ORGANOCHLORINE PESTICIDE RESIDUE CONTAMINATION OF AGRICULTURAL PRODUCTS IN UGANDA

BY

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A RESEARCH REVIEW SUBMITTED TO THE FACULTY OF SCIENCE AND EDUCATION, DEPARTMENT OF CHEMISTRY IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF BACHELOR OF SCIENCE EDUCATION OF BUSITEMA UNIVERSITY

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Declaration

I, Chemutai Charity, declare that this research review is my own original work otherwise cited, and where such has been the case reference has been stated and that the same work has not been submitted for any award in any other university or other tertiary institute of higher education.

Signature…………………………………… Date…………………………….

Approval

This research review has been submitted for examination and has been approved by my supervisor.

Dr. Andima Moses

Signature………………………………….. Date 15.05.2022……………………………

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Dedication

This report is dedicated to my parents Mr. Moses Kitikoy and Mrs. Janet Kitikoy Yapkwobei who have always supported me spiritual, physically and financially in the entire walk in pursuing my dream. Special thanks also to my siblings, Chebet Herina, Chemutai Levi, Chelangat Brian, Chebet Emmanuel, Chelimo Daniel, Kwemboi Shedrack and Mercy Chepkwemboi who have always supported me in their prayers. Not forgetting my Aunts Esther Cherop and Harriet Yariwo and uncles Lawrence Mutai and Andrew Bushendish who have always advised and guided me in my academic journey.

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List of Acronyms

BHC: benzene hexachloride

DDD: 1,1-ichloro-2,2bis(p-chlorophenyl)ethane

DDT: Dichlorodiphenyltrichloroethane

FAO: food and agricultural organization

HCH: Hexachlorohexane

LOD: lower limit of detection

MRLs: maximum residue levels

OCP: organochlorine pesticides

WHO: world health organization

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Abstract

Organochlorine pesticides have been on use widely having severe usage in the chemical industry, they are developed with an intension of targeting at specific pests, however in their action, it's even toxic to even non targeted organisms Due to continuous usage of OCP's, it is stipulated that the residues of OCP's accumulate in the different matrices of the environment in different parts of the country Uganda because of the usage in both the health sector and also in agriculture. Measurements of organochlorine pesticides can be in fat, blood, urine, semen, and even breast milk, obtaining the levels in urine and blood is easier though may give levels of low concentration regardless of moderate or excessive exposure. Organochlorine pesticides show a greater variety of different structures with much different chemical properties. This may be due to high atomic weight of chlorine, and most of these organochlorine pesticides are heavier than water (denser than water).

CHAPTER ONE: INTRODUCTION

1.1 Background

The invention of organochlorine pesticides started since the 20th century worldwide, organochlorine pesticide compounds have been in use in large quantities both in agriculture and for pest control from 1940s but by 1070s, most countries banned their use since it proved so persistent in the environment. In Uganda, some of these chemicals under the OCPs are being used for vector control and crop production inspite of the bans and restrictions issued in 1970 (Ben et al., 2021).

Pesticides belong to a group of chemicals used to control or destroy insects, pests' fungi, bacteria and many others, they basically include fungicides, herbicides, rodenticides, bactericides and many others, and they may be specific or non-specific in their mode of action (Darko & Acquaah, 2015; Ben et al., 2021).

Organochlorine pesticides also known as synthetic compounds are a group of derivatives of chlorinated hydrocarbons applied adversely is agriculture and chemical industry. The classification of organochlorine compounds is based in three groups; benzenehexachloride isomers (e.g., lindane), cyclodienes (aldrin, chlordane, endosulfan, dieldrin, endrin, heptachlor,), and DDT and its analogues (methoxychlor, dicofol, and chlorobenzylate) (Jayaraj et al., 2016).

Organochlorine pesticides gets into the environment during pesticide applications, land fill disposal of contaminated wastes, releases by manufacturing plants. Organochlorine compounds degrade slowly in the environment, and over or inappropriate use of this pesticides by farmers' results into contamination of environmental water, soil, air, and other types of crops and this has a long-term effect on humans. Organochlorine pesticides are characterized by high lipophilicity, bioaccumulation, having a longer half-life and potential of being transported for long distances, which result into increased chances of air, water and soil degradation even after many years of application (Ntirushize et al., 2019).

Organochlorine pesticides being toxic and carcinogenic, they can possibly cause serious and dangerous health problems to both animals, mankind, and the environment. The toxicity properties of OCPs are brought about by lipophilic nature, and as a result, they form biological compounds and chemically form combinations which are stable (Kumar et al., 2010).

In reference to epidemiological studies, there are indications that some of these compounds may result into cancer in humans (Aaron et al., n.d.) and in addition, influences the levels of thyroid hormones and reported delays in neurodevelopment in the early childhood caused by the effects of prenatal exposure to dichlorodiphenyltrichloroethane (DDTs). Over exposure to some organochlorines may result to abnormalities in the functioning of the liver, skin, and the nervous system in general (Konuk, n.d.).

1.2 Problem Statement

Organochlorine pesticides (OCP) have been used for agricultural and livestock for a couple of years by most developing countries to combat the problem of crop pests and animal ectoparasites. The need and use of the organochlorine pesticides arouse after the need to increase the productivity of agricultural products, the highly spreading malaria, disease and other deadly human diseases (Harris et al., 2001).

