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Review Article

Assessment of Human and Ecosystem Contamination by Organochlorine Pesticides in Cote d'Ivoire -

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ABSTRACT

The agricultural policy of Cote d'Ivoire has promoted the intensive use of pesticides. Since colonial times, organochlorine pesticides have been used to improve agricultural productivity and vector control in public health. The high persistence of these active ingredients is today the real reason for their complete ban in agriculture because they represent a risk for human health and the environment. The purpose of this study is to set up an environmental assessment of human and ecosystem contamination by organochlorine pesticides in Côte d'Ivoire. A literature review of scientific studies carried out on organochlorine pesticide contamination in various matrices covering the periods of 1985 to 2015 was conducted. The bibliographical sources consulted were original articles of studies performed on matrices taken in Cote d'Ivoire and published in national and / or international journals. The studies were grouped according to three types of matrices such as human (adipose tissue and breast milk), food and environment. Fourteen scientific studies on the identification and determination of organochlorine pesticides revealed an appalling levels of DDT (10017 μg/kg), total HCH (854 μg/kg), dieldrin (23.6 μg/kg) and endosulfan (48 μg/kg) in breast milk and adipose tissue. Foodstuffs such as fish, dairy products and vegetable crops were also contaminated by organochlorine pesticides at levels that sometimes exceeded the threshold limits defined by WHO. To sum up, it is clear today that organochlorine pesticides used in the past were found in all stages of the food chain with a high concentration in humans. There is therefore a real risk of harming human health.

Keywords: Organochlorine pesticides; Foodstuffs; Aquatic ecosystem

INTRODUCTION

The agricultural policy of Cote d'Ivoire has promoted the intensive use of pesticides. Thus, Organochlorine Pesticides (OCPs) were the first generations of synthetic organic pesticides to be used in agriculture to ensure the destruction or prevention of plants and harmful microorganisms. These products have contributed in improving agricultural productivity and have led to a significant advancement in the control of food resources [1]. Moreover, from colonial times up to now, organochlorine pesticides have also been used in public health to fight against disease vectors (mosquitoes, trypanosomes, onchocerciasis) [1,2] and chemical control of pests of coffee, cocoa and cotton trees [4]. Others such as DDT and dieldrin have been used in mosquito control campaigns in several parts of the country [2]. These chemicals are called Persistent Organic Pollutants (POPs) because of their long-term stability, lipophilicity and their tendency to accumulate in the environment and in living organisms.

In addition, the high persistence of these active ingredients is today the real reason for their complete ban in agriculture because they represent a risk for human health and the environment, though very effective, their side effects on health and on the environment were quickly known.

Furthermore, several authors reported the neurological, mutagenic, carcinogenic, teratogenic and dermatological effects as well as hormonal disorders related to the use of these products [5-9]. Thus, aware of the risks related to the use of POPs, the international community adopted in 2001 the Stockholm Convention on persistent organic pollutants for the protection of human health and the environment through a global ban of the use of some POPs.

In Cote d'Ivoire, a National Implementation Plan (NIP) to fight against POPs called "POPs project-Cote d'Ivoire was set up. "Pops project-Cote d'Ivoire" initiated with the support of UNEP is a melting pot to fight against these products. After more than a decade of NIP implementation in Cote d'Ivoire, one wonders about its effectiveness. This question is all the more justified since several studies carried out in Cote d'Ivoire in recent years outlined the presence of POPs, banned by the Stockholm Convention in different matrices. This present work is a retrospective study with the objective to assess the ecosystem contamination by organochlorine pesticides in Cote d'Ivoire before and after the implementation of NIP in order to appraise the effectiveness of this program.

METHODOLOGY

A literature review, carried out on organochlorine pesticide contamination in various matrices covering the periods of 1985 to 2015 was conducted. The bibliographical sources consulted were original articles of studies performed on matrices taken in Cote d'Ivoire and published in national and / or international journals. In total, fourteen scientific studies of OCPs identification and assay were included. The studies were grouped according to three types of matrices such as human (adipose tissue and breast milk), food and environment. Analysis of data was focused on the different methodologies of research, dosage and the results obtained.

