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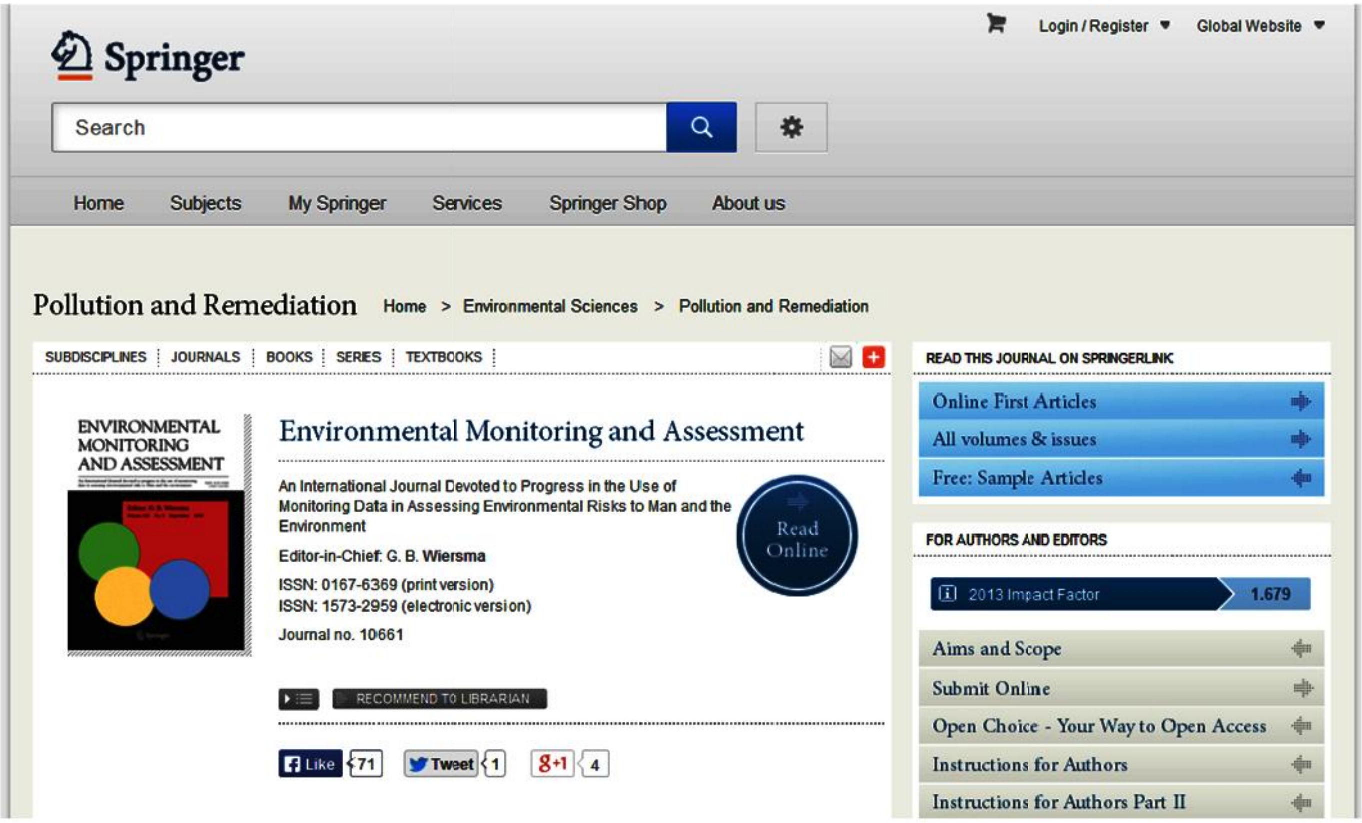