The use of these organochlorine pesticides in most developing countries in particular Uganda has left the environment destroyed, (water, air, and soils). Destruction of soils therefore results into distortion of the life of both macro and microorganism, also, the chemicals are transferred in the plants since the plants absorb them from the soils, destruction of the air makes the aerial life risky and similarly, the water destruction definitely affects the aquatic life (Nyaundi et al., 2019).

Most of these compounds are non-degradable or are slowly degraded, for that reason, the residues remain and accumulate in the food chain and is therefore transferred from one organism to another in the ecosystem (Ntirushize et al., 2019). Examples of these organochlorine pesticides may among others include: aldrin, dieldrin, heptachlor, DDT, HCH and many others yet to be discussed.

Despite the ban on the use of these organochlorine pesticides, locals still use because of the effectiveness for example the use of DDT on the mosquitoes. As a result, there is accumulation of residues of organochlorine pesticide compounds in most parts of Uganda (Ntirushize et al., 2019) which is harmful to both nonhuman and human beings. The purpose of this review therefore is to:

- Assess the nature of organochlorine pesticides and their residues in the environment.
- Assess the levels of organochlorine pesticide residues in some selected agricultural products within Uganda.
- To compare the levels of contamination of agricultural products with organochlorine pesticide residues.
- To assess the impacts of excess consumption of organochlorine pesticide residues in human beings.

1.3 Significance of the Review

The significance of this review is therefore to provide information about the permissible levels of organochlorine pesticide residue consumption, also to develop an idea about the alternative sources of improving agricultural productivity in both plant and animal perspective and avoiding the spread of diseases caused by vectors which are destroyed using organochlorine pesticides.

1.4 Scope of the Review

The scope of this review covers all parts of the country (Uganda) involving both soil, water, air and agricultural products, sold in the local markets in Uganda, agricultural products considered include milk, fish, plant products (different food stuff), meat supplied in the markets inclusive.

CHAPTER TWO: LITERATURE REVIEW

2.1 Pesticides

Pesticides are compounds consisting of one or more substances developed with an objective of eliminating pests, for example carriers of human, plant or animal diseases. Weeds that interfere with the growth of plants or animals and inflicts harm, or other words distorts production, process of storing, transportation, or even the process of marketing of agricultural products, wood and wood products or even food (animal feeds). Other pesticides that can be used to administer to animals for the process of controlling insects, arachnids or other pests can be endothermic or ectothermic (Augustinjn et al., 1994).

2.2 Pesticide Residues

2.2.1 Definition of a Pesticide Residue

When pesticides are applied in the soils, there are gradual processes, in which they are lost in the soils, for example leaching and evaporation, what remains after application is known as the residue (Fruits et al., 2013). Some pesticides have a longer period of residual activity and for that reason, persists in the environment while others have short period of time for residual activity, they therefore do not persist from the environment or results into low residue concentration. It is therefore possible to find pesticide residues in the environment and agricultural products. Residues of the pesticides may get into the chain of food and may results into complications to lives of humans and animals (Bolor et al., 2018).

2.2.2 Ways Through Which Pesticide Residues get into Agricultural Products

The pesticide residues in the environment and agricultural products occur as a result of application of insecticides to the vegetation with an intention of eliminating the insects. The draining of pesticides (herbicides) or insecticides through the soils to the underground water as a result of heavy rains is another source of exposure.

The transfer of soils contaminated with pesticide from one side/place to another as a result water, air or even animals as well as disposition of pesticides in or around water bodies are other sources (Nyaundi et al., 2019).

2.2.3 Ways in Which Pesticide Residues Gets into Human Bodies

Pesticide residues get into the human body through breathing polluted air. Direct penetration through ingestion or eating of contaminated foods and drinking water contaminated with OCPs also lead to exposure. The foods in question include fruits, vegetables, cereals and various meats. Transfer through the mother's placenta to the fetus has been reported as another source of exposure of infants (Chandra et al., 2021).

2.3 Organochlorine Pesticides

2.3.1 Composition of Organochlorine Pesticides

The constituents of organochlorine pesticides include carbon, hydrogen, and chlorine. The persistent type of organochlorine pesticides is found to poses one or more rings in their structures, the polychlorinated biphenyls and Dichlorodiphenylethanes are made up of two rings (Longnecker et al., 1997).

2.3.2 Characteristics of Organochlorine Pesticides

Organochlorine pesticides have different characteristics which are attributed to the different groups attached to them; however, in general, the following are the major features.

They are degraded at a slow rate, and therefore are persistent in the soils (environment); they do not dissolve in water and can be put in the classes of dichlorodiphenylethanes, cyclodienes, and chlorinated benzenes (Ademoroti, 1996). They may be grouped into three general classes; the dichlorodiphenylethanes (DDT, DDD, dicofol, etc.), the chlorinated cyclodienes (aldrin, dieldrin, heptachlor, etc.) and the hexachlorocyclohexanes (lindane) considering the following features, toxic doses, skin absorption, fat storage, metabolism, and elimination. The significance of toxicity in humans is related to the effects of DDT. The only difference is the lipophilic nature of DDT which gives it higher percentages of bioaccumulation in the chain of foods more so in the foods containing to much fat (Nyaundi et al., 2019). The extensive usage by farmers is because of the first knock down ability, and the fact that it can be applied on a variety of activities (Darko & Acquaah, 2015). Because of the lipophilic character, they are easily absorbed (easily dissolves in the fats (lipids) in the cuticles of insects. For the case of animals with backbones' (vertebrates), most of these insecticides containing chlorine remains in the adipose tissue and is then released in to the circulatory system (Nyeko & Obwoya, 1993). The summary of the classes of this organochlorine pesticides is shown in Table 1.

