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Distribution of heavy metals and pesticides residues in sediments of some rivers in Ekiti state, Southwest Nigeria

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Abstract
Sediments are habitats and major sources of nutrients for benthic organisms. High concentration of pollutants can impact negatively on the lives of such organisms and ultimately on the lives of human beings who may feed on them. This study was carried out in order to evaluate some environmental pollutants' load: heavy metals and pesticide residues in Irintan, Omi-Eye and Egbigbu river sediments in Ekiti State, Southwest Nigeria. Sediment samples were taken at upper, middle and lower courses of each river relative to the farm used for the study. The samples were air-dried in the laboratory, disaggregated, sieved and analysed for heavy metals and organochlorine pesticides (OCP) residues using standard methods. The heavy metal range at floodplains (mg/kg) was: Cr (0.25-2.08), Cu (0.19-14.28), Zn (BDL-2.53), Cd (BDL-0.87), Pb (BDL-0.32), Fe (0.38-22.35) while for OCP residues, the range (µg/kg) was α-BHC (0.15-0.33), β-BHC (0.19-14.28), δ-BHC (0.25-1.09), lindane (BDL-1.23), chlorothalonil (0.87-1.44), heptachlor (BDL-1.04), heptachlor epoxide (BDL-1.96), endosulfan I (0.20-1.98), endosulfan II (BDL-0.67), aldrin (BDL-1.93), endrin (BDL-0.37), dieldrin (BDL-0.42), p,p-DDE (BDL-0.52), p,p-DDT (BDL-1.20), methoxychlor (0.21-0.88). The pollutants' concentrations in the sediments were generally low at all the sites when compared with international guidelines for each pollutant. Governments in Nigeria should checkmate indiscriminate dumping of refuse most of which end in our rivers in order to reduce pollutants' concentration in rivers/sediments so as to protect the lives of benthic organisms.

Keywords
Benthic, ecosystem, sediments, PAHs, pesticides, pollutants

Introduction

The industrial revolution of 19th century came with increased pollution of the earth's environment. Since then, rivers from all over the world have received significant amounts of pollutants from industrial effluents (Perey, 2006). Sediment is a matrix of materials which composed of detritus, inorganic and organic particles and it is relatively heterogeneous in terms of its physical, chemical and biological characteristics (Kumar *et al.*, 2011). It serves as habitat and major nutrient source for benthic organisms (Davies and Abowei, 2009). It is a known fact that pollutants dropped in water bodies eventually settle to the bottom sediment. Therefore, sediment acts as sink for pollutants like heavy metals, pesticide residues and polycyclic aromatic hydrocarbon (PAHs) amongst others (Amadi *et al.*, 2016). Pollutants are of environmental concern in aquatic ecosystems due to their environmental persistence, toxicity, bioaccu-

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cumulation and biomagnification in the food chain (Saria, 2016). Though heavy metals may be discharged into aquatic ecosystem in low amounts, the constant deposits through anthropogenic activities can raise their concentration, creating environmental problems in lakes, rivers, streams as well as households (Saria, 2016). According to (Nfon *et al.*, 2008), sources of heavy metals in sediments include industrial effluents, municipal sewage, mining and agricultural activities among others. Pesticides, in particular organochlorine pesticides (OCPs), can enter the aquatic environment through paths like runoff from contaminated soil, industrial effluents and atmospheric deposition. In water, hydrophobic OCPs (such as DDTs and HCHs) tend to adsorb to particulate organic matter and deposit in sediments (Ivanova *et al.*, 2021).

As a result of their persistence and bio-accumulative nature, these pollutants can enter the food chain thereby creating health issues to man (Vesel *et al.*, 2013). Thus, there is the need to determine sediment qualities of rivers especially in a developing country like Nigeria where, as a result of her large population, great amount of wastes are generated daily without good management practices and technology to treat such wastes effectively (Howard *et al.*, 2021).

A lot of research works have been done on heavy metal, pesticide residues in sediments worldwide (Mahugija *et al.*, 2017; Skorbiloicz *et al.*, 2018, El-Alfy *et al.*, 2019). However, only scanty reports are seen on state of sediment pollution in developing countries, Nigeria inclusive. The aim of this study therefore is to evaluate the distribution of heavy metals and pesticide residues in sediments of some rivers in Ekiti State, Southwest Nigeria in order to present, perhaps for the first time, a multipurpose environmental data as an index for environmental evaluation.