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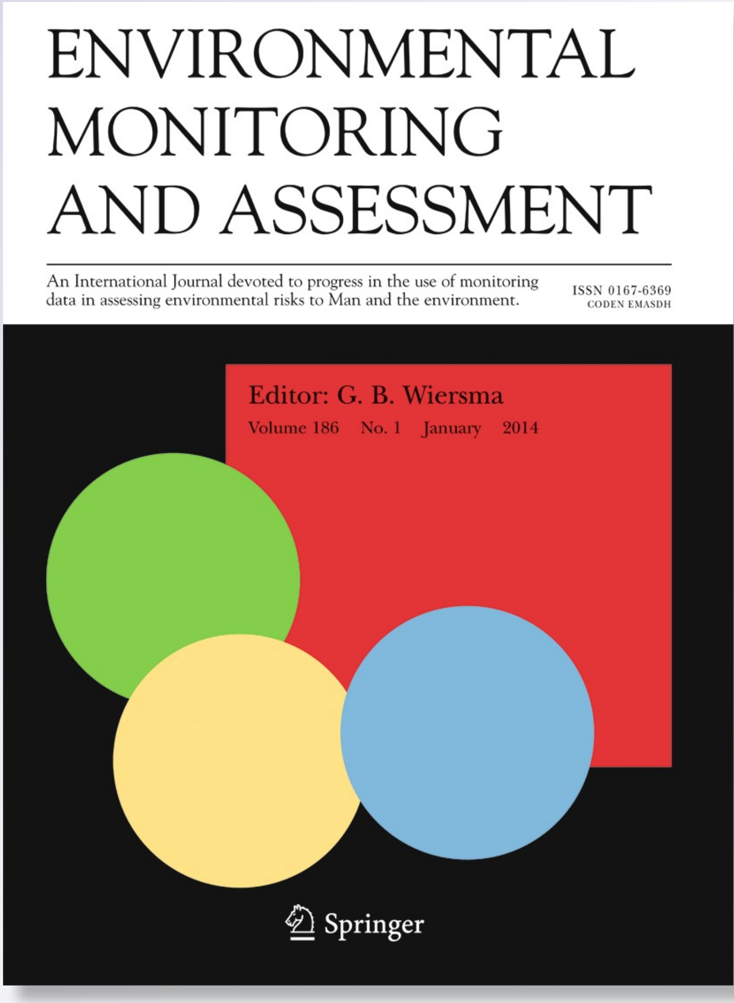

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Pesticide residues in sediments and aquatic species in Lake Nokoué and Cotonou Lagoon in the Republic of Bénin

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Abstract Lake Nokoué and Cotonou Lagoon are the most important and most productive continental freshwaters in Bénin, with an estimated fish production of over 2 tonnes per hectare in Lake Nokoué. Organochlorine pesticides are used in agriculture and to repel tsetse flies, malaria mosquitoes and other diseases raised. Sediment, fish, shrimp and oyster species were collected in Lake Nokoué and Cotonou Lagoon for pesticide residues analysis. The main pesticides identified in sediment were *pp*′-DDT and its metabolites *pp*-DDE and *pp*′-DDD, with residue levels between the detection limit and 24.4 μg/kg dry weight. Fish species commonly consumed such as *Elops lacerta*, *Podamasys jubelini*, *Gobbienellus occidentalis*, *Ethmalosa fimbriata*, *Mugil cephalus* and *Hemichromis fasciatus* were contaminated with residues of seven to nine pesticides, including *pp*-DDE, *op*′-DDD, *pp*′-DDD, *op*′-DDT, *pp*′-DDT, α-endosulfan, aldrin, dieldrin and γ-hexachlorocyclohexane. The levels ranged from detection limit to 289 ng/g lipid. The same pesticides were also detected in other aquatic species, such as shrimp and oysters. A summed risk assessment, comparing pesticide intake levels through fish consumption with tolerable daily intake levels proposed by the World Health Organization, showed in all cases a low risk for human health.

Keywords Pesticide residues · Sediment · Fish · Oysters · Shrimp · Human health risk

Introduction

The complex freshwater formed by Lake Nokoué and Cotonou Lagoon is the most important continental

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freshwater in Bénin, with high productivity. According to Lalèyè et al. (2003), it is also the most productive lake of West Africa with a fish production of over 2 tonnes per hectare. Lake Nokoué is a water reservoir fed by the Ouémé River. Cotonou Lagoon is a man-made reservoir, created in order to connect Lake Nokoué with the Atlantic Ocean. The biodiversity of this complex freshwater system is very high, with a large diversity of fish, molluscs, shellfishes, birds and amphibians (Villanueva et al. 2006).

In the catchment of the complex freshwater, DDT was used to control tsetse fly and malaria mosquitoes, and to combat *Dracunculus medinensis* larvae (Dehoux 1993). Although DDT application was banned, some small-scale applications are still allowed in some tropical countries (UNEP 1997). Other persistent organochlorines are extensively used as insecticides on vegetable crops around Lake Nokoué and for agriculture along the Ouémé River (Yehouenou A. Pazou et al. 2006a, b). Erosion, pollution by metals and organic contaminants, and increased anthropogenic activities have caused a profound change in Lake Nokoué and Cotonou Lagoon including sedimentation and biodiversity shifts (Lalèyè et al. 2004). Lake Nokoué is used for transportation of people, fuel transport and for business with the neighbouring country Nigeria. These activities contributed to the pollution of Lake Nokoué. Because of their persistency and lipophilicity, organochlorine pesticides accumulate in organisms higher in the food chain, as has been shown before in several studies (see e.g. Kidd et al. 2001). Accumulation of these chemicals in fish may pose a risk to these organisms and their consumers including humans.