2.3.3 Comparison of Different Classes of Organochlorine Pesticides

Table 1: Comparison of Different Classes of Organochlorine Pesticides

Class of the organochlorine pesticide	Solubility in Water	Solubility in Fats	Bioaccumulation
Dichlorodiphenylethanes e.g. (DDT, DDD, Dicofol.	Insoluble in water	Highly soluble	Highly accumulate
Chlorinated cyclodienes e.g. aldrin, dieldrin, heptachlor	Insoluble or Slightly solubility	Very soluble	Bioaccumulates
Hexachlorocyclohexanes e.g. lindane.	Slightly soluble	Highly soluble	Bioaccumulates in living organisms

2.4 Mode of Transfer of Organochlorine Pesticides

The organochlorine pesticides (OCP) were used to improve the productivity of agricultural activities, and livestock for quite some time to prevent different agricultural crop pests and majorly animal ectoparasites and also human disease vectors, for example mosquitoes that spreads malaria and other diseases which cause discomfort to human lives. Of recent, most of the species of the group of organochlorine pesticides for example aldrin, dieldrin, heptachlor, DDT, HCH, and many others are often in use (*Annurev.Publhealth.18.1.211(0).Pdf*, n.d.) and are constituents of the toxicity group of persistent organic pollutants (POPs). The restriction and ban of the organochlorine pesticides was brought by the ability to highly resist degradation, this is because they are chemically stable and have the lipophilic property which makes it to bio-accumulate in the different environments and in chain of food therefore resulting to contamination in the tissues of human body (Turyahikayo, 2013).

The residues of organochlorine pesticides are bio concentrated in tissues containing lipids (fats) and the rate of the breakdown is very low even though the primary sources of contaminants are removed completely. According to Chandra et al. (2021), the pesticides enter the animal body when animals are fed on spoilt or contaminated feeds, which results into contamination of the products like milk and meat, which ultimately results into contamination of human body whenever they feed of these animals or even their products.

The invention of yet new species of molecules and improvement in the practices of insect and pests' management have resulted into reduced contamination. Milk as a product of livestock, is good to be part of diet of infants or children and aged and is regarded as the best natural food. It is a fat rich food and acts as a source of organochlorine pesticide residue accumulator (Nag & Raikwar, 2008).

2.5 Major Properties of Organochlorine Pesticides

Persistency, highly toxic, chemically stable, low solubility in water, low vapour pressures and finally accumulation. The persistency of organochlorine compounds can be classified as moderate persistence in which the half-life is approximately 60 days or high persistency in which the half-life is between 10–15 years. Dichlorodiphenyltrichloroethane (DDT), is one of the major pesticides used in agriculture and is classified as moderately hazardous, characterized by high persistence with half-life of between 2–15 years (Augustinjn et al., 1994).

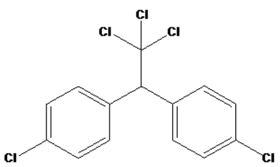
2.6 Extent of Usage of Organochlorine Pesticides

Organochlorine pesticide usage in large quantities to increase agricultural productivity and pest control was rampant in most developing countries in the early 20th century but by 1970s, their usage had been banned because of the element of persistence in the environment. Regardless of the fact that their use was restricted and banned, by 1970s, Ugandans have continued to use to maximize crop production and control the spread of vector pest and for that reason, residues are found in different matrices of the environment in Uganda (Kampire et al., 2011; Turyahikayo, 2013).

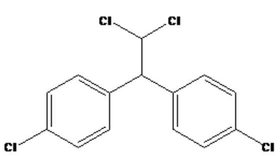
2.7 Areas Found to be of Interests

2.7.1 DDT and Its Metabolites

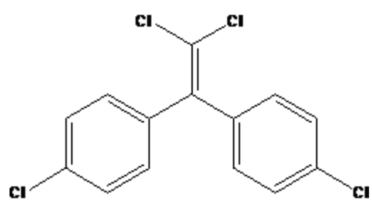
To start with, fish and water fetched from Lake Victoria, had elements of organochlorine pesticides. The fish fetched from Lake Edward, in Uganda were found to contain DDT and its metabolites, organochlorines were detected in soil samples obtained from south-western Uganda. The skin, flesh and whole carrots (Daucus carota) fetched from Lake Victoria basin, markets in Uganda had organochlorine pesticides. The main pesticides include: DDT and the major products of its metabolism (Kumar et al., 2010).



DDT



DDD



DDE

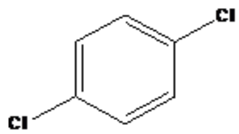
A new invention on the use of pesticide in Uganda showed a 6% response when dieldrin was used, implying its usage as a pesticide by farmers to stop different pests. Because these pesticides are degraded slowly in the environment, their use in large quantity results into contamination of the environment, (water, soil, air), including crops and indirectly animals including humans (Jayaraj et al., 2016).

The development of health problems including reproductive problems, induction of tumors, destruction of endocrine system and cancers may result due to over exposure to organochlorine pesticides. For the case of the young, whose systems of enzymes and metabolism are not fully developed, organochlorine pesticides may affect them more (Bolor et al., 2018). Epidemiologists suggested that; expectant mothers employed in agriculture are at risks of developing birth defects. Honey can be treated with organic solvent to remove the pesticide in it, or in the case of a solid phase, honey is made dilute by mixing it with water and octadecylsilane cartridges can be passed through. The above processes as a result of growing concerns over environmental pollution resulted to the raise in the need to solve the problem, Because of the ability of the honey to accumulate residues of pesticides majorly organochlorine, determining the presence organochlorine pesticide residues in honey can be simply obtained by analyzing the honey (Ntirushize et al., 2019).

