

RESEARCH ARTICLE

OCCURRENCE OF ORGANOCHLORINE PESTICIDES IN SOILS AND FOODS FROM COTTON FIELDS AND RELATED HEALTH RISKS IN THE HAMBOL REGION (CÔTE D'IVOIRE)

Camara Monty Abibata and Elleingand Fattoh Eric

Industrial Processes, Synthesis and Environment Laboratory (LAPISEN), National Polytechnic Institute Félix Houphouët-Boigny of Yamoussoukro (INP-HB), BP 1093 Yamoussoukro, Côte d'Ivoire.

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Manuscript Info

Abstract

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Key words:-Contamination, Cotton Fields, Foods, Health Risk, Organochlorine Pesticides, Soils Organochlorine pesticides derived from the chlorination of cyclic and/or aromatic hydrocarbons. But, due to their persistence in the environment and their bioaccumulation in the body leading health problems, they were banned from using. They have been widely used around the world in agriculture and public health in particular in Côte d'Ivoire. This study was aimed to determine the concentrations of organochlorine pesticides residues in soils and crops from Hambol region (Côte d'Ivoire) and to evaluate the potential carcinogenic risk based on the concentrations found.Organochlorine pesticides residues were determined in soils and crops in cotton fields by using an HPLC. Soil samples analysed showed the presence of five organochlorine pesticide residues namely DDT (ND - 0.39 µg/kg), lindane (ND - 0.972 $\mu g/kg$), α -endosulfan (ND - 0.481 $\mu g/kg$), β -endosulfan (ND - 0.435 µg/kg) and sulfate-endosulfan (ND - 0.44 µg/kg). In crop samples, no detected. The concentrations of detected pesticides were organochlorines in soil samples were less than United States and FAO maximum residues limits for agricultural soils. The cancer risk assessment and hazard quotient values are under 10⁻⁶ and 1. The risks related to farmer exposure to DDT and lindane from soil via ingestion, inhalation and dermal route is negligible.

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Introduction:-

Organochlorine pesticides, so called first-generation pesticides derived from the chlorination of cyclic and/or aromatic hydrocarbons. These are broad-spectrum insecticides that act by contact or ingestion, for the most part, and they have adverse effect on the nervous system (Ensley, 2012; Mrema et al., 2014). Because of their persistence in the environment and their high toxicity, they are banned for using. According to the Stockholm Convention, some organochlorine pesticides have been classified as persistent organic pollutants (POPs) (Wang et al., 2016). Organochlorine pesticides bioaccumulate in the body and can lead to health problems such as neurological, developmental and reproductive disorders, cancer (Inserm, 2013; Guo et al., 2014) and endocrine disruptions (Briz et al., 2011). They are also incriminated in the occurrence of metabolic diseases such as diabetes, obesity (Azandjeme, 2014). Organochlorines have been widely used around the world in agriculture and public health. In Côte d'Ivoire, with the modernization and intensification of agriculture, pesticides use has increased, especially on cash crops such as cotton. Cotton is the 4th export crop and a driving force for the socio-economic development of the savannah zone in Côte d'Ivoire (CNRA, 2006). However, this crop is subject to multiple parasitic attacks.

Corresponding Author:- Camara Monty Abibata

Address:-Industrial Processes, Synthesis and Environment Laboratory (LAPISEN), National Polytechnic Institute Félix Houphouët-Boigny of Yamoussoukro (INP-HB), BP 1093 Yamoussoukro, Côte d'Ivoire.

Indeed, cotton is one of the most parasitized plants in the world (attacked by more than 500 species of insect pests in Africa) (FIRCA, 2015). In the absence of protection, production losses can be as high as 70% (Sarr et al., 2016). Several pesticides have been used in cotton fields, including organochlorine pesticides that persist in the soil and can be transferred to the plants especially accumulating in the underground parts. Thus, the use of land, where organochlorines have been applied, for the production of food crops; could constitute a health risk.

Hambol region is part of the Ivorian cotton basin and production areas for food crops such as yams, cassava and groundnuts.