This study therefore aimed at quantifying the pollution level of the freshwater ecosystems of Lake Nokoué and Cotonou Lagoon and to assess the potential risk for human health. The present study addressed the accumulation of organochlorine pesticide residues in different compartments such as sediments, fish and crustaceans collected at different sites along the lake and the lagoon.

Material and methods

Study area

Lake Nokoué is located in the south–east of the Republic of Bénin (6° 25′N, 2° 26′E), and has a surface area of 150 km^2 (Fig. 1). The lake measures 20 km in the east–west and 11 km in the north–south direction. In the east, Lake Nokoué is linked to the Porto-Novo Lagoon with which it forms a freshwater lake with a surface area of about 180 km^2. Lake Nokoué is connected with the Atlantic Ocean by the channel of Cotonou, named Cotonou Lagoon, which has a total length of 4.5 km.

Sampling

In 2002, sediment samples of around 250 g wet weight were collected from the approx. 5 cm top layer with a grab sampler in Lake Nokoué and Cotonou Lagoon. Replicate samples were processed and analysed separately. In 2004, fish, crustaceans and oysters were caught with a net. The fish were identified using the taxonomic key of Lévêque et al. (1990, 1992). Samples were kept at 4 °C during transportation from the field to the laboratory, where they were dissected and lyophilised.

Sediment characteristics

The grain size distribution of the sediment was determined with a laser diffraction spectrophotometer according to Konert and Vandenberghe (1997). Total carbon and nitrogen concentrations in duplicate samples were measured by burning the dried samples in a stream of pure oxygen in combination with column chromatography with an elementary analyser (Carlo Erba, Strumentazione model 1106). 2,5-Bis-(5-tert-butyl-benzoxazol-2-yl)-thiophene (Fluka 14555) was used to create a calibration curve. Organic matter content in sediment was determined as the loss on ignition (LOI) by burning dry sediment samples at 550 °C.

Pesticide analysis

Sediments were analysed at the Institute of Environmental Studies of the VU University in Amsterdam. Fish and other aquatic organisms were analysed in the certified laboratory of the Hoogheemraadschap Hollands Noorderkwartier in Edam.

All solvents (*n*-hexane, acetone, sodium sulphite, petroleum ether, diethyl ether, isooctane) and other chemicals used (anhydrous sodium sulphate, aluminium oxide, copper, silica gel) were of analytical grade quality (Merck, J.T. Baker) to ensure purity.