Materials and Methods

Study Area

The Ekiti State is mainly an upland zone rising over 250 meters above sea level. The state is located between longitudes 4045' and 5045' East of Greenwich Meridian and between latitudes 7015' and 8050' North of Equator. It is generally undulating with a characteristic landscape that consists of old plains broken by step sided outcrops or ridges. The state enjoys tropical climate with distinct wet and dry seasons (Akinyemi *et al.*, 2013). The state is the source of many notable rivers in the South western Nigeria.

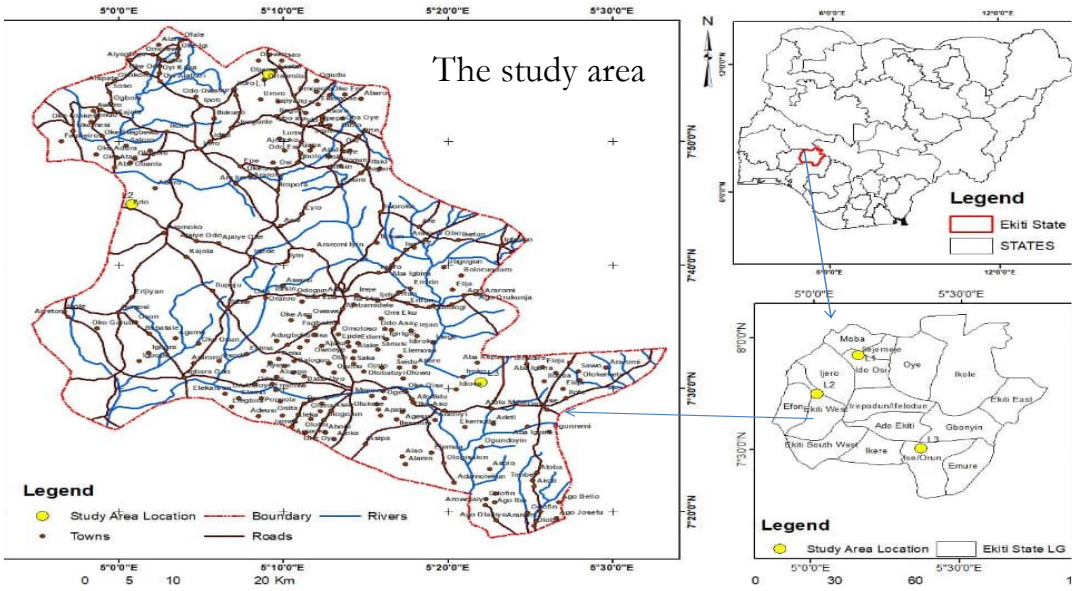

Figure 1
Map of Ekiti State showing the sampling sites

Sample collection and preparation

Three rivers with floodplains used for dry season farming (FGN Fadama project) were selected for the study; these were Irintan river, tributary of Ogbese River in Ogbese Town, Ise-Ekiti; Omi-Eye River at Erio-Ekiti and Egbigbu River at Ayetoro-Ekiti in southern, central and northern parts of the state respectively. The coordinates of the farm locations taken with GPS

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e-trek 10 are: Longitude – 05^0 22.019'E, Latitude - 07^0 30.528'N (Altitude - 420m); Longitude – 04^0 52.882' E Latitude - 07^0 43.450'N (Altitude - 417m); Longitude - 05^0 09.131'E, Latitude - 07^0 55.457'N (Altitude - 531m) respectively. Sediment sampling at the three rivers took place between October 2019 and April 2020 which were dry season months during which the rivers could be accessed to obtain the samples. Sediment samples were obtained at upper, middle and lower parts of each river relative to the FADAMA farm. All samples were put in separate polythene bags, appropriately labeled and transported to the laboratory under a sealed box. They were subsequently air dried, disaggregated with agarte mortal and pestle, sieved with 2.0mm (BS) stainless steel mesh and kept in polyethylene terephthalate (PET) bottles pending analysis.