The objective of this study is to assess organochlorine pesticides residues in soils and crops from Hambol and to evaluate the potential carcinogenic risk based on the concentrations found.

Material and Methods:-

Study area:

The study area was conducted in the departments of Dabakala (04°26'W - 08°23'N) and Niakara (5°18'W - 8°43'N), both belonging to the administrative region of Hambol in north-central Côte d'Ivoire (figure 1).



Figure 1:- Study area representation.

Sampling:

Collection and pre-treatment of soil samples:

Samples were taken from two types of cotton fields: historical and current cotton fields. A total of 15 soil samples were taken from the entire field at a depth range from 0 to 30 cm using the method described by Mawussi (2008). All portions of soil collected were mixed together to form a sample of at least 500 g per site which was wrapped in aluminium foil, placed in a freezer bag and transported to the laboratory in a cooler for analysis. The samples were dried at room temperature for 2 days, then sieved with a 2 mm sieve, wrapped with aluminium foil and placed in freezer bags and stored in the freezer at -18°C pending chromatographic analysis.

Collection of crop samples:

Crop samples were collected at the same time as soil samples using the method described by Aïkpo et al. (2016). Mature tubers were removed from the stalk, separated from the top, cleaned (to remove roots and adsorbed soil) and separated from the pedicle (so as to retain a pseudo cone corresponding to the central portion of the tuber). For the groundnut samples, the pods were just pulled from the plants and cleaned. A minimum portion of 200g was wrapped

in aluminium foil and then bagged 1 litre freezer bags. The samples were placed in situ in a cooler and then frozen in the laboratory waiting analysis.

Physicochemical and particle size characterization of soil samples:

On the dry and sieved samples (at 2mm), different parameters were determined.

Water pH and KCl pH were determined by the AFNOR method using a pH meter in a soil suspension diluted at 1:5 (volume fraction) in water (pH_{H2O}) and in a potassium chloride solution at 1 mol/L (pH_{KCl}) (AFNOR, 2005). After treatment of the samples with ammonium acetate, the cations Ca²⁺, Mg²⁺ and K⁺ were determined with the atomic absorption spectrometer. Total nitrogen was determined by the classical Kjeldahl method (Bremner, 1965), and organic carbon by the Walkley-Black method (Walkley, 1947). The organic matter content was determined by multiplying the organic carbon content by 1.72. Physical analysis in five particle size fractions (clay, fine and coarse silts, fine and coarse sands) was carried out by the Bouyoucos method (Bouyoucos, 1951). The USDA (United State Department of Agriculture) texture triangle was used for the classification of soil texture.

Determination of pesticide residues in soil and crop Samples:

Chemical reagents:

The reagents used are all HPLC grade. Methanol and N-hexane were purchased from VWR. Acetonitrile and dichloromethane were purchased from CARLO ERBA.

Five organochlorine pesticides were analyzed in soil and crop samples (DDT, lindane, α -endosulfan, β -endosulfan and sulfate endosulfan).

Sample treatment and pesticides extraction:

50 g of soil, finely crushed with a porcelain mortar and sieved on a 0.5 mm mesh sieve, was taken and introduced into an Erlenmeyer flask. Then 100 ml of dichloromethane was added and the mixture was vortex homogenised for 1 hour. The homogenization was followed by filtration on Whatman paper with a diameter 90 mm and the filtrate was evaporated dry with BUTCHI brand rotavapor at a temperature of 40°C. The dry residue was recovered with 5 ml of hexane and transferred to a vial for injection by HPLC.

Pesticide residues were extracted, in the same manner as with the soil samples, from 50 g of crushed cassava, yam or groundnut in a blender.

Detection and quantification of pesticide residues:

Pesticide residues analysis was performed using a SHIMADZU high performance liquid chromatograph coupled with a SPD-20A UV/VIS detector. The columns used were Spherisorb S50DS2 250 x 4, 6 mm ID with a water-acetonitrile mobile phase (10: 90 v/v) for DDT and endosulfan and C18 type, 300 mm x 3.9 mm x 5 μ m with a water-acetonitrile mobile phase (50: 50 v/v) for lindane. The analytical conditions were as follows: wavelength 254 nm (DDT and lindane) and 273 nm (endosulfan), oven temperature 30°C, flow rate 1 ml/min, gradient mode, analysis time 15 min, injection volume 20 μ l for DDT and endosulfan and 10 μ l for lindane.

