

**DETERMINATION OF POSSIBLE
SOURCES AND SEASONAL
FLUCTUATION OF
ORGANOCHLORINE PESTICIDES IN
LAKE NAKURU**

BY

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Thesis submitted in partial fulfillment for the requirements of
the Degree of Master of Science in Chemistry of Egerton
University.



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This thesis is my original work and has not been presented for a degree in any other university.

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DEDICATION

This work is dedicated to my dear husband Mr. Peter Wangila Nyongesa and my children Brian, Teddy and Marval.

ABSTRACT

This thesis reports on the determination of organochlorine pesticides sources in lake Nakuru. The samples investigated were collected from Lake Nakuru and rivers within the Lake's catchment area, viz Rivers Njoro, Nderit, Makalia and Larmudiac. Water and sediment samples were collected using a macvuti and an ekman sampler respectively, and these were collected both from the lake and from the above named rivers. The samples were collected in two parts, the dry and rainy seasons. Gas chromatography (G.C.) employing the electron capture detector ((ECD) was used for the analysis of the extracted pesticide samples. In the extraction of the collected samples 15% diethylether in hexane was used.

Analysis of the organochlorine pesticide residues was done for 1,1-dichloro-2,2-bis (heptachloro)-3,9,4,7,7-tetrahydro-4,7-methanoindene [DDD], 1,1-DICHLORO-2,2-bis (p-chlorophenyl) ethylene [DDE], 1,1,1-trichloro-2,2- bis (p-chlorophenyl) ethane [DDT], Lindane, Methoxychlor and heptachlor. From the analysis, levels of these pesticides tend to increase during the rainy season. It is therefore true to conclude that pesticide residues increase with rains. Rivers Njoro, Makalia and Nderit are the possible sources of the organochlorine pesticides named above. All the pesticides named in this study were detected in samples collected from river Njoro, with methoxychlor as the highest pollutant [4433.5 ppb]. DDD, DDE and methoxychlor were found in samples collected from river makalia, with DDD [4700 ppb] as the highest pollutant. River Nderit had DDE [6255.6 pb] as the only pollutant. The other possible source is the town sewerage whose samples were detected to have DDE, DDD and DDT.

From the analysis, it can be noted that sediments contain the highest concentrations of the organochlorine pesticide pollutants. Rivers, Njoro, Makalia and Nderit are the major sources of the organochlorine pesticide that find their way into the Lake, while the town sewerage also contributes to the lake's pollution. Of the 88 samples collected for analysis in the period of April-November, 1999, 6% had DDD, 10% had DDE, 6% had DDT, 14% had Lindane, 3% had heptachlor and 4.5% had methoxychlor. It can therefore be concluded that Lindane seems to be the highest pollutant of the lake followed by DDT, DDD and DDE; with Heptachlor as the least amongst the pollutants.

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ABBREVIATIONS

The following abbreviations are used in the test

g or gms	-	gram (s)
µg	-	micrograms
ppb	-	Part (s) per billion
ml	-	Mililiter (s)
NIOSH	-	National Institute for Occupational safety and Health.
IDHL	-	Immediately Dangerous to Life or Health
OCS	-	Organochlorine Pesticides
UTM	-	Universal transect map
Oxid	-	Oxidation
Hyd	-	Hydrolysis
Red.	-	Reduction
Conj	-	Conjugation
Wax sol	-	Wax Solubility
H ₂ O Sol	-	Water Solubility
Molec. Dimen.	-	molecular dimension
Dilut.	-	Dilution
Oil stor.	-	Oil storage
RH	-	Relative humidity
V.P	-	Vapour Pressure
T*	-	Temperature

CHAPTER ONE

1.0 INTRODUCTION

In the last two decades the world has become aware of the effect of environmental pollutants on human health, animals and even plants. There is increasing social and political pressure to continuously monitor the quality of the environment. Pesticides are of economic benefit to man but their potential for producing adverse health effects resulting from low level exposure directs most of the world's environmental focus on them. They tend to affect man rather than eradicate pests.

Pesticides encompass many different classes of chemicals. The more specific terms used to describe them are; acaricides, herbicides, rodenticides etc. In addition to use in agriculture, these substances are employed in a wide variety of other pursuits such as structural pest control, vector control, wood treatment, termite proofing, moth proofing and maintenance of utility and transportation. Thus potential occupational exposure to pesticides are numerous and varied.

The increased pesticide manufacture and use has presented mankind with many new sets of human health problems and risks. There is no doubt that those who are in close contact with pesticides during their manufacture or application experience real risks of poisoning. The cumulative effects from these compounds are major contributors to an alarming increase in human toxification.

Pesticides are also among the chief pollutants of the human environment and unless their effects are carefully controlled they can result in serious damage to the health of people and the environment.

Pesticides are applied in many different ways and from all types of equipment handled by men and women who may differ widely in experience and general intelligence. Pesticides pose many health hazards, including the hazards brought about by improper disposal. Clearly the biggest risk of acute poisoning is experienced by those who apply the diluted forms of pesticide preparations, the main routes of absorption being through the skin as the result of splashes particles. It is during the application of pesticides that poisonings arise.

Pesticide toxification may occur from sudden brief exposure, at high concentration, to prolonged exposures at low concentrations over a period of years which may be as long as a working lifetime. Generally, pesticide dusts, fumes, gasses and vapours are inhaled and liquids and solids are ingested or absorbed through the skin. During their applications delayed effects of pesticides exposures may be carcinogenic or mutagenic (East Africa Newsletter, 1989).

The number of cases of pesticide poisoning is thought to be much larger than reported. One can think of a hippopotamus floating in water, with only its face above the surface, representing the cases of pesticide poisoning that are reported to health or other government agencies. Below the surface and not reported are those cases which are asymptotic, those which are recognized by workers but not brought to the attention of physicians or other health care providers, those that are brought to their attention but not correctly diagnosed and those that are correctly diagnosed but not reported. The total

number of people affected adversely by pesticides is not known. But recent estimates (Choudhry, 1989) indicated that there are almost 11 million cases of pesticide poisonings in Africa alone each year.