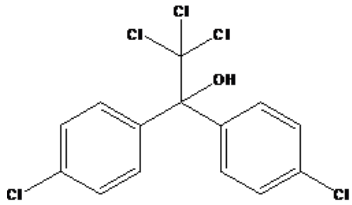
2.7.2 Other Organochlorine Pesticides

DDT, DDD, dicofol, aldrin, dieldrin, chlorobenziate, lindane, BHC, methoxychlor chlordane, heptachlor, endosulfan, isodrin, isobenzan, toxaphene, chloropropylate.

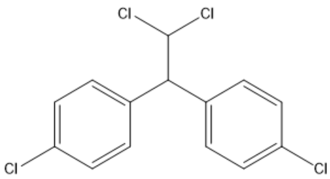
2.7.3 Other Different Organochlorine Compounds and their Structures



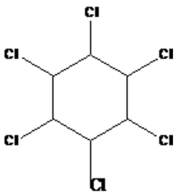
1,4-dichlorobenzene



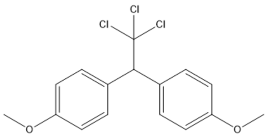
Dicofol



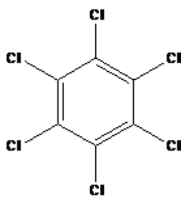
1, 1-Dichloro-2, 2-bis (p-Chloro phenyl) ethane



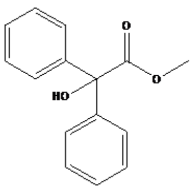
1, 2, 3, 4, 5, 6-hexachlorocyclohexane



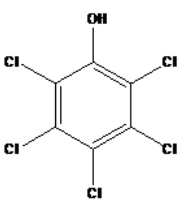
Methoxychlor



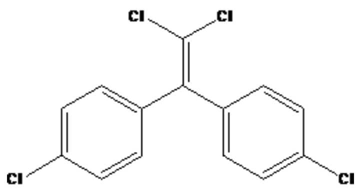
Benzene hexachloride



ChloropropylatePentachloropenol



Pentachlorophenol



Dichlorodiphenyldichloroethane

2.8 Adverse Effects of Organochlorine Pesticides

2.8.1 Short Term Effects of Organochlorine Pesticides

Exposure to organochlorines pesticides for a short time would result into headache, dizziness, nausea, vomiting, tremors confusion, muscle weakness, salivation and sweating (Aaron et al., n.d.).

2.8.2 Long Term Effects of Organochlorine Pesticides

OCPs are known to be endocrine disorganizing chemicals, and may result to different health problems in people, for example induce infertility and fecundity, miscourages, skewed sex ratios within the offspring of exposed communities, and male and female reproductive tract abnormalities (Publication, 2017).

Furthermore, epidemiological studies have shown that exposure to persistent organic pollutants, mainly organochlorine pesticides, is strongly associated with type 2 diabetes. Some classes of organochlorine pesticides cause hypertension, cardiovascular disorders and other health related problems in humans (Singh et al., 2016).

Organochlorines act as endocrine disrupting chemicals (EDCs) by interfering with molecular circuitry and function of the endocrine system, resulting into neuromuscular disorders and stimulation of drug and steroid metabolism (Jacobson & Jacobson, 1996; Jayaraj et al., 2016).

OCPs residues also are reported to be responsible for gall stone disease in human beings, it also disrupts or causes interference of the neonatal thyroid hormone, over exposure to DDT (technical grade) increases the risk of pancreatic cancer (Longnecker et al., 1997; Rica et al., 2019).

2.8.3 Toxicity, Use and Persistence of OCPs

Table 2: Toxicity, use and persistence of organochlorine pesticides (Jayaraj et at., 2019)

Chemical name	**Toxicity**	**Use**	**Persistence in the Environment**	**WHO Classification based on Rat oral LD50**
Dichlorodiphenyltrichloroethane (DDT)	Rat Oral: 113–130 mg/kg Dermal: 2510 mg/kg **Mice** Oral: 150–300 mg/kg **Guinea Pigs** Oral: 300 mg/kg **Rabbit** Oral: 400 mg/kg	Acaricide Insecticide	High persistence, half-life of 2-15 years	Moderately hazardous
1,1-ichloro-2,2bis(p-chlorophenyl)ethane(DDD)	Rat Oral: 4000 mg/kg	Insecticide	High persistence, half-life of 5-10 years	Acute hazard is unlikely
Dichlorodiphenyl dichloroethane(DDE)	Rat Oral: 800-1240 mg/kg	Insecticide	High persistence, half-life of 10 years	Slightly hazardous
Dicofol	Rat Oral: 684–1495 mg/kg **Rabbit** Oral: 1810 mg/kg Dermal: 2.1 g/kg	Acaricide	Moderate persistence, half-life of 60 days	Moderately hazardous
Endrin	Rat	Avicide	Moderate persistence,	Highly hazardous