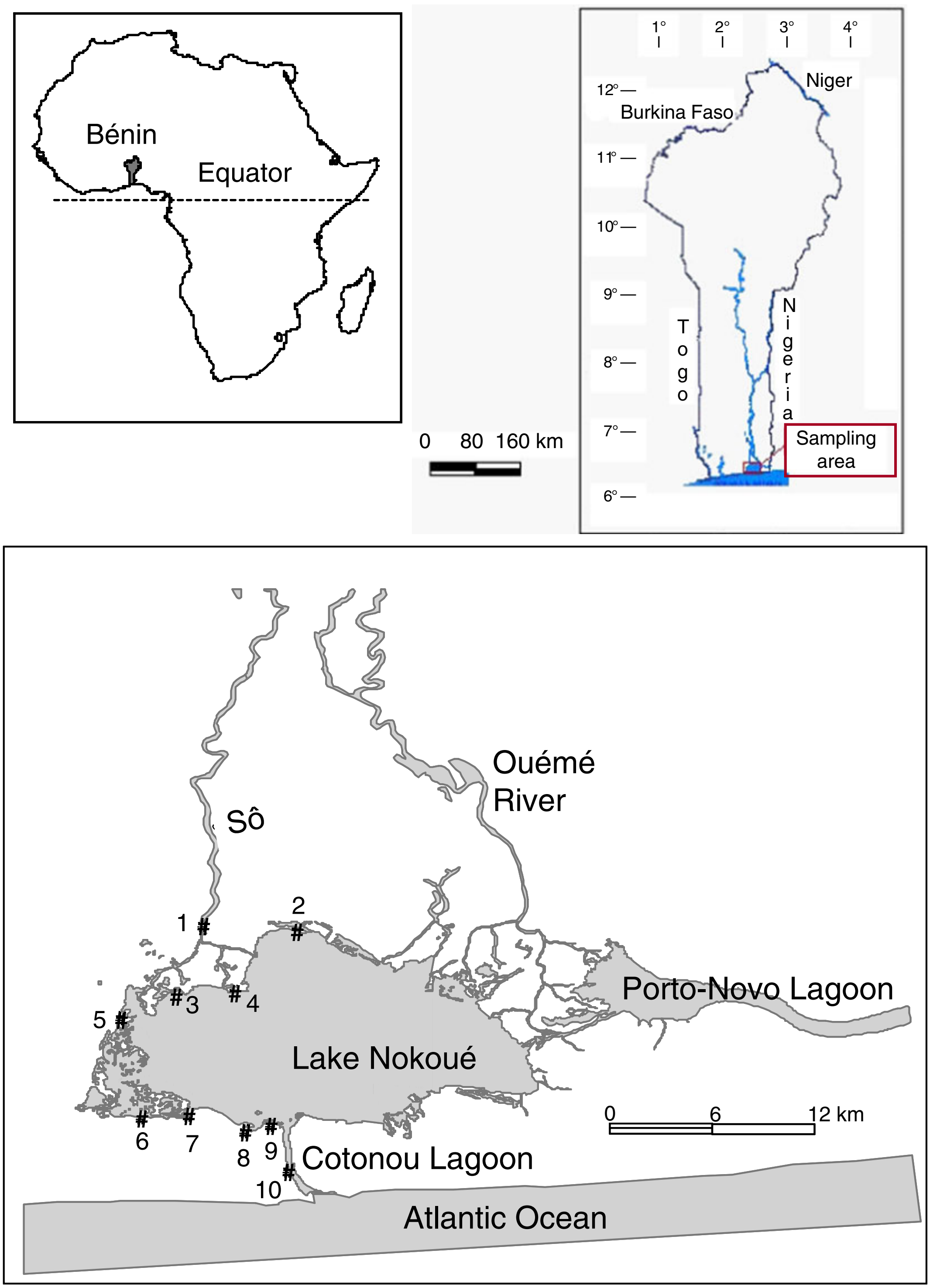

Fig. 1 Map of Lake Nokoué and Cotonou Lagoon and their position in the Republic of Bénin and the African continent. The locations of the areas used for sampling sediment and biota for pesticide analysis are indicated with *number signs*: 1 = So-Ava, 2 = Vêki, 3 = Ganvié, 4 = So-Tchanhoué, 5 = Abomey-Calavi, 6 = Zogbo, 7 = Jesuko, 8 = Awansori, 9 = Ladji, 10 = Dantokpa

Sediments

After transportation to the Netherlands, the lyophilised samples were ground in a ceramic mortar. Pulverized sediment (5 g) samples were extracted in an accelerated solvent extractor (ASE 200, Dionex, Sunnyvale, CA, USA) with 20 ml of an *n*-hexane–acetone mixture (9:1 *v*/*v*; Merck, Darmstadt, Germany). To each extract, 2 ml isooctane (Merck) was added and concentrated to approximately 1 ml under a gentle stream of nitrogen gas using a water bath (30 °C).

The extracts were placed on top of a column containing a small amount of glass wool at the bottom, covered with 3 g aluminium oxide 15 % (type Woelm, ICN, Fisher Scientific, Landsmeer, The Netherlands) deactivated with water and conditioned with 4 ml petroleum ether–diethyl ether (95:5 *v*/*v*, Merck) before adding the concentrated extract. In total, 17 ml petroleum ether–diethyl ether was used to elute pesticides from the column. The extracts were concentrated to about 0.5 ml under a gentle stream of nitrogen gas (at 30 °C). One millilitre isooctane was added to the extracts that were again concentrated to 0.5 ml. The extracts were transferred into vials for automated analysis by gas chromatography with electron capture detection (GC-ECD). The ECD response was calibrated using a standard containing 24 organochlorinated pesticides and 8 polychlorinated biphenyls (PCBs).

Chlorinated pesticides in sediment and biological samples were measured with GC (Varian 3800, Walnut Creek, CA, USA) in combination with an auto sampler (Varian 8200) and an ECD (Varian EFC 13). ECD temperature was 300 °C. Helium was used as the carrier gas with a flow rate of 1 ml/min and nitrogen makeup gas at a flow rate of 30 ml/min. The injection volume was 3 μl with a split-less injection mode. Organochlorine residue compounds were identified by comparing their retention times with those of the standard mixture of PCBs and organochlorine pesticides. The calibration line of the standard was slightly quadratic for almost all compounds. For quantification, sample extracts were diluted so that the response was well within the approximate linear part of the calibration curve. The limit of detection (LOD) was derived from the variability of procedural blanks and was determined as 0.1 μg/kg for all pesticides including the different DDT analogs and isomers (*pp*′-DDE, *op*′-DDD, *pp*′-DDD′, *op*′-DDT, *pp*′-DDT), while the corresponding limit of quantification (LOQ) was 0.3 μg/kg sediment.