1.1 PESTICIDES

Pesticides are chemical substances intended for preventing, destroying, repelling or mitigating the effects of pests. They are substances that kill or interfere with the life cycle of certain pests (Scientific Encyclopædia, 1996). About 5% of pests found in the world can be controlled biologically and by the use of chemicals (Gresty, 1977). Due to the widespread usage and persistence of pesticides in the environment, international organisations like Food for African Organisation (FAO), United Nations Development Programme (UNDP) and United Nations Environmental Programme (UNEP) are trying to promote Integrated Pest Management (IPM) to reduce their use. (Our planet, 1992)

Pesticides can be divided into two major groups, the biodegradable and non-biodegradable pesticides, with the later causing more problems, both to the fauna and the flora. Contamination of surface water and soils arises when these pesticides are carried by water or wind to other places. During application persistent pesticides may find their way to the ground water system causing direct and indirect effects (Wandiga, 1986).

1.2 ORGANOCHLORINE PESTICIDES

Organochlorine compounds, in the form of insecticides and industrial pollutants, represent a major class of environmental contaminants. Most of these chemicals are fat soluble and highly persistent in the environment. Also called chlorinated hydrocarbons, organochlorine pesticides can also be subdivided into three groups: DDT [1,1,1 – trichloro – 2, 2 – bis (p-chlorophenyl) ethane] and its derivatives, cyclodienes and hexachlorobenzene isomers. The insecticidal potential of certain organochlorine insecticides was discovered in 1939 (Hassall, 1982). They have had a wide usage in agricultural, insect control and malarial programmes since early 1940's. As a group of pesticides some have become unpopular because they are very persistent in the environment and tend to accumulate in biological and non-biological media. (Hassall, 1982).

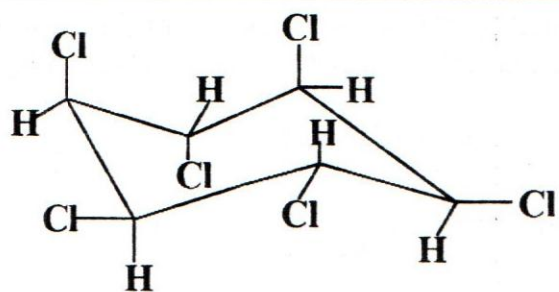
In Kenya, for instance, these insecticides have previously been extensively used in agriculture country wide and aerial control of mosquitoes in Lake Victoria region. DDT and its analogues include pesticides residues like DDE [1, 1 – dichloro – 2, 2 – bis (p-chlorophenyl) ethylene], DDD[1, 1 – dichloro – 2, 2 –bis (heptachloro) – 3,9,4,7,7 – tetrahydro – 4, 7 – methanoindene] and the like, which tend to be stored in fatty tissues and organisms exposed to them have some levels in the body (Hassall, 1982). They are known to accumulate in natural food chains by a process known as bioconcentration on ecosystems, (Edwards, 1970).

Cyclodienes on the other hand, include Aldrin, Dieldrin, Endrin and Methoxychlor, and are known to affect the hepatic histology compared to DDT, and its microsomal drug metabolising enzymes, (Hassall, 1982). Benzene hexa chloro isomers produce acute toxic signs of convulsions in animals.

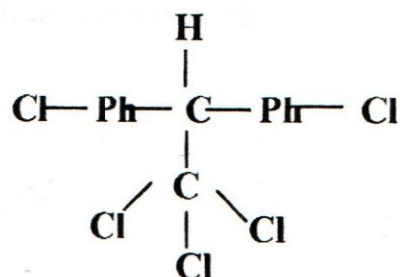
Today several organochlorine pesticides are being used in agriculture and public health (Wandiga, 1995). DDT for example has had much use globally in the eradication of Malaria and other disease vectors, although it was banned in Kenya back in 1986 and there has not been any import for some time now. The following organochlorine compounds have had wide usage in Kenya, DDT, Lindane or gamma-BHC, Dieldrin, Aldrin, Endosulfan, Heptachlor and Endrin; Their technical names and structures are given in Appendices 1(a) and 1(b) below.

Structures and names of commonly used organochlorine pesticides.

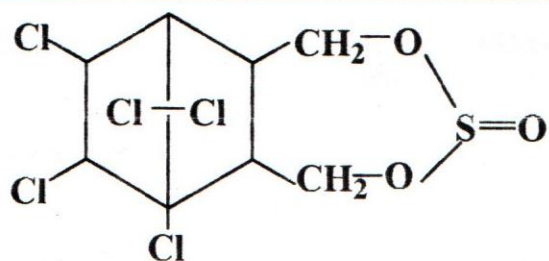
APPENDIX 1(a)