	Oral: 3 mg/kg Dermal: 15 mg/kg **Mouse** Oral: 1.37g/kg Intravenous: 2300 g/kg **Goat** Oral: 50 mg/kg **Rabbit** Oral: 60–94 mg/kg	Insecticide	half-life of 1 day to 12 years	
Dieldrin	Rat Oral: 46 mg/kg Dermal: 50–120 mg/kg **Mouse** Oral: 38–77 mg/kg **Dog** Oral: 56–120 mg/kg **Rabbit** Oral: 45–50 mg/kg **Cow** Oral: 25 mg/kg **Duck** Oral: 381 mg/kg	Insecticide	High persistence, half-life of 9 month	Highly hazardous
Methoxychlor	Rat Oral: 5000–6000 mg/kg	Insecticide	High persistence, half-life: of <120 days	Acute hazard is unlikely

	Mice Oral: 2000 mg/kg **Monkey** Oral: 2500 mg/kg			
Chlordane	Rat Oral: 200 to 700 mg/kg Dermal: 530–690 mg/kg **Mice** Oral: 145–430 mg/kg Dermal: 153 mg/kg **Rabbit** Dermal: 780 mg/kg	Insecticide	High persistence, half-life: 10 years	Moderately hazardous
Heptachlor	Rat Oral: 40– 220 mg/kg Dermal: 119–320 mg/kg **Mouse** Oral: 30–68 mg/kg **Guinea pigs** Oral: 116 mg/kg Dermal: 1000 mg/kg **Rabbit** Dermal: 2000 mg/kg	Insecticide	High persistence, half-life: 2 years	Highly-moderately hazardous

Lindane	Rat Oral: 88 – 270 mg/kg **Mouse** Oral: 59–246 mg/kg	Acaricide Insecticide Rodenticide	High persistence, half-life:15 month	Moderately hazardous
Endosulfan	Rat Oral: 18 to 220 mg/kg Dermal: 74 mg/kg **Rabbits** Dermal: 200–359 mg/kg **Ducks** Oral: 33 mg/k	Insecticide	Moderately persistent, half-life alpha isomer: 35 days Beta isomer: 150 days	Highly hazardous
Isodrin	Rat Oral: 8.8 mg/kg	Insecticide	High persistence, half-life:0.5-6 years	High hazardous
Isobenzan	Rat Oral: 4.8 mg/kg **Rabbit** Dermal: 12 mg/kg **Mouse** Oral: 8.4 mg/kg	Insecticide	High persistence, half-life: 2.8 years	Highly hazardous
Chloropropylate	Rat Oral: 5000 mg/kg **Birds** Oral: 2500 mg/kg	Insecticide Acaricide	Moderately persistent, half-life of 50 days	Acute hazard is unlikely

	Rabbit Oral: 10200 mg/kg			
Aldrin	Oral: 39 to 60 mg/kg Dermal: 100 mg/kg **Mouse** Oral: 44 mg/kg **Dog** Oral: 65–95 mg/kg	Insecticide	Moderate persistence, half-life 4-7 years	Highly hazardous
1,4-dichlorobenzene	Rat Oral: 1516-2138 mg/kg		Moderate persistence, half-life of <50 days	Moderately hazardous
Benzene hexachloride (BHC)	Rat oral: 10,000 mg/kg **Guinea pigs** Oral: < 3000 mg/kg **Rat** Oral: 4000 mg/kg	Acaricide Insecticide Rodenticide	High persistence, half-life of 3-4 years	moderately hazardous
Mirex	Rat Oral: 600-740mg/kg	Insecticide	High persistence, half-life of 10 years	Acute hazard is unlikely
Pentachlorophenol OH	Rat Oral: 27–211 mg/kg Dermal: 96–330 mg/kg **Mice**	Fungicide Herbicide Insecticide	Moderately persistent, half-life: 45 days	Highly-moderately hazardous

	Oral: 74–130 mg/kg **Rabbit** Oral: 70–300 mg/kg Dermal: < 100 mg/kg			
Toxaphene(camphechor)	Rat Oral:80-293 mg/kg Dogs: 25 mg/kg	Acaricide Insecticide	Moderately persistent, half-life of 11 years	Slightly hazardous

2.9 Reported Levels of Pesticides in Various Foods in Uganda

Studies on different foodstuff in Uganda revealed the presence of organochlorine pesticides, it was found out that, nile perch and nile tilapia did not have DDT pesticides but had hexachlorohexanes whereas the fresh cow milk contained DDT in the range of 0.052-0.152 mg/kg. The summary of these data is shown in Table 3. (An extract from table 1 as per the "journal of veterinary medical science" dated 17th of Feb 2017).

Table 3: Levels of organochlorine pesticides in various foods in Uganda

Foodstuff	**Pesticide Concentration (ng/gdw, except where specified) in DDT**	**Pesticide Concentration (ng/gdw, except where specified) in others**	**References**
Nile perch and nile tilapia		∑HCHs ND-73,000 pg/g lw	(Ssebugere et al., 2009)
fresh cow milk	Mean 0.052 (range 0.018-0.152) mg/kg	Lindane (0.026, 0.001-0.086), aldrin (0.009, 0.002-0.018), dieldrin (0.007,	(Kampire et al., 2011)