Fish and other aquatic organisms

The freeze-dried and lyophilised fish (2 g) samples were ground using a ceramic pestle and mortar. Samples were shaken with 200 ml acetone for 10 min, after which 20 ml of a saturated sodium sulphite solution and 100 ml petroleum ether were added. After shaking for 10 min, the suspension was filtered over a paper filter and washed with 500 ml deionized water to which 20 ml sodium chloride solution was added. This procedure was repeated, after which, the petroleum ether fraction was dried with sodium sulphate and volume reduced evaporation in a Kuderna–Danish rotavapor at 75–80 °C.

Lipid contents of the fish and other aquatic organisms were obtained by weighing and drying 1 ml of the extract.

For the clean-up of extracts, a similar procedure was followed, using first an aluminium oxide column and next a column of deactivated silica gel; both steps used elution with petroleum ether. The petroleum ether extracts were concentrated to 2.0 ml under a gentle stream of N_2 gas. Analysis was done by GC (Hewlett Packard 6890) with ECD, equipped with an autosampler Hewlett Packard injector 7673 and a Chrompack 8753 CP-Sil-8 CB column. Helium was used as the carrier gas. Organochlorine pesticides were identified by comparing their retention times with those of a standard mixture of PCBs and organochlorine pesticides. To calibrate the analysis, PCB155, mirex and tetrachlorobenzene were used as internal standards.

The LOD for the individual organochlorine pesticides in the biological samples was determined as 0.1 ng/g lipid for samples with an average lipid content of 2 %, the LOQ was 0.3 ng/g lipid.

Quality control

Quality assurance measures applied in the laboratory included rigorous contamination control procedures (strict washing and cleaning procedures); monitoring of blank levels of solvents, equipment and other materials; analysis of procedural blanks; recovery of spiked standards; monitoring of detector response and linearity; and analysis of a reference material (sediment SETOC 701) from the SETOC international proficiency testing programme (Van Dijk and Houba 2000). Concentrations of chlorinated pesticides determined in the reference material were between 80 and 110 % of the certified values of this material.

Risk assessment

To assess the risk of pesticide intake by the local population through the consumption of fish or other aquatic organisms, it was assumed that local people would eat one fish (2.5–5.1 g dry weight) or an estimated 10 g dry weight of another aquatic organism per day. Using these food consumption data and the pesticide concentrations measured, for each pesticide, the daily intake was estimated. Daily intake was normalized for an average human weighing 60 kg. The resulting intake values were compared with the tolerable daily intake (TDI) values reported by the WHO (2004). Assuming all pesticides have the same mode of action, the toxic unit approach was adopted to enable summing the risk of the different pesticides detected. To that end, a toxic unit was defined as the estimated daily intake of a pesticide by fish consumption divided by its TDI. The summed toxic unit combining the different pesticides was used as an indication of the risk. In case the sum of the toxic units would approach or exceed the value of 1, this would indicate a risk for the local population.

Results and discussion

Sediments characteristics in Lake Nokoué and Cotonou Lagoon

The grain size distributions of sediments from Lake Nokoué and the Cotonou Lagoon showed large variability (Table 1). Most of the sediments were sandy, except for the samples from Ganvié and Abomey-Calavi that had very high silt contents and therefore were loamy in nature. At these two sites, sediments also contained much higher organic matter contents than at the other sites. High silt and organic matter contents in the sediments from these areas may be explained by human activities. An important part of the local community lives in houses made on the lake and waste and garbage are directly dumped into the lake.

Sediment of the So-Tchanhoué area had the lowest organic matter content and the lowest percentage of carbon. Along the Cotonou Lagoon, the Ladji area had the highest levels of organic matter. The Ladji area is not far from the Atlantic Ocean and also near the international market of Cotonou. This area received a lot of pollutants and rubbish disposed into the lagoon. Some 25 years ago, liquid rubbish was poured directly into the lagoon. Decomposition of this rubbish may explain the high levels of organic matter.