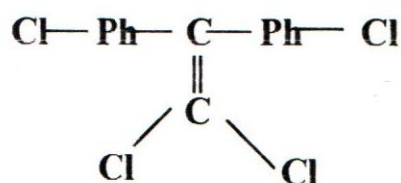
Lindane



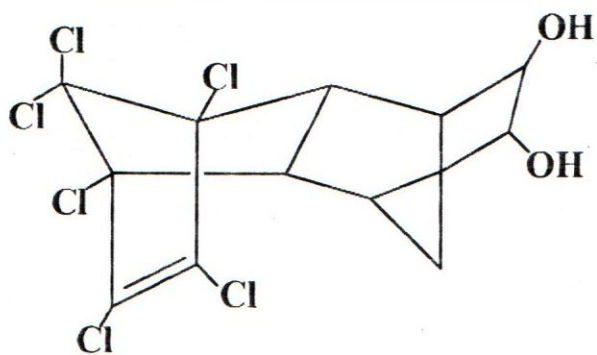
DDT



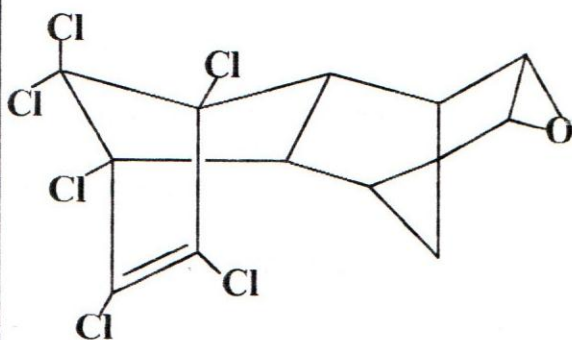
Endosulfan



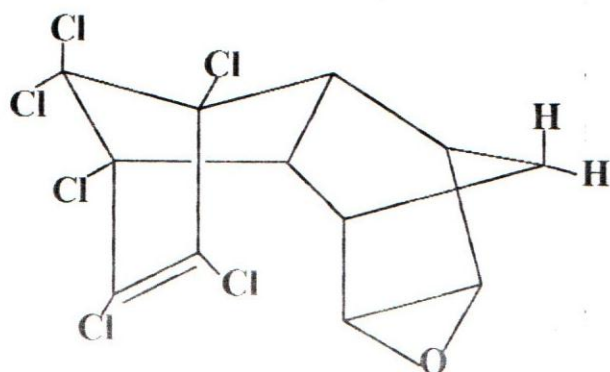
DDE



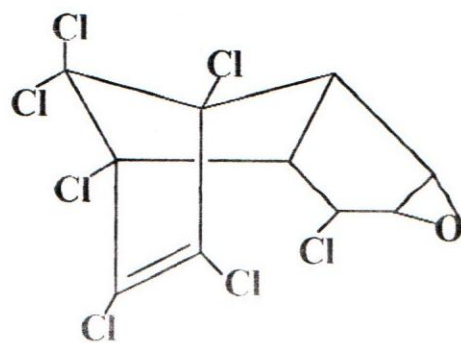
Aldrin



Dieldrin



Endrin



Heptachlor

APPENDIX 1(b)

The following are the organochlorine (OCs) Pesticide residues analysed for during the period April- November, with their technical names.

Ocs	IUPAC NAME
DDT	1,1, 1 - Trichloro - 2, 2 - bis (<i>p</i> - chlorophenyl) ethane.
DDE	1, 1 - dichloro - 2, 2 - bis (<i>p</i> - chlorophenyl) ethylene.
DDD	1, 1 - dichloro - 2, 2 - bis (heptachloro - 3 α , 4, 7, 7 - tetrahydro - 4, 7 - methanoindene.
Hepatachlor	1, 4, 5, 6, 7, 8, - Heptachloro - 3 α , 4, 7, 7 - tetrahydro - 4, 7 - methanoindene.
Lindane	1, 2, 3, 4, 5, 6 – Hexachlorocyclohexane

1.3 Objectives of the study

Studies done in 1975 by Greichus and (Thampy et al, 1995) indicated that the status of Lake Nakuru with respect to pesticides and their residues change with time. However, these two major studies do not show the origin of the pollutants. This study therefore aims at investigating ;

- 1.The current status of the Lake in terms of pesticide pollution and
- 2.The possible sources of the pesticides and whether their concentrations in the lake vary with the season.

1.4 Description of the study area (Lake Nakuru Catchment basin)

Lake Nakuru is a highly alkaline Lake that supports no vascular plants in open water. The lake is typical of many of the Rift Valley lakes in that it is a shallow, alkaline entrophic lake surrounded by agricultural land. (Vareschi, 1978).

The Lake is entirely within the boundaries of Nakuru National Park. However, the catchment area includes rich agricultural land, in which there is pronounced use of pesticides and herbicides. It is situated just south of the town of Nakuru, which discharges its sewage effluent into the Lake after treatment through a one-stage digester (Greichus, 1978). It covers an area of about 44 square kilometres, with an average depth of less than 1 metre. The catchment area of 1938 km² includes several rivers, which empty into the Lake as indicated in appendix 13-. Rivers, Njoro, Makalia, Nderit and Larmudiac. The town has about 400,000 inhabitants.

The lake has an exceptionally high productivity of the fauna and supports a great bird population per unit area and is the main feeding ground for lesser flamingo (*Phoeniconotus Murion Geoffrey*) whose population is relatively high, about 1,000,000 at times (Koemann et al, 1971).

1.5 LITERATURE REVIEW

1.5.0 Introduction

The insecticidal potential of certain organochlorine (chlorinated hydrocarbon) insecticides was discovered during the 1939-45 world war II. DDT and γ -BHC (benzene hexachloride) were first praised as almost perfect insecticides. Since several billions of people have been exposed to DDT, and other insecticides.

Some organo-chlorine compounds are notoriously persistent in the environment and so can be real hazard to wildlife and, many believe, a potential hazard to man. In addition, their use has led to the indiscriminate killing of beneficial as well as harmful insects and increasingly to the development of insect resistance (Carson, 1963).

Studies have been carried out on organochlorine pesticides and these have indicated that their use has led to the natural environment being detrimentally affected. A great mortality rate on fish and birds has been partly attributed to the presence of pesticides in the industrial and agricultural effluence, which are discharged in Lake Nakuru (Vareschi, 1978; Wandiga, 1986).

1.5.1 History of the use of Organochlorine pesticide .

Organochlorine insecticides beginning with DDT [1,1,1-trichloro-2,2-bis (p-chlorophenyl) ethane] were introduced over a period of about 5-10 years after the end of World War II (Edwards 1974).

Although there were no major concerns as to their environmental effects for at least ten years it was soon realised that organochlorines were not only readily toxic to known pest invertebrates but were very persistent in soils and aquatic sediments.