		0.001-0.018), α-Endosulfan (0.002, 0.001-0.004), β-Endosulfan (<LOD)	
Pasteurized cow milk	Mean 0.041 (range 0.012-0.088) mg/kg	Lindane (0.022, <LOD-0.066), aldrin (0.006, 0.005-0.008), dieldrin (0.005, 0.001-0.021), α-Endosulfan (<LOD), β-Endosulfan (<LOD)	
Fish	ND-68 µg/kg fw		(Ssebugere et al., 2009)
Nile perch (belly flap oil)	Mean 43.74 µg/kg oil		(Ogwok et al., 2009)
Nile perch and american cat fish	*p,p'*-DDE (<0.01), *p,p'*-DDT (0.002) mg/kg	Endosulfan sulphate <0.002 mg/kg ww	(Bagumire.A et al., 2008)
Nile tilapia	Mean *p,p'*-DDE (0.80), *p,p'*-DDT (0.59) µg/kg	Mean Lindane (0.74), aldrin (0.28), α-Endosulfan (1.70), dieldrin (0.30) µg/kg	(Kasozi et al., 2006)
Nile perch	Mean *p,p'*-DDE (0.86), *p,p'*-DDT (0.81) µg/kg	Mean Lindane (0.87), aldrin (0.48), α-Endosulfan (1.45), dieldrin (0.18) µg/kg	(Kasozi et al., 2006)

2.9.1 Biochemical Effects of Organochlorine pesticides

Different organochlorine pesticides have different biochemical effects on different organisms. (Extracted from table 3 of the article “Division of forest ecology and biodiversity conversion, kerela forest research institute, dated 22nd July 2016”), Table 4 presents the biochemical effects of different organochlorine pesticides in a human being.

Table 4: Major biochemical effects of major organochlorine pesticides on human beings (Jayaraj et al., 2019)

S/N	Chemical Name	Biochemical Effects	References
1	Aldrin and Dieldrin	Neurotoxic, reproductive, developmental, immunological, genotoxic, tumerogenic effects, nausea, vomiting, muscle twitch in and aplastic anemia	(USEPA, 2003)
2	Chlordane	Convulsions, tremor, mental confusion and incoordination	(ATSDRs, 1997)
3	BHC/DDE	Cyst in hands, itching, psoriasis, eczema, leucoderma, skin rashes	(Subramanaim & Solomon, 2006)
4	DDT	Prickling sensation of the mouth, nausea, dizziness, confusion, headache, lethargy, incoordination, vomiting, fatigue, tremors in the extremities, anorexia, anemia, muscular weakness, hyperexcit ability, anxiety, and nervous tension	(Klaassen et al., 1996)
5	Diazon	Dark or blurred vision, anxiety and restlessness, as well as psychiatric symptoms	(Vijaya et al., 2011)

		such as depression, memory loss, and confusion and acute pancreatitis.	
6	Endosulfan	Decreases the white blood cell count and macrophage migration, Adverse effects on humoral and cell-mediated immune system. Affects semen quality, sperm count, spermatogonia cells, sperm morphology and other defects in male sex hormones DNA damage and mutation	(Susan & Sania, 1999) (Singh et al., 2007)
7	Lindane	Damage human liver, kidney, neural and immune systems, and induces birth defects cancer, cause neurotoxicity, reproductive toxicity and hepatotoxicity	(Sahoo et al., 2008) (Bano & Batti, 2010) (Vijaya et al., 2011)
8	Polychlorinated biphenyls	Neurological disorders and short-term memory	(Jacobson & Jacobson, 1996)
9	Pentachlorophenol	Inflammation of the upper respiratory tract and bronchitis, blood effects such as aplastic anemia, effects on the kidney and liver, immunological effects, and irritation of the eyes, nose, and skin	(ATSDR., 1999)

CHAPTER THREE: RESEARCH METHODOLOGY

3.1 Selection of Articles Used in the Review

The used data in this section was obtained/got from a number of closely related scientific articles using the search engine google scholar**,** all publication used were in English. Articles with related information with more citations were considered most.

Selection of the most appropriate articles used involved using specific words which included “organochlorines”, which yielded many articles involving those of the related searches. Articles of interest from a number of the obtained listed articles prompted the search for specific data. The used word in this case was “organochlorine pesticide residues”. Which yet yielded related articles with related data, in the same way, the scope was narrowed to “organochlorine pesticide residues in Uganda”.

The used articles under “organochlorines” are the articles which had the history of development and usage of organochlorines, involving which countries were the first to use and the years between which these compounds were used and banned indicated. The articles obtained and used under “organochlorine pesticides” were the articles which contained data about what organochlorines are and what are the residues. Also, with data giving the different types of organochlorine pesticides.

In the same way, the articles obtained under “organochlorine pesticide residues in Uganda”, had data relating to areas which are greatly affected by pesticide residue contamination, products closely affected or closely found to be associated with organochlorine pesticide residue contamination which includes both animal products.

3.2 Methods of Analysis of Organochlorine Pesticides

3.2.1 Gas Chromatography as a Method of Analysis of Organochlorine Pesticides

Gas chromatography is a technique of analysis and separation of components of a given sample, this technique uses the gas chromatograph as an instrument and results into a gas chromatogram which is seen as an electric signal in the data processor. A schematic diagram of a gas chromatograph is shown in Figure 1.