RESULTS AND DISCUSSION

Methods

The extraction of organochlorine pesticides is performed using different organic solvents in mixture (hexane / ionized water; isooctane / ionized water; ethanol / cyclohexane) or only one (dichloromethane, hexane). This extraction is usually followed by a purification on florisil column before quantification. All quantifications were carried out by gas chromatography equipped with electron capture detectors (μECD) and as stationary phase, a capillary column (DB-5 or SE-54, SPB-608). In some cases, confirmation is made on another capillary column with a polarity different from the first one. Nitrogen U. is the mobile phase used.

Except two of the authors who quantified their samples in Europe: at the oceanological center of Bretagne in Brest [10] and at CVA laboratory in Germany for WHO / UNEP study, all the other studies were done in cote d'ivoire. The validation of the different methods was carried out according AFNOR (1996) [11] and included study of linearity, repeatability, detection limits, reproducibility, and extraction yield. The standards were either mixture of 16 or 18 POP provided by Dr. Ehrenstorffer (Germany) or by EPA, supelco. The organochlorine compounds sought were: aldrin, alpha HCH, beta HCH, delta HCH, lindane or gamma HCH, dieldrin, endosulfan I, endosulfan II, endosulfan sulfate, endrin, endrin aldehyde, ketone endrin, heptachlor, heptachlor epoxide, DDD, DDE, DDT and methoxychlor. The reported extraction yields were all above 80%.

The samples used for the studies came from three areas of Cote d'Ivoire: south-west (Buyo), north (Korhogo and Sinematiali) and south (Abidjan and the Lagoon water stream).

Contamination of humans by organochlorine pesticides

Direct human exposure to OCPs in Cote d'Ivoire was assessed through two matrices: breast milk and adipose tissue. Breast milk, the first human food, is an indicator in terms of OCPs residues accumulation in the human body [12]. Four studies were devoted to these two matrices.

Contamination of breast milk by OCPs was observed in the region of Buyo (South-west) within a community whose main activity is fishing. Human breast milk samples were collected from 40 mothers permanently living in the area for 5 to 6 years. The main OCPs identified in the milk were: total DDT (2671.5 µg/Kg), total HCH (854 µg/kg), dieldrin (23.6 µg/Kg) and endosulfan (48 µg/kg). The high levels of OCPs in human breast milk were attributed to the consumption of water coming from the dam of Buyo and to contaminated fishes [3]. The contamination of breast milk by OCPs was observed in Korhogo and Sinematiali (North of Cote d'Ivoire) as well. This region, known for its high cotton production, is a major user of phytosanitary products. In addition, variable mean levels in OCPs were detected in breast milk at a rate of 13-63 µg/Kg of DDT, 20-103 µg/Kg for HCH [13-14].

In 2010, WHO, in collaboration with UNEP, conducted a study on OCPs persistent in breast milk with 50 first-time mothers. These samples, were all collected in the district of Abidjan and were analyzed in a reference laboratory in Germany. The results of this study revealed the presence of ten OCPs with a high concentration of total DDT (1073 µg/Kg) followed by total HCH (13 µg/Kg), chlordane (5.7 µg/Kg) and dieldrin (4,6 µg/kg) [15].

In addition, because of their ability to accumulate in fats, the adipose tissue is a matrix of choice for the assessment of exposure to OCPs. Two studies were conducted on this matrix in the north of Cote d'ivoire (Korhogo and Sinematiali) [13-14]. The authors collected adipose tissue from pregnant women during a caesarean. Indeed, the women included in the study had a number of childbirths ranging from 1 to 11 and lived at least 5 years in the region. Several OCPs with mean variable concentrations from 6932 to 10017 µg/Kg (DDT), 11 to 21471 µg/Kg (heptachlor), 1861.9 µg/Kg (endrin), 347.2 µg/kg (Dieldrin) and from 13 to 677.2 µg/Kg (total HCH) were identified. A correlation between the contamination and the number of births was established.

Thus, for DDT and its degradation products, an increase in levels in breast milk and adipose tissue was observed as time goes on. The accumulation of OCPs in human breast milk and adipose tissue is a threat to the health of the mother, the fetus and the child fed with breast milk. Indeed, once in the body, OCPs passes through the milk (consequence of the mobilization of fat), crosses the placental barrier and can be found in the fetus by this pathway. The presence of OCPs in breast milk is recurrent in Africa and particularly in West Africa. Table 1 summarizes the results of breast milk and adipose tissue contamination by OCPs. Studies on the biomonitoring of breast milk indicated contamination by OCPs such as DDT with a concentration of 2081 µg/kg in Mali [16] and in Ghana with 490 µg/kg in total DDT [17].