During the 1960s, reports of significant numbers of invertebrates, fish, birds and mammals being found dead, often in large numbers, after extensive field treatments and spraying operations using organochlorines became quite common especially in Europe. (Edwards, 1974).

Some organochlorines especially DDT and dieldrin, were incriminated later in the reproduction failures of many predatory birds, including endangered species, through the effects of egg shell thinning and other mechanisms (Wheathey, 1973). There was increasing evidence of the organochlorines persistence in the environment and of widespread global transport (Wheathey, 1973). Their overall use in developed countries, particularly in United States and Europe was progressively restricted or phased out.

1.5.2 Use of organochlorine Pesticide in Africa

Since organochlorines were out of patent agreement by the 1970s, and also cheap to produce and very effective in pest control, they continued to be produced in developed countries and exported to developing countries where their use expanded rapidly in the 1970s and 1980s, (Edward, 1973). The increased use of organochlorines use in developing countries was higher for DDT, followed by dieldrin, HCH (1,2,3,4,5,6-hexachlorocyclohexane) and then Endosulfan. DDT was particularly used quite extensively for the control of mosquitoes and tsetseflies.

HCH was used all over Africa to control soil and cotton pests and is still in use in some African countries (Edwards 1974). Other Organochlorines like aldrin, endrin and toxaphene were also used to control important agricultural and medical pests. Edwards, (1986), forecasted that the use of organochlorines in Africa would continue through the 1990s, although he predicted a fall in their use based on regional expenditure from a level of \$120 million in 1978 to \$60 million in 1973.

1.5.3 Historical support for the wide distribution of chemicals in the environment

The revitalization of the Germany economy after world war II was the direct result of chemical manufacturing and industrialization (Ihde, 1970). Chemicals were not only produced in the Great lakes region but were also used there, as the widespread use of fertilizers, pesticides and herbicides became standard agricultural and silvicultural practices. (WHO, 1979; WHO, 1984). Great lake sediments became the final risk for many of the residuals (U.S.EPA, 1984). By 1969, it was estimated that approximately 1 million metric tons of DDT had been released globally (PANS, 1969).

A wealth of literature verifies the penetration of the persistent and toxic organochlorines, organochlorine pesticides and industrial chemicals into biological systems in post-world war II in the 1940s and early 1950s, (Holleman and Hammons, 1990). Bioaccumulation of these persistent chemicals by other wild life species occurred in the Great Lakes food web during the same period (Colborn, 1988).

In 1995, analysis of some organochlorine pesticide residues in surficial sediments was done and the following results obtained, (Thampy & Raini, 1994-95).

Whereas in 1975 there was no evidence of organochlorine contaminations of lake Nakuru bottom sediments (Greichus et al, 1975) current data indicates that contamination had occurred in 1995, (Thampy and Raini, 1995). The most prevalent organochlorine pesticide in the lake sediments was gamma-isomer of BHC; which was detected in 9 out of 10 sediment samples; with a mean concentration of 705 ppb; in the range of 3.4-5470 ppb. There were 5470 ppb from river Njoro, 1360 ppb from the sewage release area and 880 ppb at the river Makalia Mouth. The γ -isomer of BHC is considered to be highly

toxic and its appearance in the lake's surficial sediment is an indication of its wide usage in the catchment area of the lake and the high sediment loads carried by feeder rivers into the lake.

The other prevalent organochlorines detected in surficial sediments were dieldrin and DDT and its degradation products. Both compounds are officially banned in Kenya but their presence in the lakes surficial sediments is an indication that they are still in use in the catchment area of the lake. This is why this study was undertaken to try and establish the possible sources of these organochlorine pesticides.

1.6 Structural diversity and properties of organochlorine insecticides.

The organochlorine insecticides are usually divided into three main families comprising respectively compounds related to DDT, γ -BHC and compounds related to aldrin i.e. as shown in Appendix 2. One of the common structural feature of the three families is that they contain one or more chlorinated carbocyclic rings.

The chemical stability of many members of the group (or of their immediate and often toxic metabolites) is high because their molecules are constructed, entirely or largely, from C-C, C-H and C-Cl bonds, all of which tend to be chemically inactive under normal environmental conditions.

Kenaga (1972) list typical concentrations of DDT and its derivatives in various organisms - for example, 3×10^{-4} ppm in plankton, 1×10^{-3} in aqueous invertebrates and 5×10^{-1} ppm in marine fish. Similarly, vegetables contained 2×10^{-2} ppm, meat contained 2×10^{-1} and human adipose tissue contained 6 ppm.

Most organochlorine insecticides are waxy, solids at room temperature. Their vapour pressures are low. Their volatilisation leads to atmospheric contamination, while the volatility of such compound as aldrin and γ -BHC enables them to be used as soil fumigants.

1.6.0 Organochlorine Pesticides and their properties

Uncertainty about the long-term environmental effect of highly persistent insecticides, as well as political pressures arising as response to public concern about contaminated food, have led to voluntary and compulsory control of the use of organochlorine insecticides in most countries. The increasing reluctance of manufacturers to disclose production statistics makes it impossible to assess the present status of organochlorine insecticide production (Hassall, 1982). The use of brand names rather than chemical names and formulae also makes it impossible to assess the amounts of organochlorine pesticides in use.

1.6.1 (I) DDT and its analogues.

The remarkable insecticidal properties of *p,p'*-DDT were recognised in 1939 and the Swiss firm of Geigy patented it for this purpose in 1942. It was used for hygiene purposes and was later to be used in the control of malaria and other diseases carried by insect vectors.

DDT is a white waxy solid, which is quite insoluble in water. It is moderately soluble in organic solvents although its solubility is generally higher in olefinic and aromatic hydrocarbons than in saturated aliphatic hydrocarbon. The primary insecticidal effect of DDT, except at high doses is not upon the motor nerve but upon a distant sensory nerve.