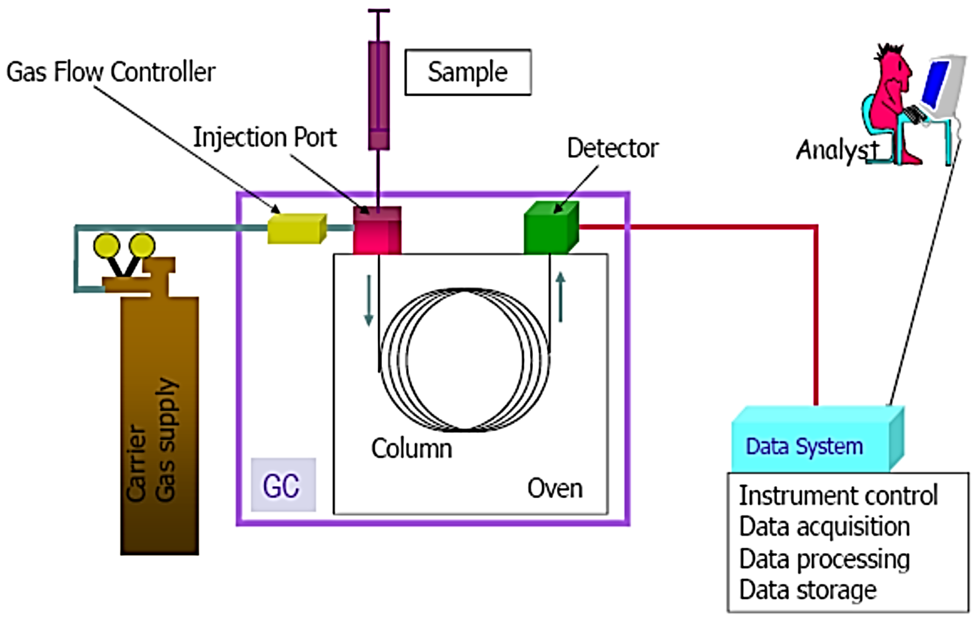


Figure 1: Schematic Diagram of Gas Chromatography (AL-Bukhaiti et al., 2017)

Parts of a gas chromatograph include gas cylinder which contains a carrier gas, that moves the sample along the column and is commonly inert gas like nitrogen, helium and hydrogen, a flow controller, an injection port used for introducing samples into the instrument, the column that contains the stationary where actual separation of components of the sample occurs, a detector which sends signals referring to the concentration of compounds to the data processor which outputs them as electric signals. A typical gas chromatograph can be represented in the Figure 1.

3.2.2 Cleaning of Samples for Analysis

The samples are cleaned by the florisil method, which is the method of removing compounds which would otherwise interfere with the chromatographic analysis of the sample analyte of interest. The florisil cleanup process is accomplished with the use of a chromatographic column which is embedded with florisil, compounds are eluted by the use of solvent mixtures of different polarities.

3.2.3 Analysis of the Samples

The cleaned sample is introduced to the instrument by means of a syringe which is in contact with the injection port. The separation of the components of the sample is achieved due to the retardation of the individual as they move through the column containing the stationary phase.

As the sample moves along with the carrier gas, which is in contact with the stationary phase, the molecules of the individual components of the sample will constantly move between the carrier gas and the liquid in the stationary phase in a dynamic equilibrium. Components which are more volatile have a greater tendency of its molecules moving faster in the carrier gas and therefore will be eluted first at the end of the column. The elution times of the different components of the sample can then be recorded and hence the retention times determined.

CHAPTER FOUR: RESULTS AND DISSCUSION

4.1 Organochlorine Pesticides in Fish

A study by Jayaraj et al. (2016) found that fish, for example, nile perch and nile tilapia obtained from the shore of the northern part of Lake Victoria in Uganda had hexachlorohexanes at lower concentrations which were safe for human consumption. Analysis of other organochlorines in the fish species had residues lower than recommended maximum residue levels (Jayaraj et al., 2016). In some parts of southwestern Uganda, different species of fish (5) obtained from Lake Edward and analysis for DDT, showed a higher and maximum level of 68 μg/kg. Almost all samples analyzed had below FAO/WHO maximum residue levels. The products from fish farms of Uganda are exported internationally, and in the analysis of such, nile tilapia and African catfish had organochlorines, though in the range of prescribed limits. Also, DDT and endosulfan were found to be contained by catfish, which implied that this species is easily contaminated than tilapia. Analysis of the belly flap oil obtained from the nile perch from Lake Victoria revealed the presence of many organochlorine pesticide residues. It was found that DDTs were more predominant, and their concentrations increased with increase in the fish size. However, notable levels of endosulfan were found of largest fish, with concentrations exceeding the recommended maximum residue levels (Singh et al., 2016).

4.2 Organochlorine Pesticides in Milk

The cow's milk sold in the markets of Kampala showed that the samples which were pasteurized contained smaller amounts of organochlorine pesticides compared to fresh samples, but however, most had above international residue limits and this would likely put a risk to the health of humans (Publication, 2017).

4.3 Organochlorine Pesticide Residues in Honey

Ntirushize et al. (2019) investigated the levels of pesticide residues in honey samples from Kabale District, Western Uganda by comparing retention times. The study was done because there is wide spread use of organochlorine pesticides in the region, and the fact that honey is known to have a high tendency to bioaccumulate pesticide residues. For this reason, samples were extracted for the organochlorine pesticides residues by the use of solid-liquid dispersion method. Samples were cleaned using florisil method and organochlorine pesticides residues were analyzed using gas chromatography.

A typical chromatogram obtained from this analysis is shown in Figure 1 (Ntirushize et al., 2019). From Figure 1, it can be observed that DDD is the most predominant residue in the honey sample. The organochlorine pesticide residues were identified by comparison of their retention times with those of the standards. The results are presented in Table 5.