Detection limit and quantification limit:

The detection and quantification limits for the different pesticides are 0.012 μ g/kg and 0.036 μ g/kg for DDT 0.041 μ g/kg and 0.123 μ g/kg for lindane, 0.0025 μ g/kg and 0.0075 μ g/kg for α -endosulfan, 0.005 μ g/kg and 0.015 μ g/kg for β -endosulfan, 0.0015 μ g/kg and 0.0045 μ g/kg for sulfate endosulfan, respectively.

Statistical analysis:

Excel and STATISTICA version 7.1 software were used to generate the averages. A one-factor analysis of variance (ANOVA) was used to show significant differences and similarities between physico-chemical characteristics and between pesticide concentrations found. The significant means obtained were separated by the Newman-Keuls test at a significance level of 5%.

Health risk assessment of DDT and lindane in the soil:

Human routes exposure to soil contaminants are: direct ingestion of substrate particles, dermal absorption of particles adhering to exposed skin, and inhalation of resuspended particles through the mouth and nose.

In this study, the health risk associated with soil contaminants was assessed by determining the ILCR for carcinogenic effects and the hazard quotient (HQ) for non-carcinogenic effects by calculating the LADD. The equations described by the United States Environmental Protection Agency (USEPA) were used in the calculations (USEPA, 1989, 2002, 2009).

 $LADDing=(C \times IngR \times EF \times ED \times ET \times CF) / (BW \times AT) (1)$

In equation (1), LADDing is the average daily lifetime intake by ingestion in mg/kg/day, C is the concentration of the contaminant in the soil in mg/kg, IngR is the soil ingestion rate in mg/day, EF is the frequency of exposure in day/year, ED is the duration of exposure in years, ET is the exposure time in hours/day, CF is the conversion factor in kg/mg, BW is the average body weight in kg, AT is the average time in hours.

LADDinh= $(C \times InhR \times EF \times ED \times ET \times AFinh)/(PEF \times AT)$ (2)

In equation (2), LADDinh is the lifetime average daily inhalation dose in mg/kg/day, C is the concentration of the contaminant in soil in mg/kg, InhR is the soil inhalation rate in m^3/day , AFinh is the absorption factor for the lungs, PEF is the particulate emission factor in m^3/kg .

LADDderm= $(C \times SA \times AF \times ABS \times EF \times ED \times ET \times CF \times GIABS)/(BW \times AT)$ (3)

In equation (3), LADDderm is the lifetime average daily dose by ingestion in mg/kg/day, SA is the exposed skin surface area in cm^2 , AF is the dermal soil adhesion factor in mg/cm², ABS is the dermal absorption factor (specific to each contaminant), GIABS is the fraction of the contaminant absorbed from the gastro-intestinal tract (specific to each contaminant).

The different carcinogenic risks are determined according to equations (4), (5) and (6) ILCRing=LADDing×CSF (4) ILCRinh=LADDinh×IUR (5) ILCRderm=LADDderm×CSF (6)

In equations (4), (5) and (6), ILCRing, ILCRinh, ILCRderm are risks from exposure via ingestion, exposure via inhalation, dermal exposure respectively, CSF is the carcinogenic slope factor in $(mg/kg/day)^{-1}$ (specific to each contaminant), IUR is the unit inhalation risk (specific to each contaminant)

The hazard quotient for each contamination route is defined according to equation (7) HQx=LADDx/RfD (7) In equation (7), HQx is the hazard quotient with x being the exposure via ingestion, inhalation or dermal exposure;RfD is the reference dose in mg/kg/day (specific to each contaminant).

The exposure parameters used for the assessment of carcinogenic health risks and those specific to individual pesticides are listed in Tables 1 and 2.