Removal of one chlorine atom from the trichloromethyl group of *p,p'*-DDT and its replacement with a hydrogen atom gives the structure of *p,p'*-DDD as is shown in appendix 3. DDD is a minor insecticide called rhothane compared to DDT and is frequently referred to as TDE (tetrachloro-diphenylethane) in US literature.

In certain circumstances DDD is also a metabolic product of DDT and is next to DDE, the commonest breakdown product of DDT to be found in the adipose-tissue of man (Robinson, 1969). DDD is, in general, inferior to DDT as an insecticide but has proved useful as a mosquito larvicide. It's only about one-fifth as toxic as DDT to higher animals, (Hassall, 1982).

The three major pathways by which DDT is degraded includes dehydrochlorination to DDE, reductive dechlorination to DDD and oxidative leaching to Dicofol. as shown in appendix 3.

DDE is the major DDT-derived residue normally found in the autopsy or biopsy samples of animal tissues (Robinson, 1969). The development of resistance to DDT in some species of house flies and mosquitoes is closely correlated with the greater capacity of its resistance to conversion to the less insecticidal DDE. DDE is particularly effective at inducing microsomal enzymes in mammalian liver. This alters the body's capacity to metabolise many types of foreign compounds, including pollutants. The primary metabolism of methoxychlor is summarized in Appendix 4: (Kapoor et al, 1970)

1.6.2 (II) BENZENE HEXACHLORIDE (hexachlorocyclohexane) γ - BHC.

There is only one important member of this sub-group namely, the gamma (γ) isomer of benzene hexachloride (BHC); structure shown in Appendix 2. The gamma BHC isomer is highly toxic to insects. The purified gamma isomer is called lindane which is one of the organochlorine residues investigated in this study. Lindane contains about 99% of the gamma isomer. It's slightly soluble in water (10 ppm) and very soluble in acetone (43%), [Hassall, 1982]. It has a vapour pressure of about 10^{-5} mmHg at 20°C and is stable to heat and light. The only significant chemical reaction it undergoes is the loss of three molecules of HCl under mildly alkaline conditions, the product being 1,2,4-trichlorobenzene. It's about twice as toxic as DDT to higher animals.

The insecticidal action of lindane is almost similar to that of DDT. It causes hyperexcitation and paralysis at higher dosage. However, insect resistance to lindane is linked to resistance to cyclodienes than to DDT. It is known that γ -BHC, unlike DDT acts primarily on the central nervous system.

1.6.3 (III) THE CHLORINATED CYCLODIENE FAMILY

The structural chemistry of cyclodiene insecticides is complex because the molecule is not planar. Aldrin and dieldrin are stereochemically related and aldrin is rapidly metabolised to dieldrin by an NADPH - dependent enzyme in hepatic microsomes. Dieldrin has been of great importance in locust control and very effective to insects like blowflies and lice.

Technically, chloridane is a mixture of various chlorinated dicyclopentadienes. Chlorinated cyclodiene insecticides are amongst the most toxic and persistent of all pesticides. The use of chlorinated cyclodienes is now subject to control in most countries. In Britain for example, the Cooke Report of 1964 recommended use of DDT, BHC and organophosphorus insecticides instead of chlorinated cyclodiene, (Hassall, 1982).

Chlorinated cyclodienes evoke the same general neurotoxic symptoms as DDT with several differences. Both compounds cause uncoordinated body movements, repetitive discharges upon stimulation, but whereas the toxicity of a given dose of DDT is enhanced by lowering the temperature, most chlorinated cyclodienes show a positive correlation between temperature and level of response. Again chlorinated cyclodienes elicit a fanning movement of the wings of house flies, a characteristic action of γ -BHC not DDT, [Hassall, 1982].

1.7 PESTICIDE USE AND RELATED PROBLEMS

When pesticides are applied to the soil or crops, they have no in-built screening mechanism hence they end up killing all pest together with their predators and parasites. This disturbs the natural ecosystem within an area. Pollinating insects for example are widely affected such that the ecology of an area is disturbed. Other than agricultural effects, pesticides may also have an impact on man. When applied, and even after, wind and/or water may carry them to the surrounding environment. This may end up contaminating both surface water and soils. Since pesticides to a larger extent do not degrade easily i.e persist for long in the

pesticides to a larger extent do not degrade easily i.e. persist for long in the environment, they may have long-term effects to some species. Such pesticides may even migrate to ground water systems and cause contamination to drinking water.

Secondary poisoning by feeding on pesticide residues containing prey may also affect many organisms. Therefore the dose, rate, frequency of usage and local circumstances e.g. condition of soil and water, climate disturbance cycles like floods and droughts, geomorphology ecosystem structure, presence of areas and species of recognised ecological value are factors worthy of consideration when pesticides are to be used in a given area (Wandiga, 1995).

1.8 OCCURRENCE AND MODE OF INTRODUCTION OF PESTICIDES IN THE ENVIRONMENT.

Pesticides occur in detectable amounts throughout the environment in virtually all inhabited areas of the world. Pesticides are introduced into the environment in a variety of ways, including direct application in agriculture, in forest pest control, and for control of pests affecting human health. Comparatively small areas of the world are treated, but transport by wind, water and movement of food and feed in commerce results in universal distribution of minute amounts of these compounds.

• The heavy contamination of areas on which livestock dipping Vats are located is recognised as is the contamination of streams and ponds from careless dumping and cleaning of spray tanks, (Bovard et al, 1961). Pesticides used in homes and gardens may be partially disposed of in the sewer, ultimately reaching streams, lakes and oceans.

Accidental contamination of the environment occurs during and after application of pesticides to crops and forest lands by several routes as can be seen in Appendix 5. These sources of contamination can be minimised but not eliminated. Agricultural by-products and wastes also constitute a major source from which pesticides are introduced into our environment. Bovard et al, (1961) for example, found that some apple pomace, used as beef cattle feed, contained 103 ppm of DDT. Beef animals fed on this pomace for 104 days stored an average of about 70 ppm in their fat.