Sample analyses

Heavy Metals Analysis. One gram of sample was placed in a 250 mL digestion tube and 10 mL of Conc. HNO_3 was added. The mixture was boiled gently in a fume cupboard for 30-45 minutes to oxidize all easily oxidizable matter. After cooling, 5 mL of 70 % $HClO_4$ was added and the mixture was boiled gently until dense white fumes appeared. It was cooled again before 20 mL of deionised water was added and the mixture was boiled further to release any fumes. The solution was finally cooled, filtered through Whatman No 42 filter paper and transferred quantitatively to a 25 mL volumetric flask and made up to mark using deionised water (Zang-Yei, 2004). The heavy metals were analyzed with Atomic Absorption Spectrophotometer (AAS) Perkin Elmer Analyst 400 model.

Pesticides Analysis. The reagents used were all of analytical grade and glasswares used were cleaned as prescribed by USEPA method 1699 (USEPA, 2007). The extraction of organochlorine pesticides in the sediments was carried out using the method described by (Ize-Iyamu and Egwakhide, 2007). Twenty five grammes of the dry sediment sample was mixed with fifty grammes of granular sodium sulphate, ground carefully into fine particles using pestle and mortal after which it was extracted using 150 mL mixture of n-hexane and acetone (1:2) in a 250 mL Erlemeyer flask. The extract was transferred into a round bottomed flask and concentrated to 20mL on a water bath with temperature maintained at 55 ^{0}C. The concentrated extract was further concentrated using a rotary evaporator to 5 cm^3. The concentrated extract was transferred to centrifuge tube and concentrated on a centrifuge tube where it was concentrated on a nitrogen evaporator to 0.5 cm^3 and diluted to 2 cm^3 in hexane before analysis.

Pesticide extract clean-up

A 15 cm (length) x 1cm (internal diameter) column plugged at its lower end with glass wool was packed with 5 g activated silica made in slurry form in dichloromethane. Two grams (2 g) of anhydrous sodium sulphate (Na_2SO_4) was placed on top of the silica gel to absorb water in the sample or solvent in the clean-up extract. Pre-elution was done with 15 cm^3 dichloromethane without exposing the sodium sulphate layer to air, in order to prevent the drying up and cracking of the packed silica gel adsorbent. The extract was then introduced into the column and allowed to sink below the sodium sulphate layer. Elution was done three times each with 10 cm^3 portions of dichloromethane (DCM). The combined eluate was evaporated to dryness on a rotary evaporator at about 45 ^{o}C using a gentle stream of pure nitrogen (99.99 %). The dried eluate was reconstituted with 1 cm^3 trimethylpentane and transferred into glass GC vials in readiness for gas chromatographic analysis.

Gas Chromatographic operating conditions

The sample (1 µL) was injected into the injection port of an Agilent 7980 Autosampler Gas Chromatograph system equipped with an Electron Capture Detector. The oven temperature started at 150 ^{0}C and increased to 280 ^{0}C at 6 ^{0}C per minute. The run time was 21.67 min. The individual OCPs were identified by comparing the elution time of standard OCPs with those in the samples, while each OCP was quantified by comparing the peak areas of the OCPs in the samples with those in standard.

Quality Assurance

All glass wares were first soaked in 14% HNO_3 for 24 hours to remove possible contaminants, washed with detergent and rinsed with de-ionised water before commencing analysis. Quality control was assured through replicate samples, use of pure analytical grade reagents and procedural blanks, limit of detection and limit of quantification (Olawale *et al.*, 2017). Other methods adopted in order to further ensure that the result obtained in this study is valid and reliable included determination of percentage recoveries of organochlorine pesticides residues from spiked and

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unspiked samples which were found to be within the 70-120% range approved by the European Commission (EC) for evaluating the efficiency and precision of an analytical method (EU, 2017).

Data Analysis

The data obtained from this study were statistically tested for analysis of variance (ANOVA), t-test, Pearson correlation using SPSS 16.0 package. The interpretation of statistical results was done using one level confidence limit ($p<0.05$).