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Parameters	Units	Adult	References
IngR	mg/day	100	(USEPA, 2002)
EF	day/year	313	(Man et al., 2013)
ED	Year	70	(USEPA, 2002)
ET	hour/day	10	(USEPA, 2002)
CF	kg/mg	10-6	(USEPA, 2002)
BW	Kg	70	(USEPA, 2002)
AT	Hour	70 x 365x10= 255500	(USEPA, 2009)
AF	mg/cm ²	0.2	(USEPA, 2002)
SA	cm ²	3300	(USEPA, 2002)
InhR	m ³ /day	20	(USEPA, 2009)
AFinh	-	1	(Ge et al., 2013; Gereslassie et al.,
			2019)
PEF	m ³ /kg	1.36 x10 ⁹	(USEPA, 2002)

Table 1:- Exposure parameters used for health risk assessment (carcinogenic and non-carcinogenic).

 Table 2:- Pesticide specific parameters.

Pesticides

Parameters	DDT	lindane	endosulfan	References
ABS	0.03	0.04	-	(USEPA, 2002)
GIABS	1	1	1	(USEPA, 2002)
IUR	9.7x10 ⁻⁵	3.1x10 ⁻⁴	-	(USEPA, 2002)
$(\mu g/m^3)^{-1}$				
CSF	3.4×10^{-1}	1.3	-	(USEPA, 2002)
(mg/kg/day) ⁻¹				
RfD	5.10-4	3.10 ⁻⁴	6.10 ⁻³	(USEPA, 2002)
(mg/kg/day)				

Results and Discussion:-

Physicochemical and particle size characteristics of soil samples:

The physicochemical characteristics of the soil samples are listed in Table 3.

The pH values obtained are between 5.54 and 7.39 with an average of $6.11\pm0.45\%$, indicating that the soils are mostly acidic. Most of cultivated plants grow well in soils with a pH between 5.5 and 7.0 (Mbonigaba et al., 2009). The low pH values observed could be due to the low levels of calcium and magnesium ions. There is no significant difference (p > 0.05) between the pH values of the different samples.

The carbon and organic matter contents vary respectively from 0.483% to 1.59% and from 0.831% to 2.735% with averages of $0.92\pm0.29\%$ and $1.59\pm0.51\%$. It should be noted that there is a significant difference (p < 0.05) between the averages of the carbon and organic matter rates of the different samples. The Newman-Keuls test, used to compare averages, showed a significant difference between the averages of carbon and organic matter levels at the different sites.

The organic nitrogen contents are between 0.05% and 0.137% with an average value of 0.08 \pm 0.02%. There is a significant difference (p < 0.05) between the average nitrogen content of the different samples. The Newman-Keuls test used revealed a significant difference in total nitrogen between Dabakala and Niakara.

The carbon/nitrogen (C/N) ratio has values between 9.73 and 12.72 with an average of 10.96 ± 0.75 . C/N values between 8 and 12 reflect a normal rate of organic matter decomposition and for values above 12, decomposition encounters difficulties (Pallo et al., 2009). There is no significant difference (p > 0.05) between the C/N ratios of the different samples.

Particle size analysis of the samples identified 5 (five) fractions, specifically clay, fine silt, coarse silt, fine sand and coarse sand. The percentages of clay, silt and sand in the soil samples vary respectively from 3.25% to 15.5% with an average of $8.1\pm3.55\%$, from 10.29% to 56.95% with an average of $24.51\pm12.24\%$ and from 36.05% to 84.96% with an average of $65.80\pm14.45\%$. Based on the USDA textural classification, the results obtained show that the soils are mainly silty-sand and sandy-silt textured. Regardless of the fraction considered, there is no significant difference between the percentages of the grain size fractions in the samples.