Industrial wastes from pesticide and other manufacturing processes merit particular attention. These compounds will leach from already existing "dumps" into our waters and soils for hundreds of years.

1.9 FATE AND PERSISTENCE OF ORGANOCHLORINE PESTICIDES IN THE ENVIRONMENT

The persistence and ultimate fate of pesticides in the food, soil, water and air of man's environment is affected by such interrelated factors as volatility, solubility, ultraviolet irradiation, surface adsorption, systematic action, hydrolysis, chemical rearrangement, (Hassall, 1982). However, the fate of pesticides in soils also depends on their chemical characteristics, soil type, moisture, microorganisms, cultural practices among others. Pesticides usually find their way into surface and ground waters as a result of agricultural land drainage or industrial waste discharges. The persistence of a pesticide in ambient air is a function of the toxicant's properties, mode of application, and existing atmospheric conditions.

In varying degrees, pesticides may be contaminating and accumulating in man's food supplies as well as the soil, water and air of his environment. When a pesticide is applied to plants, animals, soils, water or air, there are many factors that may affect chemical changes, and the rates of such alterations will depend on the nature of the compound and the particular environmental conditions to which it is subjected.

Various metabolic and physical factors will influence the fate or rate of degradation of the parent compound. The metabolic factors, as illustrated in Appendix 5, affect the fate of the pesticides and involve either molecular alteration or migration phenomena. Molecular changes may be precipitated by chemical reactions such as oxidation, hydrolysis, reduction and conjugation.

The physical factors affecting fate and persistence of pesticides in our environment are primarily climatic parameters such as sunlight, temperature, humidity, rain, wind and the toxicant's vapour pressure (Ebeling, 1963).

Most organochlorine pesticides have been used widely and have tendency of persisting in the environment for a long time. This long persistence causes them to accumulate in the soil, water, plants and animal tissues and organs. All these bring an effect on animal species and plants causing disequilibrium.

In soil, most organochlorine compounds persist for months or even years. This is especially so when high doses are applied to clay soils or to soils rich in organic matter. Volatility of such compounds as γ -BHC may limit persistence in light soils, but for aldrin the situation may be more complex. There is little evidence that a long-term effect on soil fungi or bacteria takes place when organochlorine compounds are applied at normal concentration. However, there may be temporary disturbance in the equilibrium existing

between the various species of soil micro-arthropods when DDT is applied at one bag per acre (Hassall, 1982).

Indirect problems may also arise from the presence of persistent substances in or on soil. Predators may be threatened indirectly if for example they eat earthworms that have been living in soil contaminated by pesticides, because worms, like many other organisms, often have more pesticides in them than exists in the neighbouring environment. The ratio of the concentration in a named organism to the concentration in its surroundings is known as the biomagnification factor. Table 3 gives biomagnification of DDT and its metabolites (Kenaga, 1972).

In plants, substantial amounts of even sparingly soluble substances may enter the roots over a period of time and may then move up to accumulate in the edible parts of food crops that are rapidly transpiring. γ -BHC is probably taken up more rapidly than most other members of the group, especially at high rates of application, and tainting of root crops has often followed the use of technical BHC, (Lichtenstein and Schulz, 1960).

In water, residues can be quite high, due to factory effluent, animal dips and run-off from agricultural land (Holden, 1966). Of possibly greater long-term concern is the flowing of contaminated rivers into the lakes, oceans of the world and the general wash down from the air in rain water. Drainage water from treated fields is almost free from organochlorine contamination because of the high adsorption on to soil particles.

Work on the possible chronic effects of DDT on animals has been reviewed by several people, (e.g Matsumura, 1975). Exposure of higher animals to appropriate doses of organochlorine insecticides, polychlorinated biphenyl, and other lipid soluble substances can cause the induction of liver enzymes which metabolise potential poisons.

The level of contamination of meat, milk and eggs with organochlorine compounds is of importance to man. In particular, the reliance of the young upon cow's milk places this food in a very special category. Several surveys have been made of organochlorine levels in human milk, and most of them indicate that levels are higher than cow's milk and that placental transfer seems to favour higher amounts (0.07 ppm) in the milk than in the maternal blood, (Matsumura, 1975; Zweig et al, 1961)

The food chain effect poses a great danger due to the consequence of high stability and lipid solubility. Dependancy of organisms on one another in a biological sequence, means that many members of a species of one trophic level may be eaten by one organism of the next higher trophic level. An illustration is produced by Robinson et al. (1967) who sampled marine organisms off the Northumber land coast for their content of dieldrin and of DDT. This is given in table 4.

DDT is not water-soluble but is easily adsorbed to organic matter in water. This organic matter is eaten by fish which through the food chain the pesticides is biomagnified hence causing a great effect by reducing their reproduction. To demonstrate this, is the evidence from Menzie, 1972; Cooke and Bell, 1976 on DDT residues found in bird tissues and eggs correlate with the phenomenon of egg-shell thinning. In man and other higher animals, DDT is accumulated in adipose, blood and tissues. Due to this accumulation, chronic diseases like cancer, portal cirrhosis, carcinoma and hypertension have been correlated to these pesticides. DDT affects human erythrocytes at concentrations as low as 10^{-6} to 10^{-5} M, (O' Brien et al, 1962).

Lindane, unlike DDT, has been found to affect man, by inducing herpatic porphyria. Lindane is reported also to have caused cutanea tarda in a population that ingested grains

treated with the insecticide, [Saxena et al, 1981]. Lindane, like aldrin, DDE and DDT, is believed to act as an antagonist to pregnancy in humans (Saxena et al, 1981).

Although DDT is quite resistant to breakdown, it's degraded slowly into DDE by micro organisms. Since DDE is even more stable than DDT the discrepancy between DDT dispersal and DDT and DDE accumulation in the biosphere became even more puzzling. This gap now seems due the conversion, aided by UV light, DDT and DDE into other chemicals such as PCBs. (Wandiga, 1986). An example is given in Appendix 9.