Pesticide residues in Lake Nokoué and Cotonou Lagoon sediment

Pesticide residues levels in top sediment layers in the different areas of Lake Nokoué and Cotonou Lagoon are presented in Table 1, expressed on a dry weight basis. Pesticide residues levels in sediments from So-Ava and So-Tchanhoué areas were below the detection limit and this was also the case for sediment from Vêki and Jesuko. Lake Nokoué sediments were contaminated by *pp′*-DDE and *pp′*-DDD, which may be explained by transport of pesticides from the Ouémé River into the lake. The fact that only metabolites were identified suggests that DDT was not recently used in or near the lake (Gitahi et al. 2002; Dem et al. 2007; Darko et al. 2008). *pp′*-DDE levels ranged from the detection limit to 24.4 μg/kg dry weight (Table 1). Σ(DDE, DDD) levels in the Ganvié and Abomey-Calavi areas were lower than the maximum permissible concentration (MPC) for sediments according to Dutch sediment quality criteria (58 μg/kg OM for *pp′*-DDE, 39 μg/kg OM for ΣDDD) (Verbruggen et al. 2001). The highest level of *pp′*-DDE identified in Lake Nokoué (4.0 μg/kg d.w.) was lower than the concentration in Cotonou Lagoon at Ladji (24.4 μg/kg d.w.). The latter concentration exceeds the Dutch MPC.

To evaluate the relative degree of pesticide contamination in Lake Nokoué and Cotonou Lagoon, present data were compared to available data reported for other African, Turkish and Indian lakes. *pp′*-DDE levels in Lake Nokoué were much lower than those identified in several lakes in Turkey (mean values of 90–1,420 μg/kg) (Barlas 2002). *pp′*-DDE concentrations in sediments were higher in Lake Nokoué than in the Uganda side of Lake Victoria (0.13 to 3.59 μg/kg d.w.) (Wasswa et al. 2011) and six times lower than in Cotonou Lagoon at Ladji, and also lower than in Bosomtwi Lake in Ghana (11.5 to 26.4 μg/kg d.w.) (Darko et al. 2008). *pp′*-DDD levels in Nokoué and Victoria Lakes were lower than in the Yala/Nzoia basin in Kenya (13.2 μg/kg d.w.) (Musa

Table 1 Characteristics and residue levels of organochlorine pesticides in sediments from Lake Nokoué and Cotonou Lagoon in the Republic of Bénin (see Fig. 1 for sampling areas). Pesticide levels are expressed in microgram per kilogram dry weight. In the other areas, all residues levels were below the detection limit (<dl)

Areas	% clay	% silt	% sand	LOI (%)	% carbon	C/N ratio	Pesticide levels in sediment		
							pp′-DDE	*pp′*-DDD	*pp′*-DDT
So-Ava	2.0	4.1	94.0	3.1	2.54	16.6	<dl	<dl	<dl
So-Tchanhoué	2.1	4.6	93.9	2.2	0.91	11.2	<dl	<dl	<dl
Ganvié	2.8	53.2	26.0	17.5	5.60	12.7	2.0	4.0	<dl
Abomey-Calavi	26.1	58.3	15.6	26.7	11.5	14.8	2.0	4.0	<dl
Zogbo	4.8	18.5	76.7	6.7	2.53	12.7	1.0	<dl	<dl
Awansori	7.1	13.3	79.6	5.4	1.65	12.1	4.0	3.2	<dl
Vêki	1.2	3.4	95.4	2.9	1.50	10.7	<dl	<dl	<dl
Jesuko	4.5	13.8	81.8	0.55	0.17	9.3	<dl	<dl	<dl
Ladji	7.1	13.3	79.6	8.7	3.10	14.2	24.4	11.1	2.0

et al. 2011). HCH, endosulfan, dieldrin and aldrin were not detected in sediments of both the lake and the lagoon.

Pesticide residues in fish from Lake Nokoué and Cotonou Lagoon

The results of this study indicate varying levels of pesticide residues in the six fish species collected in the lake and lagoon (Table 2). DDT and its metabolites α-endosulfan, aldrin, dieldrin and γ-HCH were found in more than 50 % of the analysed fish. *Elops lacerta* was contaminated by seven pesticides, *Gobbienellus occidentalis* and *Mugil cephalus* by eight pesticides, and *Hemichromis fasciatus*, *Ethmalosa fimbriata* and *Podamasys jubelini* by nine pesticides. In all six fish species, *pp′*-DDE concentrations ranged from the detection limit to 289 ng/g lipid with the highest levels in *E. fimbriata* and the lowest in *H. fasciatus*. *E. fimbriata* had the highest levels of all identified pesticides. In all fish samples, DDT levels were lower than those of its metabolites DDD and DDE, confirming that DDT was not recently used in or near the lake (Gitahi et al. 2002; Dem et al. 2007; Darko et al. 2008).