	Locations			•			
	Dabakala			Niakara			
Parameters	Minimum	maximum	Mean	minimum	maximum	mean	
pH _{H2O}	5.60±0.02	6.51±0.23	6.02 ± 0.28^{a}	5.54±0.00	7.39±0.17	6.22 ± 0.59^{a}	
pH _{KCl}	4.48±0.00	5.67±0.09	4.96±0.39	4.11±0.01	6.84±0.16	5.45±0.82	
Ca^{2+} (cmol.kg ⁻¹)	0.536 ± 0.002	3.832 ± 0.002	1.456 ± 1.089^{a}	0.619±0.01	4.684±0.001	1.783 ± 1.382^{a}	
Mg^{2+} (cmol.kg ⁻¹)	0.344 ± 0.001	0.813±0.002	$0.556{\pm}0.180^{a}$	0.287±0.001	0.785±0.001	0.435±0.171 ^b	
K^+ (cmol.kg-1)	0.057±0.001	0.221±0.001	0.111 ± 0.056^{a}	0.057±0.001	0.096±0.001	0.074 ± 0.013^{b}	
Organic carbon (%)	0.48±0.06	1.59±0.01	1.01 ± 0.33^{a}	0.49±0.01	1.08 ± 0.00	0.82 ± 0.23^{b}	
Organic matter (%)	0.83±0.01	2.74±0.02	$1.74{\pm}0.57^{a}$	0.84±0.02	1.86 ± 0.00	1.42 ± 0.40^{b}	
Total nitrogen (%)	0.05±0.01	0.14±0.01	$0.09{\pm}0.03^{a}$	0.05±0.01	0.10±0.01	0.08 ± 0.02^{b}	
C/N	10.13±0.76	11.7±0.62	11.03 ± 0.58^{a}	9.73±0.23	12.72±0.10	10.89 ± 0.95^{b}	
Clay (%)	3.25	15.5	8.56 ± 4.28^{a}	5.25	12.5	7.57±2.73 ^a	

 Table 3:- Physicochemical and particle size characteristics of soil samples from Dabakala and Niakarasoils.

Silt (%)	10.29	38.62	22.83±10.34 ^a	14.78	56.95	26.44±14.73 ^a
Sand (%)	43.78	84.96	66.86 ± 14.88^{a}	36.05	79.14	64.58±15.03 ^a
Texture			silty-sand			silty-sand
			sandy-silt			sandy-silt

Mean values within the rows followed by the same alphabet letters (a, b) are not significantly different (p > 0.05) while using ANOVA and test of Newman-Keuls

Concentrations of organochlorine pesticide residues in soil and crop samples:

The analysis of soil samples showed the presence of five (5) organochlorine pesticides namely lindane, DDT, (α and β)-endosulfan and its metabolite sulfate-endosulfan. They were detected at a frequency of 80% in all samples analysed (Table 4). The analysis of variance applied to the results showed that there was no significant difference (p>0.05) between the different means of pesticide concentration detected in soil samples at the different sites (Table 5).

DDT concentrations range from ND to 0.39 μ g/kg with a mean of 0.19±0.15 μ g/kg. The average concentrations of DDT detected in the different soil samples are all below 0.05 mg/kg, the maximum residue limit for agricultural soils defined by the United States (Fosu-Mensah et al., 2016). They are also lower than the mean value of 11 μ g/kg found in soil samples from cotton-growing areas in Mali (Dem et al., 2007). DDT has been used to control pests of cotton plants, in particular *Helicoverpa armigera*, carpophagus caterpillar.

The level of lindane quantified in soil samples ranged from ND to 0.972 μ g/kg with a mean of 0.5±0.32 μ g/kg. Lindane contents quantified in the different soil samples are all below the maximum residue limit in agricultural soils defined by the United States which is 0.04 mg/kg (Fosu-Mensah et al., 2016). The average lindane concentrations obtained in our study are lower than those of Mawussi (2008) which ranged from 0.64 to 4.79 μ g/kg and of Wang et al (2016) ranged from 2.7 to 19.5 μ g/kg in the the cotton zone soil of Togo and China respectively. Lindane was used as an active ingredient in the seed treatment of cotton (Ton, 2004).