In some environments, pesticides decompose much more quickly. Decomposition, fortunately does not depend solely on microbial attack, or we might never get rid of some organochlorines. Volatilization into the air, photodecomposition by various wavelengths of solar energy, mechanical removal in crops, the leaching are also involved in reducing levels of persistent organochlorine pesticides but volatilization and microbial are the most important.

1.9.0 Half-lives of some organochlorine pesticides

Data on persistence of DDT, Lindane, DDD, DDE, dieldrin and heptachlor has been reviewed by Edwards, (1966) Cooke and Stringer ((1981) and Dix (1981). DDT lasts 50 years in the soil while lindane is estimated to be 15 years.

Edwards (1966), with the available data up to 1966, calculated the half-life of DDT in temperate soils to be 2.8 years with a range of 2-16 years. Cooke and Stringer (1981) working in apple orchard soil in Canada for eight years calculated a DDT half-life of 11.7

years. Table V gives a summary of these data, including dissipation of DDT, DDE and Lindane under various climatic conditions, in table VI.

1.9.1 TABLES I-VIII

TABLE I: MEAN CONCENTRATIONS FOR ORGANOCHLORINE PESTICIDES

Residues in surficial sediments (L.Nakuru,1995)

Contaminant	Mean Conc (ppb)	No. of samples Detected(n=10)	Range (ppb)
Aldrin	ND	0	
DDD	1.5	3	5.2-9.6
DDE	1.64	2	7.8-8.6
DDT	4.26	5	3.4-17.2
γ-BHC	706.0	9	3.4-5470
Dieldrin	8.6	6	1-29.1
Heptachlor	ND	0	—
Endosulfan	ND	0	—
Chlordane	ND	0	—

TABLE II: Classes of Chlorinated Hydrocarbon insecticides

Class I. Oxygenated compounds

Chlorobenzitate	Methoxychlor
Dicofol	Neotran
Endosulfan	Sulfenane
Gondrine	Tetradifon
Kepone	

Class II. Benzenoid, nonoxygenated compounds

γ -BHC
Chlorobenzene
DDT
Lindane
TDE
Perthane

Class III. Nonoxygenated, nonbenzenoid compounds

Aldrin
Chlordan
Heptachlor
Mirex
Toxaphene
Strobane

TABLE III : Biomagnification of DDT and its metabolites**(Kenaga (1972); (Edwards, 1970)**

Environment	Organism	Maximum observed Biomagnification
Soil	Roots crops	0.1
	slugs	4
Water	Earthworms	73
	algae	33
	crabs	144
	shrimps	2800
	clams	70000
	fish	829300

TABLE IV: Bioaccumulation of dieldrin in sea weeds.

Samples	Tropical level	Dieldrin (ppm)
Sea weeds		
1. Fucus Serratus & Laminaria digitata	1	0.001 ppm
2. Echimus esculents & Mytilus edutis	2	0.027 0.023
Herrings (Clupea Harengus)	3	0.57
Fish eating birds	4	0.5ppm

TABLE V: Pesticides residues in soil and water.

Insecticide	Half-life soil (years)	95% disappearance (years)
Aldrin	0.3	3.0
Heptachlor	0.8	3.5
Chlordane	1.0	4.0
Lindane	1.2	6.6
Endrin	2.2	7.0
Dieldrin	2.5	8.0
DDT	2.8	10.0

REF: Edwards C.A, 1973, pesticides residues in soil and water. Environment Pollution by pesticides. Plenum Press, London

TABLE VI: The dissipation of DDT, DDE and Lindane under various climatic conditions.

Country	Time for 50% Dissappearance (Half-life/days or years)	Metabolites identified
TEMPERATE CLIMATE		
UK, USA,		
- DDT		
- Lindane	2.8 years	DDE, DDD
- Canadian soil - DDT	1.2 year	
	11.7 years	DDE, DDD

TROPICAL CLIMATE

KENYAN SOILS

NARIOBI

- DDT		
- DDE	98 days	
- DDT	145 days	DDE (Unchanged)
	270 days	DDT, D

MOMBASA

- DDT		
- DDT	88 days	
	270 days	DDT, DDE

Ref: (Wandiga, 1995)

TABLE VII: Solubility of pesticides in water (ppb)

Organochlorine pesticides	Concentration (ppm/mgl ⁻¹)
DDT	0.0012
Heptachlor	0.056
Methoxychlor	0.10
Lindane	7.0

TABLE VIII: PESTICIDE EXPOSURE LIMITS

Chemical Name	Exposure Limits	IDLH Level
Heptachlor	5.0×10^{-7} ppb	0.1×10^{-3} ppb
Methoxychlor	1.5×10^{-5} ppb	7.5×10^{-3} ppb
Lindane	5.0×10^{-7} ppb	1.0×10^{-3} ppb
DDT	1.0×10^{-5} ppb	Carcinogenic

REF: Tomlin, C. The Pesticide manual. 10th ed. Crop protection publications. U.K. 1994.

CHAPTER TWO

2.0 Experimental Methods

2.0.0 Survey Analysis

A survey of pesticide chemicals used in the Lake Nakuru catchment basin was carried out in the month of March, 1999. This was done on large-scale farms, small-scale farms and in town firms that deal with such chemicals. From the survey it was found that chemicals are widely used, some of them sold under a concealed trade name that does not reveal the actual ingredients. Below is a sample of the chemicals in use;

From the survey, it was also revealed that the sink for all these chemicals are the rivers and the sewerage all of which ultimately drain into the Lake. Once a chemical has been sprayed or applied, the residues are washed down into rivers which end up into the lake. Improper disposal of empty containers after removal of the chemicals is quite worrying since most of them are taken by farmers for other uses, especially tinned and plastic containers. Others are just thrown away into pits or even left lying around. This increases chances of pollution of the catchment basin.