Results and Discussion

Heavy Metals in Sediment

The results of heavy metal concentration in sediments at Irintan (Ogbese), Omi-Eye (Erio) and Egbigbu (Ayetoro) rivers are presented in Table 1. All the metals studied were detected in the sediments samples The concentration ranges (mg/kg) are: Cr (0.25-0.79), Cu (0.19-0.77), (1.54-1.74), Cd (0.54-0.87), Pb (0.09-0.29), Fe (0.38-1.14) with the highest value recorded in Zn (1.74±0.39mg/kg) at middle course and the lowest value recorded in Pb (0.09±0.03mg/kg) at upper course for Irintan floodplain; Cr (0.46-0.73), Cu (0.74-1.84), Zn (2.17-2.53), Cd (BDL-0.28), Pb (BDL-0.25), Fe (7.45-18.88) with the highest value recorded in Fe (18.88±4.16mg/kg) at upper course and the lowest concentration obtained in Pb and Cd (BDL) at upper course for Omi-Eye floodplain and Cr (1.59-2.08), Cu (7.03-14.28), Zn (BDL-3.83), Cd (BDL-0.03), Pb (0.14-0.32), Fe (6.17-22.35) with the highest values obtained in Fe (22.35±1.29mg/kg) at middle course and lowest values recorded in Zn at upper course and Cd at upper and middle course (BDL) for Egbigbu floodplain.

Table 1. *Heavy metal comcentration (mg/kg) in Sediments at the study sites and Mean comparison with USEPA Guidelines.*

Site	R/Course	Cr	Cu	Zn	Cd	Pb	Fe
Irintan	Upper	0.25±0.01	0.19±0.08	1.56±0.04	0.65±0.02	0.09±0.03	0.38±0.06
	Middle	0.55±0.04	0.36±0.03	1.74±0.39	0.54±0.17	0.11±0.01	1.05±0.10
	Lower	0.79±0.04	0.77±0.19	1.54±0.05	0.87±0.12	0.29±0.06	1.14±0.03
Omi-Eye	Upper	0.46±0.03	1.84±0.00	2.17±0.11	BDL	BDL	7.45±1.62
	Middle	0.58±0.09	1.56±0.07	2.37±0.07	0.11±0.02	0.25±0.06	16.12±3.97
	Lower	0.73±0.00	0.74±0.05	2.53±0.31	0.28±0.08	0.14±0.02	18.88±4.16
Egbigbu	Upper	1.59±0.14	14.28±1.03	BDL	BDL	0.32±0.03	18.48±3.62
	Middle	1.75±0.02	7.03±0.13	1.69±0.11	BDL	0.15±0.00	22.35±1.29
	Lower	2.08±0.11	9.95±0.81	3.83±0.33	0.03±0.01	0.14±0.05	6.17±0.32
Irintan	Mean Values	0.53±0.27	0.44±0.30	1.61±0.11	0.69±0.14	0.16±0.11	0.86±0.42
Omi-Eye	Mean Values	0.59±0.14	1.38±0.85	2.35±0.18	0.13±0.02	0.13±0.12	14.15±5.96
Egbigbu	Mean Values	1.81±0.25	10.42±3.65	1.84±0.92	0.01±0.02	0.20±0.10	8.33±8.45
USEPA Metal Guideline	Not polluted	40-60	<25	<90	NA	<40	NA
	Moderately polluted	>60	25-75	90-200	NA	40-60	NA
	Heavily polluted	>75	>75	>200	>60	>60	NA

Values with different superscripts on the same row are significant ($p<0.05$). Source of USEPA Guidelines: (Ogbeibu et al., 2014)

The range of the metal concentration (mg/kg) along the courses at Irintan equally reveal that Zn recorded the highest value (1.56±0.04) while the least value was obtained in Pb (0.09±0.03) at upper course, highest value in Zn (1.74±0.39) and lowest value in Pb (0.11±0.01) at middle course and the highest value in Zn (1.54±0.05) while lowest value was recorded in Pb (0.29±0.06) at the lower course. At Omi-Eye, thehighest value was recorded in Fe (7.45±1.62) and lowest was recorded in Cd and Pb (BDL) at upper course, the highest value was obtained in Fe (16.12±3.97) and lowest value recorded in Cd (0.11±0.02) at the middle course and highest concentration in Fe (18.88±4.16) and lowest value in Pb (0.14±0.02 at the lower course of the floodplain. Finally at Egbigbu, the highest was recorded in (18.48±3.62) and lowest recorded in Zn and Cd (BDL) at the upper course, the highest value obtained in Fe