Table 5: Retention times of organochlorine pesticide residues compared to standard and average concentration (Bolor et at., 2018)

Pesticide	Mean Concentration (mg/ kg)	Non-Polar Column SPB-1 60 m × 0.53 mm i.d (RTstd (min))	Non-Polar Column SPB-1 60 m × 0.53 mm i.d (RTsample (min))	Semi-Polar Column CP-Sil CB 30 m × 0.25 mm i.d. (RTstd (min))	Semi-Polar Column CP-Sil CB 30 m × 0.25 mm i.d. (RTsample (min))
Endosulfan sulfate	0.67	16.49	16.47	16.46	16.45
α-Endosulfan	0.90	13.08	13.09	10.92	10.91
p,p′-DDE	0.74	13.98	13.96	13.10	13.07
p,p′-DDD	0.82	18.18	18.19	15.26	15.27
p,p′-DDT	0.23	19.75	19.72	19.69	19.68
o,p′-DDT	0.11	18.49	18.47	18.45	18.44

Dieldrin	1.22	13.94	13.96	12.24	12.22
α-HCH	ND	7.42	7.09	6.55	6.66
β-HCH	1.04	7.79	7.75	9.18	9.16
γ-HCH	1.52	7.48	7.45	7.05	7.09

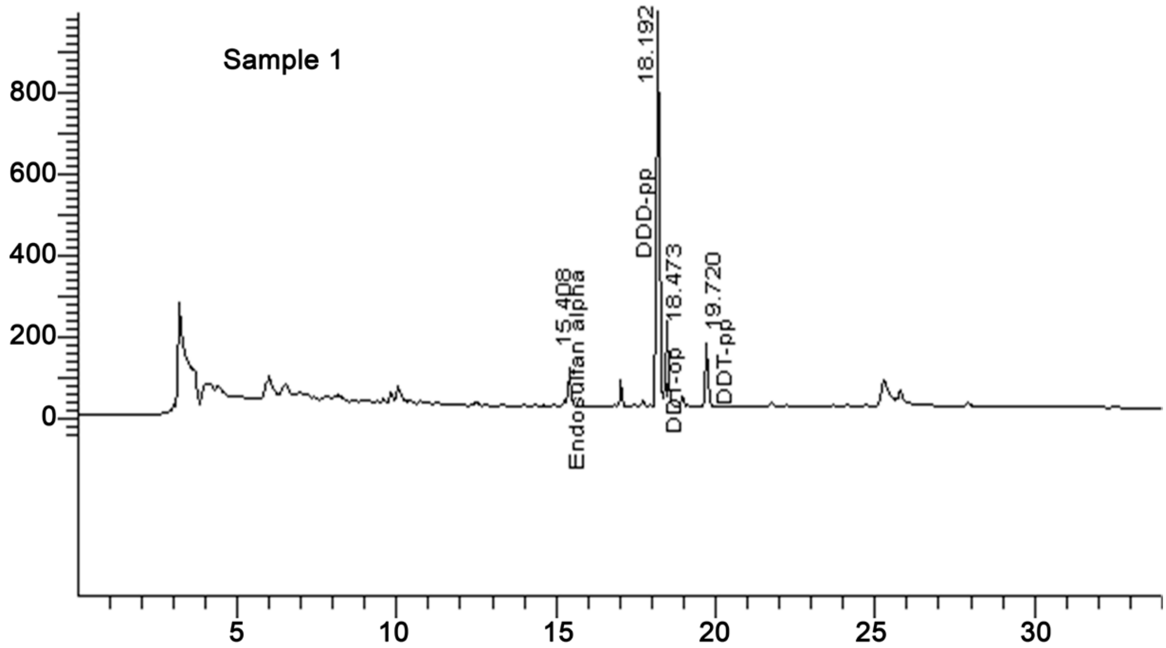


Figure 2: Chromatogram of organochlorine pesticide residues.

From the data presented in Table 5, it is evident that the honey sold contained organochlorine pesticide residues, though within the acceptable quantities (Ntirushize et al., 2019). This implied that the honey sold was safe for human consumption, however, the milk and meat sold Kampala had greater than the international residue limit, which would mean humans within this place are at a high risk of facing health problems (Publication, 2017).

4.4 Conclusion and Recommendations

4.4.1 Conclusion

There are several organochlorine pesticides, used for different purposes, From the results shown in Table 5 and Figure 1, there is enough evidence for the accumulation of this organochlorine pesticides residues, which do not only have effect on humans but also other species including fish, the honey samples analyzed showed residues present though within consumable levels, however, the results from the milk and fish sold within Kampala markets showed high percentage of accumulated residues, yet this products are directly consumed by the people, this means that, humans are indirectly exposed to this residues, through the chain of food.

From the papers analyzed above, the effects noted had implications which are highly dangerous to human health, in this case, cited effects include disruption of the central nervous system. It can be concluded therefore that the adverse effects of organochlorine pesticides can be attributed to the fact that they are non-biodegradable and they are fat soluble, making their residues to accumulate in the food chain and finally in the tissues.

4.4.2 Recommendations

There is need to set up a national body if not there and if there, they should ensure continuous monitoring of the quality and nature of agricultural products, on the levels of organochlorine pesticide residues, so as to enhance the food trade, within and across the borders of Uganda.

It could also be of great importance for the government or the concerned body to ensure enough management of the production process of these pesticides, so as to take precautions to limit the processing of highly persistent organochlorines and resort to less persistent ones to reduce the risks of bioaccumulation of these pesticide residues.

There is need for more research on the alternative pesticides, by modifying the present nature to form a less harmful ones. This would eliminate the continuous accumulation of the pesticide residues.

There is need for massive sensitization of the population on the general and adverse effects of the organochlorine pesticide residues. People should be encouraged to resort to the traditional ways of pest control and enhancement of productivity with little or no side effects.

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