 α -endosulfan was detected at concentrations ranging from ND to 0.481 μ g/kg with a mean of 0.24 \pm 0.17 μ g/kg. β -endosulfan was present at levels ranging from ND to 0.435 μ g/Kg with a mean of 0.19 \pm 0.14 μ g/Kg. Sulfate endosulfan, levels vary from ND to 0.44 μ g/Kg with a mean of 0.09 \pm 0.10 μ g/Kg.

The technical endosulfan used in the field was composed of 70% α -endosulfan and 30% β -endosulfan (Traore et al., 2007) and sulfate-endosulfan is a metabolite resulting from the oxidation of α and β -endosulfan (Kamei et al., 2011). According to the FAO, the maximum acceptable concentrations of organochlorine pesticides for contaminated soils on which vegetables and tubers are grown range from 0.1 mg/Kg to 8 mg/Kg (FAO, 2000; Kolani et al., 2017). Thus, the different values obtained for endosulfan are lower than those recommended by the FAO. The maximum values obtained with endosulfan (α and β) and endosulfan sulfate are respectively lower (1.88 µg/Kg and 3.87 µg/Kg) and similar to those found by Kolani et al. (2017) in agricultural soils in Togo which is 0.4 µg/Kg. Endosulfan was banned for use in the 1980s and then reintroduced to control *Helicoverpa armigera*, a cotton plant pest that had become resistant to pyrethroids (Glin et al., 2006; PAN / IPEN, 2008).

Following the analysis of crop samples, no pesticide residues were detected in yam, cassava and groundnut under the same analytical conditions (Table 6). The concentration of organochlorines in the roots depends largely on the concentration in the soil (Mikes et al., 2009). The more polluted the soil is, the more likely root and tuber crops will be contaminated. It also depends on the type of soil on which roots and tubers are grown. Pesticides are easily adsorbed on soils rich in organic matter or clay, which makes them poorly available to plants (Calvet et al., 2005; Woignier et al., 2015). According to (Hassine et al., 2008), soils with organic matter contents below 5% are not very rich. With organic matter contents obtained in our study, we could conclude that soils are poor in organic matter. Thus this poverty would justify a low retention of pesticides, resulting in low soil pollution and consequently less contaminated plants.

Furthermore, the sensitivity of the analytical technique for the detection of compounds and the extraction method could explain why no pesticide residues were detected in the samples. Pesticide concentrations in food crops would therefore be below the detection limits in the method used or the extraction method used is not adequate. The choice of extraction method depends on the physicochemical properties of the compounds of interest and the sample matrix

(Durovic et Dorevic, 2011). Selective extraction improves sensitivity levels of analyte detection (Fontanals et al., 2007).

Tuble IT Detection nequency of pesticide residues in son sumples.						
Pesticides	Number of contaminated samples	Percentage (%)				
DDT	12/15	80				
Lindane	12/15	80				
α-Endosulfan	12/15	80				
β-Endosulfan-	12/15	80				
Sulfate-endosulfan	12/15	80				

Table 1:- Detection frequency of pesticide residues in soil samples.

Fable 2:- Pesticide concentration	s in soilsamples	(μ g/Kg dry matter).
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Locations		Dab	akala		Niakara			
Pesticides	Min	Max	Mean	ecartype	Min	Max	Mean	ecartype
DDT	ND	0.34	0.176 ^a	0.130	ND	0.435	0.309 ^a	0.086
Lindane	ND	1.07	0.612 ^a	0.285	ND	0.972	0.634 ^a	0.187
α-Endosulfan	ND	0.424	0.274 ^a	0.116	ND	0.481	0.316 ^a	0.150
β-Endosulfan	ND	0.324	0.181 ^a	0.106	ND	0.435	0.298 ^a	0.088
Sulfate-	ND	0.103	0.072^{a}	0.028	ND	0.435	0.142 ^a	0.145
endosulfan								

Mean values within the rows followed by the same alphabet letters (a, b) are not significantly different (p > 0.05) while using ANOVA and test of Newman-Keuls, ND : No detected, Min : minimum, Max : maximum