Contamination of foodstuffs

Eggs and dairy products: Eggs, cow's milk and its by-products (butter, curdled milk) are not on the fringe of OCPs contamination. In fact, a contamination of samples of cow's milk and traditionally made butter by OCPs in the regions of Buyo (Central West), Grand Lahou (South) and Yamoussoukro (Center), has been observed [18].

This contamination is predominant in HCH (129.0 µg/kg), DDT (98.1 µg/kg) and total endosulfan (36.68 µg/Kg) in butter (Table 2). As for the samples of curdled milk (a product derived from cow's milk which is highly valued by the Ivorian population and come from various supermarkets) and eggs, had a variable concentrations of OCPs from 0.716 to 130.83 µg/Kg and from 0.997 to 96.73 µg/Kg

Table 1: Contamination of breast milk and adipose tissue by OCPs expressed in µg/kg in women.

Matrices	Study area	Total DDT	Total HCH	Endosulfan	Aldrin	endrin	Dieldrin	TOTAL trans-heptochlor epoxyde	Chlordane	Authors
Adipose Tissue	Korhogo (North)		677.2 [24-3896]		293.5	1861.9	347.2 [315-1438]	21472		[13]
		6932	60	3598		655		11		[22]
	Sinematiali	10017	13	3858		1586				
Breast milk	Buyo (South-West)	2671 [68-6002]	854 [12-2927]	48 [2-129]			23.6			[3]
	Korhogo (North)		103.4 [47.5-719]							[13]
		61	20	2		43		8		[22]
	Sinematiali	13				48				
	Abidjan (South East)	1073.2	13.55				4.6		5.7	[15]

Table 2: Mean Concentration of OCPs in animal milk products expressed in µg/kg.

Area of sample collection	Matrix	Total DDT	Total HCH	Dieldrin	Heptachlor	Total endosulfan	Authors
Buyo, Lahou (south),Yamoussoukro (central)	Cow's milk	130.8	96.3	14.3	7.45	12.81	[18]
	Butter	98.1	129	16.8	35.91	36.68	
Abidjan	Curdled milk	0.7-130	1-96.7	0.263		0.563	[19]
	Eggs	75.22	35.907	37.820			
	MRL	50	50			40	

respectively in DDT and HCH (Table 2), [19]. These concentrations of OCPs in cow's milk, butter were often higher than the MRL of 50 µg/Kg for these food products (WHO / FAO).

Contamination of agricultural products: The analysis of agricultural export products (cocoa and kola nut) grown mainly in the forest region (south of the country) revealed the presence of several OCPs. Fresh and dry kola nut samples collected in the treatment centers of kola nuts in the city of Anyama (Abidjan) [20] were contaminated by OCPs, including HCH and its isomers (2-237 µg/kg), Endosulfan and its isomers (2-99 µg/kg), DDT and its isomers (2-72 µg/kg) (table 3).

OCPs residues were also detected in cocoa bean samples collected in the town of Agboville (south) and in the ports of San Pedro and Abidjan [21]. Samples from Agboville were the most contaminated (100%). The main OCPs were total HCH (8.4-40 µg/kg and heptachlor (6-59.6 µg/kg) (table 3). Similar contaminations in OCPs (DDT, Dieldrin, Endrin, and Endosulfan) were reported by Mawussi [4] in cocoa beans in Togo.

Contamination of food crops: Samples of rice and corn from different markets of Sinematiali and Korhogo regions (north of Cote d'Ivoire) were contaminated by five different OCPs (HCH, DDT, endosulfan, cyclodiene and methoxychlor). DDT was detected in 36.5 and 38 % of samples respectively in Sinematiali and Korhogo. A sample of Sinematiali had a content of 354 µg / Kg in DDT [22]. However, except methoxychlor, all mean levels were below WHO MRLs for cereals.

OCPs were also detected in crops collected from different markets in Abidjan. Thus, the main OCPs found in the food products were HCH, aldrin and endosulfan. Lindane (HCH isomer) was found in all cultures studied with mean concentrations reaching 727.5 µg / kg in chives [23].

Foodstuff contamination by OCPs is very common in developing countries, namely in West Africa. Studies carried out in Nigeria [24] in Ghana [17] Senegal and Gambia [22,23], Togo [24] showed contamination of tubers and vegetables by various residues of OCPs. The rates of cereal and vegetable contaminations by OCPs are tabulated in table 4.