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(22.35±1.29) and lowest concentration obtained in Cd (BDL) in middle course and highest concentration recorded in Cu and lowest value recorded in Cd (0.03±0.01) at the lower course of the floodplain. The values obtained in this study are within the ones obtained by Adeyemi *et al.* (2019) in their study of heavy metal pollution in sediments from Ologe lagoon, Agbara, Lagos, Nigeria but far less than those obtained by Onoyima *et al.* (2021) in sediment of River Kaduna, Nigeria and those obtained by Algul and Beyhan (2020) from sediment of Bafa Lake in Turkey. The order of Cr in Irintan, Omi-Eye and Egbigbu was lower course>middle course>upper course. However, the order of Cu in Irintan was lower course>middle course>upper course, at Omi-Eye it was upper course>middle course>lower course while at Egbigbu it was upper course>lower course>middle course. In the case of Zn, the order was middle course>upper course>lower course at Irintan, while it was lower course>middle course>upper course at both Omi-Eye and Egbigbu. Cd has the order of lower course>upper course>middle course in Irintan, lower course>middle course>upper course at Omi-Eye while the order at Egbigbu was lower course>upper course/middle course.

For Pb, it was lower course>middle course>upper course in Irintan, middle course>lower course>upper course in Omi-Eye and upper course>middle course>lower course in Egbigbu. Iron has the order lower course>middle course>upper course in Irintan and Omi-Eye while it was middle course>upper course>lower course at Egbigbu.

Metals with higher values at upper courses may be as a result of contributions from outside the farm while metals with higher values at the lower course may be attributed to anthropogenic activities on the farm especially the use of agrochemicals like pesticides and fertilizers.

The results obtained in this report show the sediments were not polluted when compared with USEPA guidelines (Table 1). The values obtained at upper, middle and lower courses were significantly different for some metals as observed in Cr and Cu in Omi-Eye while they were not significantly different for others at as observed in Zn at Irintan and Pb in Egbigbu $p<0.05$.

Table 2 shows the concentration of organochlorine pesticide residues measured in Irintan River (Ogbese), Omi-Eye River (Erio) and Egbigbu River (Ayetoro) sediments.

Table 2. *Organochlorine residues concentrations in sediments at the study sites and comparison with Sediment Quality Guidelines*