Table 3:- Pesticide concentration	s in cropssamples	$(\mu g/Kg dry matter)$
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Locations	Dabakala	Niakara
Pesticides		
DDT	ND	ND
Lindane	ND	ND
α-Endosulfan	ND	ND
β-Endosulfan	ND	ND
Sulfate-endosulfan	ND	ND

ND :No detected

Health risk assessment:

Table 7 presents the LADD, ILCR and HQ values calculated for the different pathways of farmer exposure to DDT and lindane in soil for the different zones. The total cancer risk value (Σ ILCR) related to lindane exposure is higher than that of DDT in Dabakala and Niakara, and these values are roughly equal. Regarding the hazard quotient that defines the risk of non-cancer adverse effects, it is also higher for lindane in both areas. For each pesticide (DDT and lindane), the cancer risk is found to decrease as follows: ILCR ingestion > ILCR dermal > ILCR inhalation. This reduction in cancer risk observed according to the different routes of exposure is in line with the works of Ge et al, (2013) and Da et al, (2014) which assessed the risks associated with organochlorines in agricultural soils in the United States and China, respectively.

ILCR values (ILCR ingestion, ILCR dermal, ILCR inhalation and Σ ILCR) are all below 10⁻⁶. According to the ATSDR, cancer risk can be classified into different ranges: very low risk value≤10⁻⁶, low risk 10⁻⁶≤value≤10⁻⁴, moderate risk 10⁻⁴≤value≤10⁻³, high risk 10⁻³≤value≤10⁻¹, very high risk value≥10⁻¹(ATSDR, 1995). Regarding the risk of non-cancer adverse effects, HQ <1 which would mean that DDT and lindane in soil would not cause non-cancer adverse effects to farmers (Yahaya, 2017).

The risks related to farmer exposure to DDT and lindane from soil via ingestion, inhalation and dermal route is negligible.

Table 7:- Cancer risks related to farmer exposure to DDT and lindane in the soil.

Dabaka	Niakara		
DDT	lindane	DDT	lindane

LADD	Ingestion	2.16×10^{-10}	7.50×10^{-10}	3.79×10^{-10}	7.77×10^{-10}
	Dermal	4.27x10 ⁻¹¹	1.98x10 ⁻¹⁰	7.50×10^{-11}	2.05x10 ⁻¹⁰
	Inhalation	2.22×10^{-12}	7.72×10^{-12}	3.90×10^{-12}	8.00x10 ⁻¹²
ILCR	Ingestion	7.33x10 ⁻¹¹	9.75x10 ⁻¹⁰	1.29x10 ⁻¹⁰	1.01x10 ⁻⁰⁹
	Dermal	1.45x10 ⁻¹¹	2.57×10^{-10}	2.55x10 ⁻¹¹	2.67×10^{-10}
	Inhalation	2.15x10 ⁻¹⁶	2.39x10 ⁻¹⁵	3.78x10 ⁻¹⁶	2.48x10 ⁻¹⁵
HQ	Ingestion	4.31×10^{-07}	2.50x10 ⁻⁰⁶	7.57x10 ⁻⁰⁷	2.59x10 ⁻⁰⁶
	Dermal	8.54x10 ⁻⁰⁸	6.60x10 ⁻⁰⁷	1.50×10^{-07}	6.83x10 ⁻⁰⁷
	Inhalation	4.44×10^{-09}	2.57x10 ⁻⁰⁸	7.79x10 ⁻⁰⁹	2.67×10^{-08}

Conclusion:-

The objective of this study was to assessment the concentration of organochlorine pesticides residues in soil and crops samples from cotton growing area and the health risk related the soil contamination. Five pesticides (lindane, DDT, α and β -endosulfan and sulfate-endosulfan) were detected with a frequency of 80% in all soil samples analysed, but not in crops samples. The concentrations found in soil samples were under United States and FAO maximum residues limits for agricultural soils. The cancer risk assessment and hazard quotient values are respectively below 10⁻⁶ and 1. The risks related to farmer exposure to DDT and lindane from soil via ingestion, inhalation and dermal route is negligible.

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