Population exposure: According to Ehouman [28], the exposure of population to food risks associated with OCPs and dieldrin in particular was estimated in the region of Buyo. Dieldrin was detected in all analyzed foodstuffs and well waters with a total mean concentration of 264.8 µg/kg in the food ration considered. The Theoretical Maximum Daily Intake (TMDI) calculated was 48.78 µg/person, much higher than that of the Acceptable Daily Intake (ADI). The Daily Intake (DI) was estimated at 17.734 µg/person. The authors concluded that there was a probable health risk.

Contamination of aquatic ecosystems

OCPs were detected in various parts of the aquatic ecosystem: fish, sediments, oysters, groundwater and lagoon.

Groundwater: Analysis of well water samples in the areas of Buyo, Grand Lahou, Yamoussoukro, and Anyama, revealed the presence of POC in about 62% of the sampled wells near the coffee and cocoa plantations. The mean sample contained lindane (1.41 µg/L), endosulfan (3.057 µg/L total), heptachlor (1.93 µg/L), and dieldrin (0.375 µg/L) [29]. These concentrations were beyond the recommended standards or reference values for drinking water: 0.1 µg/L for a separate active ingredient and 0.5µg/L for total active ingredients (WHO, 1994). Compared to Côte d'Ivoire, residues of Lindane (0.22 µg/L), α-endosulfan (1.26 µg/L) and β-endosulfan (1.84 µg/L) were detected in groundwater in Senegal in the area of Niayes in Dakar [30].

Table 3: Mean Values of OCPs found in cocoa and kola nut expressed in µg/kg.

Area of sample collection	Matrix	Total DDT	Total HCH	Dieldrin	Total endrin	Total endosulfan	Heptachlor	Aldrin	Authors
Agboville, San Pédro, Abidjan	Cocoa	6.1-10.2	8.4-40	6.5-26.3	5.2-17.3	2-30	6 -59.6	5.7-6	[21]
MRL EU		< 200	< 50	< 20	< 10				
MRL-(FAO/WHO)						100			
Anyama	Kola nut	2- 72	2-237	2-5	2-4	2-99	2-6.9	2 -5	[20]

Table 4: Cereal and Vegetable contamination by OCPs in µg/kg.

Foodstuffs		Total DDT	Total HCH	Total Endosulfan	Cyclodienes	methoxychlor	Authors
Rice	Korhogo	3	1	6	7		[22]
	Sinematiali	12 (4-354)			8		
Maize	Korhogo	6	32	2	4	56	
	Sinematiali	4		1	6		
	MRL	100	500	100	20	20	
Spinach			2.5				
salads			2.4	125			
Cabbage			2				
Chives			727.5	66.3	8.7		
Parsley			2.2				[23]
tomatoes			4.6				
Cucumber			2	2.1			
Zucchini			2.5				
Onion			56.9		6.2		
Potato			2.9				
Carrot			3.3				
Turnip			2.7	2.2			

Fishes: Fish samples were collected from the fishing sites of the port of Abidjan [31] and Buyo [32]. Fish from the lake of Buyo (*Tilapia ziili, Chrysichthys walkeri and Niloticus spp*) and those collected from fishing sites of Abidjan (catfish, mackerel, sardines, carp, tuna) were found to be highly contaminated by POCs. Freshwater species (*Tilapia ziili, Chrysichthys walkeri* and *Niloticus spp)* from Lake Buyo were contaminated with dieldrin (31.58-436.80μg/kg), DDT (36.20-227.82 μg/kg), hexachlorocyclohexane (58.44 to 167.94 μg/kg) and heptachlor (8.70 to 59.91 μg/kg). Among the marine species, catfish was the most contaminated with DDT (9.1 μg/kg) and aldrin (2.5 μg/kg), while carp had the highest levels of heptachlor (7 μg/kg) and methoxychlor (2.8 μg/kg). The highest level of HCH (16.2 μg/kg) was found in mackerel. Catfish was the most qualitatively contaminated species by OCPs (Table 5), [31].