Most of the fish species caught in Lake Nokoué had more pesticide residues with higher levels than fish caught in the Ouémé River (Yehouenou A. Pazou et al. 2006a, b). Pesticide levels in *M. cephalus* caught in the Lake Nokoué and Cotonou Lagoon are compared with data reported for this species in Maroc by Benbakhta et al. (2007). *pp′*-DDT, *pp′*-DDE and *pp′*-DDD levels (corresponding with 0.5, 2.12 and 1.3 ng/g d.w., respectively) were lower in *M. cephalus* from Lake Nokoué than in fish from the Moulay Bousselham Lagoon in Maroc (4.7, 21.5 and 8.58 ng/g d.w., respectively). Also aldrin and dieldrin concentrations in *M. cephalus* from Lake Nokoué and Cotonou Lagoon (0.08 and 0.22 ng/g d.w.) were lower than the levels reported by Benbakhta et al. (2007) for fish from Maroc (0.64 and 0.66 ng/g d.w., respectively). Endrin (0.3 ng/g d.w.), heptachlor (0.89 ng/g d.w.), heptachlor-epoxy (0.31 ng/g d.w.) and γ-HCH (1.05 ng/g d.w.) were detected in *M. cephalus* collected in Lake Mouley Bousselham but not in fish from Lake Nokoué and Cotonou Lagoon. *pp′*-DDT, however, was present in *M. cephalus* from Lake Nokoué (0.5 ng/g d.w.) but not in fish from Maroc (Benbakhta et al. 2007).

Residue levels of fish collected in the Lake Nokoué and Cotonou Lagoon are lower than reported for fish from Abidjan markets and fishing areas (Biego et al. 2010), from Lake Qarun in Egypt (Mansour 2009), the Densu Basin in Ghana (Afful et al. 2010), Lake Taabo in Cote D'Ivoire (Roche et al. 2007) and Lagos Lagoon in Nigeria (Adeyemi et al. 2008).

Pesticide residues in other aquatic species

Aquatic species, such as *Callinectes* sp., *Penaeus notialis* and *Ostrea* sp., consumed by the Beninese population, also contained pesticide residues. *Callinectes* sp. and *P.*

Table 2 Pesticide concentrations in fish collected in Lake Nokoué and Cotonou Lagoon, Republic of Bénin

Parameters	Fish species (Family)					
	Elops lacerta (Elopidae)	*Podamasys jubelini* (Haemulidae)	*Gobbienellus occidentalis* (Gobidae)	*Ethmalosa fimbriata* (Clupeidae)	*Mugil cephalus* (Mugilidae)	*Hemichromis fasciatus* (Cichlidae)
Number of fish pooled	5	2	5	10	6	9
Flesh weight (g F.W.)	56.9	5.0	11.2	33.0	42.2	38.7
Lipid content	2.0 %	2.0 %	1.9 %	1.95 %	2.0 %	2.0 %
Identified pesticides in ng/g lipid						
pp′-DDE	189	194	113	289	106	99
op′-DDD	17	3	<6	26	12	4
pp′-DDD	76	67	59	142	65	51
op′-DDT	16	8	17	28	9	10
pp′-DDT	52	12	15	95	25	19
α-Endosulfan	86	25	31	174	49	60
Aldrin	6	3	31	13	4	5
Dieldrin	<6	3	19	15	11	14
γ-HCH	<6	4	28	4	<4	13

notialis were contaminated by *pp*′-DDE, *pp*′-DDD and α-endosulfan (Fig. 2). α-Endosulfan levels were higher in *Callinectes* sp. than in *P. notialis* and *Machrobracium* caught in the Ouémé River at Lowé (Yehouenou A. Pazou et al. 2006b). *Ostrea* sp. were contaminated by *pp*′-DDE, *op*′-DDD, *pp*′-DDD, *op*′-DDT, *pp*′-DDT, α-endosulfan, aldrin and dieldrin (Fig. 2), with levels from 2 to 135 ng/g lipid. Concentrations of DDT and its metabolites were higher in *Ostrea* sp. than in *P. notialis* and *Callinectes* sp., which may suggest that these organisms have different routes of exposure.

When expressed on a dry weight basis, the ΣDDT concentrations in *Ostrea* sp. from Lake Nokoué and Cotonou Lagoon (Table 3) are in the lower end of the range of concentrations (1.0–156 ng/g d.w.) found in the oyster *Crassostrea gasar* in the Ebrie Lagoon in Cote D'Ivoire (Ouffoué et al. 2009). DDE and endosulfan concentrations in *Callinectes* sp. from Lake Nokoué and Cotonou Lagoon also are below values reported for the crayfish *Procambarus clarkii* from Lake Naivaska in Kenya (Gitahi et al. 2002).