F/plain	Irintan			Omi-Eye			Egbigbu			Sediment Quality Guidelines			
R/course	Upper	Middle	Lower	Upper	Middle	Lower	Upper	Middle	Lower	ERL[a]	ERM[a]	TEL[b]	PEL[b]
α-BHC	0.15^{a}±0.03	0.33^{b}±0.05	0.34^{b}±0.00	0.25^{a}±0.07	0.25^{a}±0.00	0.33^{a}±0.05	0.24^{a}±0.03	0.30^{b}±0.04	0.31^{b}±0.04	NA	NA	0.94	1.38
β-BHC	BDL	BDL	BDL	0.42^{a} ±0.07	0.54^{a}±0.02	0.97^{b}±0.31	BDL	1.20^{a}±0.17	1.20^{a}±0.14	NA	NA	NA	NA
δ-BHC	0.72^{a}±0.04	0.80^{b}±0.07	0.92^{c}±0.00	0.25^{a} ±0.00	0.52b±0.00	1.09^{c}±0.07	0.64^{a}±0.05	0.65^{a}±0.03	0.87^{b}±0.21	NA	NA	NA	NA
Lindane	BDL	BDL	BDL	0.26^{a} ±0.04	0.23^{a}±0.00	0.35^{b}±0.13	1.23^{b}±0.57	0.23^{a}±0.02	BDL	NA	NA	NA	NA
Chlorotha	0.90^{a}±0.06	1.05^{b}±0.53	1.44^{c}±0.20	1.18^{a} ±0.02	1.13^{a}±0.57	1.06^{a}±0.25	0.87^{a}±0.11	1.30c±0.20	1.16^{b}±0.05	NA	NA	NA	NA
Heptachlor	0.35^{a}±0.08	0.35^{a}±0.10	1.04^{b}±0.23	0.22^{a} ±0.03	0.23^{a}±0.07	0.30^{b}±0.00	BDL	BDL	BDL	NA	NA	NA	NA
H/Epoxid	BDL	BDL	BDL	1.96^{c}±0.73	1.47^{b}±0.13	0.54^{a}±0.11	BDL	BDL	BDL	NA	NA	0.6	2.74
E/Sulfan I	0.20^{a}±0.06	1.55^{b}±0.32	1.87^{c}±0.20	1.98^{c}±0.55	1.40^{b}±0.09	0.47^{a}±0.15	0.21^{a}±0.05	0.39^{a}±0.08	1.41^{b}±0.33	NA	NA	NA	NA
E/Sulfan II	BDL	BDL	BDL	0.45^{b}±0.04	0.28^{a}±0.00	BDL	0.67^{b}±0.09	0.32^{a}±0.00	0.29^{a}±0.00	NA	NA	NA	NA
Aldrin	0.24^{a}±0.09	1.40^{b}±0.02	1.93^{c}±0.04	1.57^{c}±0.10	0.48^{b}±0.00	0.29^{a}±0.08	BDL	1.91^{a}±0.75	BDL	NA	NA	NA	NA
Endrin	BDL	BDL	BDL	0.32^{a}±0.02	0.36^{b}±0.00	0.36^{b}±0.05	0.37^{a}±0.02	BDL	0.36^{a}±0.00	0.02	45	2.67	62.4
Dieldrin	BDL	BDL	0.21^{b}±0.02	0.34^{b}±0.09	0.33^{b}±0.01	0.24^{a}±0.00	0.42^{c}±0.13	0.35^{b}±0.01	0.24^{a}±0.07	0.02	8	2.85	2.85
p,p-DDE	BDL	BDL	BDL	BDL	0.32^{a}±0.00	0.52^{a}±0.00	BDL	BDL	BDL	2.2	2.7	1.42	6.67
p,p-DDT	BDL	BDL	BDL	BDL	0.63^{a}±0.03	0.96^{b}±0.13	1.20^{b}±0.39	0.62^{a}±0.06	0.60^{a}±0.09	1	7	1.79	NA
Methoxy	0.58^{a}±0.11	0.55^{a}±0.07	0.66^{c}±0.15	0.21^{a}±0.02	0.49^{b}±0.05	0.51^{b}±0.00	0.88^{b}±0.07	0.23^{a}±0.00	0.23^{a}±0.00	NA	NA	NA	NA
∑ BHCs	0.87	1.13	1.36	1.18	1.54	2.74	2.11	2.15	2.38	NA	NA	NA	NA
∑ DDTs	BDL	BDL	BDL	BDL	0.95	1.48	1	0.62	0.6	1.58	46.1	7	4450

BHC= Benzene hexachloride, Chlotha= Chlorothalonil, H/Epoxide= Heptachlor Epoxide, E/sulfan= Endosulfan, DDE= Dichlorodiphenyldichloroethene, DDT= Dichlorodiphenyltrichloroethane, Methoxyc= Methoxychlor. Values with different superscripts on the same row are significant ($p<0.05$). ERL= Effect Range Low, ERM= Effect Range Medium, TEL= Threshold Effect Low, PEL= Probable Effect Level, Source: a=(Long *et al.*, 1995) b=(MacDonald *et al.*, 2000). Values with different superscripts on the same row are significant ($p<0.05$)