Sediments: In the Ebrie lagoon around Abidjan, two types of organochlorine residues, such as lindane (0.5-19 μg/kg), DDT and its main metabolites (1.1-997 μg/kg) were identified in the sediments. High levels of DDT were localized in Marcory and Bietri bays with respective concentrations of 997 and 492 μg/kg (Table 5) [10]. However, in the lagoon system of Grand-Lahou consisting of 4 lagoons (Tagba, Mackey, Tadio and Nioumouzou). The quantified levels ranged from 6.31 to 27 ng/L for lindane, from 6.08 to 23.15 ng/L in epoxide heptachlor, from 3.54 to 17 ng/L in endosulfan, from 3.70 to 6.9 ng/L in endrin and from 5.84 to 23.19 ng/L in DDT. The Mackey lagoons (Σ OCPs = 214 ng/L) and Tagba (Σ OCPs = 210.63 ng/L) were the most contaminated (tables 5 and 6), [33]. Sediment contamination by OCPs was also reported in other African countries. Thus, the organochlorine residue values of sediments in the Lekki Lagoon in Nigeria were 190 to 8480 μg/kg of dieldrin, 0.11 to 4.9 μg/kg of lindane, 1845 μg/kg of heptachlor, 347 μg/kg of aldrin, and 7 to 1155 μg/kg of endosulfan [34]. Mavura and Wangila (2004) [35] detected in the sediments of Nakuru Lake in Kenya, pesticides containing 0.43 μg/kg of DDT, 123 μg/kg of DDD, 4.47 μg/kg of DDE, 316 μg/kg of heptachlor and 8.26 μg/kg of aldrin.

Oysters: The oyster, a crustacean living in lagoon sediments, is a good indicator for assessing the level of lagoon contamination. Pesticides such as DDT (2-130 μg/kg), lindane (1.3-5.1 μg/kg), dieldrin (1-6.5 μg/kg), heptachlor (1-5 μg/kg), 2 μg/kg), and endrin (1- 4.2 μg/kg) were found at various stations in the Ebrie lagoon. High concentrations of DDT (130 μg/kg) and HCH (lindane, 5.1 μg/kg) were found respectively in the regions of Abidjan and Grand-Lahou (Table 5), [36].

Table 5: Mean OCPs values found in aquatic ecosystems (μg/kg).

		Total DDT	Total HCH	Dieldrin	Endrin	Endosulfan	Aldrin	Heptachlor	Authors
Oysters	Ebrie lagoon	2-130	1.3- 5.1	1- 6.5	1- 4.2			1- 5.2	[36]
Fish	Port of Vridi	1.4	0.8-8.3		1.3-7.1	0.6-2.1	2.5	6-7	[31]
	Buyo	36.2-227	3.14-89	31.5-436				8.7-59.91	[32] [28]
Sediments	Ebrie lagoon	1.8-997	0.5-19						[10]

Table 6: Mean values of all OCPs found in Grand Lahou lagoons (μg/L).

Organochlorine pesticides	Lagoon				Author
	Tabga	Mackey	Tadio	Nioumouzou	
Total HCH	76.92	57.8	36.41	38.83	[33]
Total Heptachlor	32.31	15.8	15.82	11.18	
Total Endosulfan	21.53	49.2	20.41	25.63	
Aldrin	9.57	10.6	2.22	4.73	
Dieldrin	4.32	7.4	5.07	5.48	
Total Endrin	14.17	27.9	15.92	9.99	
Total DDT	51.81	45.8	21.85	19.33	
Total organochlorine pesticides (ng/L)	210.63	214.5	117.7	115.17	

Data collection from some previously conducted studies showed that various parts of the environment and human food are contaminated by OCPs in Cote d'Ivoire. 10 OCPs and their metabolites were identified in all the matrices studied (DDT, HCH, Endosulfan, Aldrin, Dieldrin, Heptachlor, Endrin, Methoxychlor, Hexachlorobenzene, Chlordane). Most of the OCPs identified in the different matrices are banned from use by the Stockholm Convention to which Cote d'Ivoire is signatory.

These studies, though fragmentary, have highlighted the risk for Ivorians. Indeed, exposure to pesticides through food can entail both short-term and long-term health problems in humans [37-39]. Studies showed strong associations between chemical pesticides and health problems, including fertility problems, congenital malformations, birth defects, brain tumors, breast cancers, prostate and childhood leukemia [40, 41].

CONCLUSION

The synthesis of studies carried out on Organochlorine Pesticides (OCPs) in Cote d'ivoire revealed a contamination of surface and groundwater, sediments, agricultural products and human matrices by past use OCPs (DDT, (Aldrin, Dieldrin, Endrin, Heptachlor, Lindane) or current use (Endosulfan).

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