HCB is one of ten pesticide residues occurring above permissible limits in cereals collected from Ardo-kola, Karim-lamido, and Zing LGAs of Taraba State. The concentration of DDT recorded in this study was similar to those reported by Joseph *et al.* (2015), who found that concentrations of organochlorine, organophosphorus, and pyrethroid pesticide residues were significantly higher in sediment samples than in water samples. According to their findings, dieldrin and aldrin were the most dominant compounds among the organochlorine pesticide residues, with the total concentration of aldrin in water samples being 2.96 mg/l compared to 11.25 µg/g in sediment samples, and the total concentration of dieldrin in water samples being 4.36 mg/l compared to 13.37 µg/g in sediment samples along River Benue in Vinikilang, Yola, Adamawa State, Nigeria. The results for DDT in this study are consistent with those reported by Moses *et al.* (2022), Barau *et al.* (2023), and Ibrahim (2023).

High levels of organochlorine pesticides (OCPs) like Mirex and HCB in soil, sediment, and water can have numerous detrimental effects on the environment and human health. These include reduced soil fertility, decreased biodiversity, and impaired soil functions. They can degrade water quality, making it unsafe for human consumption, agricultural use, and recreational activities. In humans, acute poisoning from OCPs can lead to symptoms such as nausea, dizziness, headaches, and, in severe cases, convulsions and death. Long-term exposure can result in birth defects, developmental delays, and other adverse effects on fetal development.

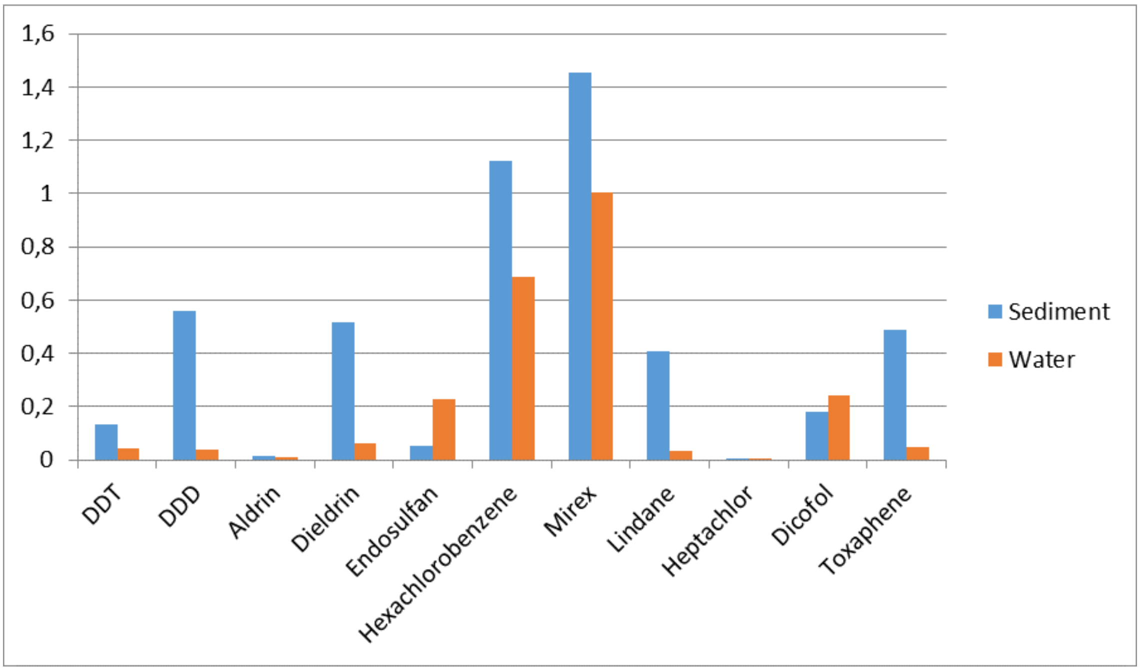

Figure 1: Mean concentrations of selected pesticide residues in Kashimbila Dam Takum, Taraba State, North Eastern Nigeria.