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All the sediments studied were detected with exception of a few at some sites. The concentration (μg/kg) ranged observed were as follows: for Irintan viz:- α – BHC (0.15-0.34), β – BHC (BDL), δ – BHC (0.72-0.92), lindane (BDL), chlorothalonil (0.90-1.44), heptachlor (0.35-1.04), heptachlor epoxide (BDL), endosulfan I (0.20-1.87), endosulfan II (BDL), aldrin (0.24-1.93), endrin (BDL), dieldrin (BDL-0.21); dichlorodiphenyldichloroethylene (p,p'–DDE) (BDL), dichlorodiphenytrichloroethane (p, p' – DDT) (BDL), methoxychlor (0.55-0.66); for Omi-Eye viz:- α – BHC (0.25-0.33), β – BHC (0.42-0.97), δ – BHC (0.25-1.09), lindane (0.23-0.35), chlorothalonil (1.06-1.18), heptachlor (0.22-0.30), heptachlor epoxide (0.54-1.96), endosulfan I (0.47-1.98), endosulfan II (BDL-0.45), aldrin (0.29-1.57), endrin (0.32-0.36), dieldrin (0.24-0.34), p,p'–DDE (BDL-0.52), p, p' – DDT) (BDL-0.96), methoxychlor (0.21-0.51) and for Egbigbu viz:- α – BHC (0.24-0.31), β – BHC (BDL-1.20), δ – BHC (0.64-0.87), lindane (BDL-1.23), chlorothalonil (0.87-1.16), heptachlor (BDL), heptachlor epoxide (BDL), endosulfan I (0.21-1.41), endosulfan II (0.29-0.67), aldrin (BDL-1.91), endrin (BDL-0.37), dieldrin (0.24-0.42), p, p'–DDE (BDL), p, p' – DDT (0.60-1.20) and methoxychlor (0.23-0.88). The total OCPs concentration at upper, middle and lower courses respectfully is 3.14, 6.03 and 8.41 μg/kg at Irintan, 9.41, 8.66 and 7.99 μg/kg at Omi-Eye and 6.73, 7.50 and 6.67 μg/kg at Egbigbu floodplain.

The OCPs values obtained in this study are within the values obtained by Okoya *et al.* (2013) in their study of OCP residues in sediments from cocoa producing Areas of Ondo State, Southwest Nigeria but lower than the ones obtained by Olofinsoye and Senkele (2016) in their study of OCPs in sediment obtained from Lagos Lagoon, Nigeria. Generally, the trend was upper course<middle course<lower course for most of the pesticide values except for methoxychlor at Irintan river; lindane, heptachlor epoxide, aldrin, dieldrin in Omi-Eye river and methoxychlor in Egbigbu river. The observed trend may imply that the OCPs were still being used by the farmers at the farm sites despite ban on their usage. The values obtained at upper, middle and lower courses were significantly different for some pesticide residues while they were not significantly different for others at $p<0.05$. For example, chlorothalonil showed significant difference between the three courses in Irintan and Egbigbu but shows no significance at Omi-Eye floodplain. The OCP values obtained at the three sites were generally low when compared with probable effect level (PEL) (MacDonald *et al* 2000) (Table 2). This implies that the benthic organisms living on the sediment may not be at risk as far as the OCP residue concentrations are concerned. The only exception to the above generalization were p,p'-DDT at Egbigbu river (Ayetoro) upper course which was above effect range low (ERL) and heptachlor epoxide at Omi-Eye river (Erio) upper and middle courses where the values were above the threshold effect low (TEL) but less than probable effect level (PEL). The concentrations of the two OCP residues call for concern in those respective regions.

Conclusions

The results of the pollutant concentrations in the sediments of Irintan, Omi-Eye and Egbigbu Rivers shows that the rivers are not polluted when compared with established sediment quality guidelines. The values obtained for heavy metals and pesticide residues are lower than effect range low of the guidelines of each pollutant which is the concentration above which aquatic organisms could be affected negatively by the pollutants. This implies that the organisms may not be negatively impacted by the concentrations of the pollutants. However, there is the need to watch the concentration of p,p'-DDT at Egbigbu river (Ayetoro) upper course which was above effect range low (ERL) and heptachlor epoxide at Omi-Eye (Erio) upper and middle courses where the values were above the threshold effect low (TEL) but less than probable effect level (PEL). This implies the concentrations of the two pesticide residues may impact the lives of the benthic organisms negatively if the trend is not checked. It is therefore recommended that regulatory agencies should constantly monitor the sediments to safeguard the organisms feeding on the sediments which apart from being affected negatively by the concentration of the pollutants, can equally bio-accumulate the pollutants and ultimately transfer them to man. Waste management practices should equally be improved upon by government to prevent indiscriminate dumping of refuse/wastes into rivers and thereby save the lives of benthic organisms.

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