Risk assessment

A summed risk of consuming fish or other aquatic species is expressed as total toxic units in Table 3. Pesticide intake was estimated from pesticide concentrations expressed on a lipid basis (Table 2), lipid content and the dry mass of fish meat consumed per fish. In case of the other aquatic species, fat contents values unfortunately were not available, so they were estimated on the basis of literature data to enable

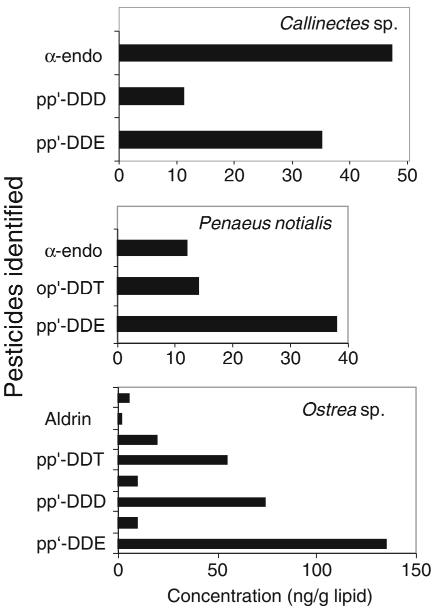

Fig. 2 Pesticide levels in *Callinectes* sp. (*top*), *Penaeus notiatis* (*middle*) and *Ostrea* sp. (*bottom*) collected in Lake Nokoué (*first bar*) and Cotonou Lagoon (*second bar*), Republic of Bénin. *α-endo* = α-endosulfan. For *Ostrea* sp., two samples were analysed and results for both samples are presented

Table 3 Risk assessment for human health of pesticide intake by consuming fish and other edible aquatic organisms caught in the Republic of Bénin. Summed toxic units (Σ TU) were obtained by relating daily intakes to the tolerable daily intakes defined by WHO (2004) of 10,000, 6,000, 100 and 5,000 ng/kg body weight, day for ΣDDT, Σendosulfan, Σaldrin and lindane (γ-HCH), respectively. Meat dry weight is given per individual fish consumed or as an estimated intake for the other organisms. Fat levels for *Callinectus*, *Penaeus* and *Ostrea* are estimated from the literature, see text

	Elops lacerta	*Podamasys jubelini*	*Gobbienellus occidentalis*	*Ethmalosa fimbriata*	*Mugil cephalus*	*Hemichromis fasciatus*	*Callinectus* sp.	*Penaeus notialis*	*Ostrea* sp.
Meat dry weight (g)	3.3	3.6	2.5	5.1	3.0	3.5	10	10	10
Fat content	2 %	2 %	1.9 %	1.95 %	2 %	2 %	0.44 %	7 %	7 %
Pesticide level in organism (ng/g dry weight)									
ΣDDT	7.00	5.68	3.88	11.3	4.34	3.66	0.20	3.90	2.72–18.5
α-Endosulfan	1.72	0.50	0.589	3.39	0.98	1.20	0.21	0.90	n.d.
Σaldrin	0.12	0.12	0.950	0.546	0.30	0.38	n.d.	n.d.	0.118–0.371
γ-HCH	n.d.	0.080	0.532	0.078	n.d.	0.26	n.d.	n.d.	n.d.
Pesticide intake by eating one fish or other aquatic species by an adult person (60 kg) in ng/kg body weight									
ΣDDT	0.39	0.34	0.16	0.96	0.22	0.21	0.034	0.65	0.45–3.1
α-Endosulfan	0.095	0.030	0.025	0.29	0.049	0.070	0.035	0.15	0
Σaldrin	0.0066	0.0072	0.040	0.046	0.015	0.022	0	0	0.020–0.062
γ-HCH	0	0.0048	0.022	0.0066	0	0.015	0	0	0
ΣTU	0.00012	0.00011	0.00042	0.00061	0.00018	0.00026	0.000091	0.000090	0.00050–0.00066

application of a similar approach. Lipid contents of 0.45, 7.5 and 7.0 % were reported for *Callinectes sapidus*, *Penaeus indicus* and *Ostrea virginica*, respectively, by Küçükgülmez et al. (2006), Ravichandran et al. (2009) and Baker et al. (1942). In all cases, the daily intake of pesticides with the consumption of fish or other aquatic species was low also in case of very frequent and high level consumption. This is in agreement with the findings of Yehouenou A. Pazou et al. (2006b) who also concluded that fish from the Ouémé River in Bénin did contain residues of several chlorinated pesticides but that concentrations were too low to pose a human health risk.

Conclusion

Sediments and biota (fish, crustaceans and molluscs) from Lake Nokoué and Cotonou Lagoon are contaminated by organochlorine residues. This contamination is due to human activities like pesticide use in agriculture (mainly cotton fields) and household discharges along the lake and lagoon and upstream of the Ouémé River, with residues transported to the lake and lagoon. The risk for humans consuming fish and other aquatic organisms from the lake or lagoon, however, is low.

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