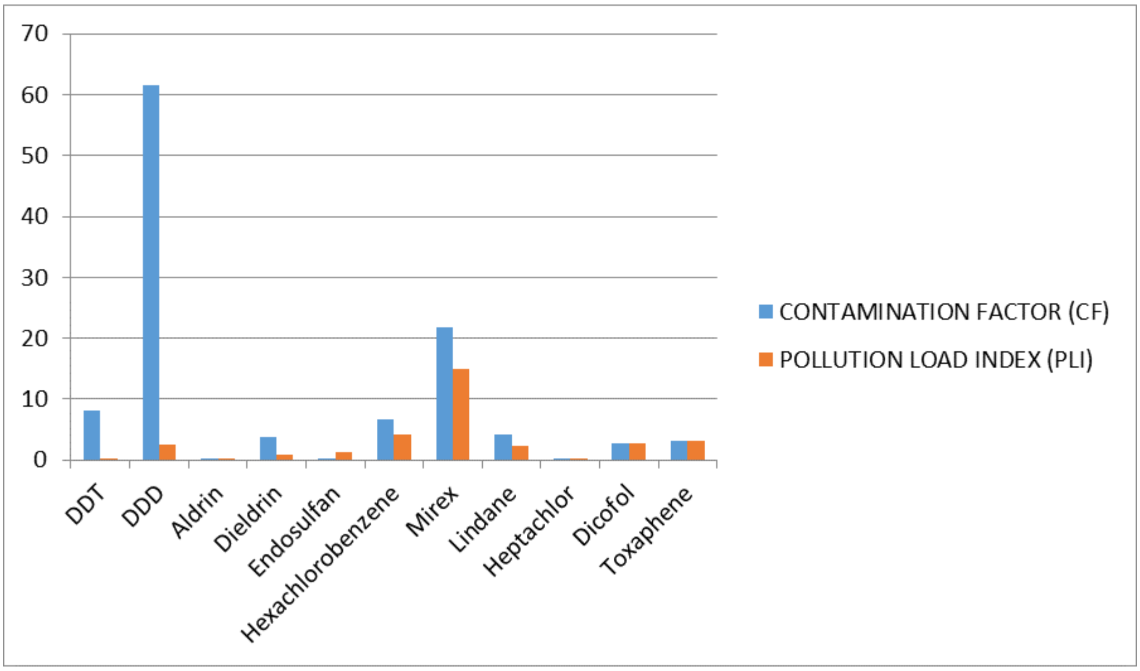

Figure 2: Shows the value contamination factor and pollution lead index of the organochlorine pesticides.

The pollution load index (PLI) of OCP in water and contamination factor (CF) of OCP in sediment ranged from 0.110 – 15.050; 0.035 – 21.835. which indicates that the pollution status of water and sediment from Kashimbila Dam ranged from low pollution, moderate to highly polluted levels.

CONCLUSION

This study revealed the levels of organochlorine pesticides in water and sediment which was measured in mg/kg. Organochlorine pesticides such as DDT, DDD, Lindane, Aldrin, Dieldrin Heptachlor, Endosulfan, Mirex, Hexachlorobenzene, Toxaphene residues were found in both water and sediment samples from the three different locations (Birama, Bibi and Shingu). Mirex and Hexachlorobenzene recorded the highest concentration levels which varies from 0.932±0.036 – 1.712±0.342 mg/kg and 0.701±0.681-1.350±0.002 mg/kg while those sediment ranged from 0.122±0.008- 2.262±0.050 mg/kg and 0.094±0.008-1.176±0.001 mg/kg respectively. The values obtained for Mirex and Hexachlorobenzene in all the samples across the locations were above the WHO and FAO (2009) permissible limit of 0.1 and 0.5 mg/kg. The distribution levels of other OCP such as DDT, Dieldrin, heptachlor, Lindane in all sample locations were also above the WHO and FAO (2014) permissible limit of 0.01 – 1.00 mg/kg., other pesticides such as DDT, DDD and lindane also have high concentration which indicates the usage of perfect killer insecticides and gamalin-20 a contraband pesticide which fishermen use in killing of fish. The pH values of the three water samples from Kashimbila dam were as follows 8.32, 9.00 and 9.03 respectively, these indicates that the water body is alkaline or basic. High alkalinity is essential for the wellbeing of aquatic organisms. The pollution load index (PLI) of OCP in water and contamination factor (CF) of OCP in sediment ranged from 0.110 – 15.050; 0.035 – 21.835 which indicates that the pollution status of water and sediment from Kashimbila Dam ranged from moderate to highly polluted levels.

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