2.0.1 Experimental Procedures

Work involving pesticide residues is of high sensitivity since concentrations are investigated in ppb levels. To avoid contamination which would otherwise affect results, glassware need a thorough cleanup.

2.0.2 Reagents

Among the reagents used include solvents, pesticides standard solutions and materials free from interferences like polychlorinated biphenyls and phthalate esters during pesticide analysis. These include: -

- a) Hexane
- b) Diethyl ether
- c) Distilled water
- d) Redistilled acetone
- e) Granulated anhydrous sodium sulphate, [Na_2SO_4]
- f) Carrier gas:- white spot nitrogen
- g) Silanized glass wool
- h) Pesticide reference standards (95% pure); DDT, DDD, DDE, Lindane, methoxychlor and hetachlor.
- i) Stock pesticide solutions
- j) Diluted standard solutions [10ppm]
- k) Working standard solution [1ppm].

2.0.3 Apparatus

They include: -

- a) Sample bottles, 1 litre capacity, glass material
- b) Hot water bath
- c) Separating funnels, 500ml capacity
- d) Funnels, 125ml capacity
- e) Graduated cylinders; 1 litre and 100ml capacities
- f) Filter papers, Whatman 1 grade
- g) Chromatographic column (30 meters long, capillary column).

- h) Microsyringes, 5ml capacity
- i) Varian 3400 Gas Chromatograph, equipped with:-
 - i). Glass-lined injection port
 - ii). Electron – capture detector
 - iii). A computer
- j). Shaker
- k). Buchner funnel
- l). Filtering pump

The gas chromatograph was the main instrument used in this analysis. The gas chromatograph, Varian 3400 has several detectors but Electron Capture detector was used because it is very sensitive to electronegative compounds, organochlorine pesticides included. The maximum injector temperature is 420⁰C and for the column is 350⁰C while that of the detectors is 400⁰C.

2.1 CLEANING OF THE GLASSWARE

The glassware used for both sample collection and pesticide residue were thoroughly cleaned. The glassware were washed in soapy tap water and rinsed in tap water, distilled water, acetone and finally rinsed with HPLC grade hexane.

Also before every extraction process, the apparatus were further rinsed with 1% diethylether in hexane.

2.2 INSTRUMENTAL CONDITIONS

2.2.0 Gas Chromatograph/Electron Capture Detector

The following instrumental settings were used after optimization: -

Column temperature	200 ⁰ C
Detector	Electron Capture Detector
Detector temperature	250 ⁰ C
Injector temperature	250 ⁰ C
Auxiliary temperature	250 ⁰ C
Attenuation	8
Sample size	1 μ l
Carrier gas	Nitrogen
Flow rate	5ml/min
Make-up gas flow rate	25ml/min

2.2.1 Oven

The oven temperature used in drying of sediment sample was 50⁰C. Sediment samples were dried for 2 days. The sediments were dried to constant weight. Weights were recorded in 4 hours interval before the constant weight was realized.

2.2.2 Hot water Bath

A temperature of between 40⁰C was used to concentrate the samples extracted to about 7ml. The samples contained in conical flasks were placed in the hot water bath for evaporation.

2.3 PREPARATION OF STANDARD SOLUTIONS

2.3.0 Preparation of 100ppm Stock Pesticide Solution.

To prepare this, 0.005g of each standard pesticide [DDD,DDE,DDT, lindane, methoxychlor and heptachlor] was put in a 50ml volumetric flask. Into this a 15% diethylether in hexane was added to dissolve the pesticide residues, and made up to the mark.

2.3.1 Preparation of 10ppm Standard Solution.

This was prepared by diluting 10ml each of the stock solutions with the 15% diethylether in hexane in 100ml volumetric flasks and making up to the mark.

2.3.2 Preparation of 1ppm Standard Solution.

These 1ppm of each of the pesticide residues was prepared by a further dilution of the 10ppm. This was done by taking 10ml for each of the intermediate standards and diluting to 100ml mark.

2.3.3 Mixed solvent

The mixed solvent was prepared by using diethylethr and hexane. For each 100ml mixed solvent comprised 15ml diethylether and 85ml of hexane.

2.4 COLLECTION OF SAMPLE ANALYTES

2.4.0 Sample collection

Water and Sediment samples were collected from the lake and its feeder rivers; which included rivers Njoro, Makalia, Nderit, Larmudiac and the sewerage entrance. Sediment samples were collected from a depth of about 50cm deep. Since one of the objectives of the study was to investigate whether there is

seasonal fluctuations in the levels of the pesticides, collection of samples was carried out in two seasons; during the rainy and the dry season.

The first batch of the samples was collected during the dry season (May-June) while the second batch was collected during the wet season, around September and November. This range of months was considered for analysis since the rains failed in the early part of the year up to around August. While most of the early part of the year was dry, rains started around September up to early December. The period between September and November was considered to be the rainy season, what is termed as short rains in Nakuru region.

2.4.1 PHASE I: DRY SEASON

2.4.1.0 Water samples

Samples were collected using a Macvuti Sampler by sampling vertically from the bottom to the surface of the water. After the collection, the water was stored in clean sample bottles of 1-litre capacity and stored for extraction, below 4°C in a cool box before transporting them to the laboratory.

During the first sampling phase the Lake and River Njoro were the only ones sampled since the other inlets were not discharging i.e. were dry. These include rivers Makalia, Nderit and Larmudiac. A total of six composite water samples were collected from the lake's 14 sampling points. Equal amounts of 167 mls of water was put in each of the 6 sampling bottles making up a total of 6 composite samples. They were labeled L₁W₁ to L₁W₆. From River Njoro, a total of 6 water samples were collected from 6 different sampling sites. This covered sites from the source (see map) to the mouth. They were labeled N₁W₁ to N₁W₆.

2.4.1.1 Sediment samples

Similar sampling points as those used for collecting the water samples were used for collecting sediment samples. A total of fourteen sediment samples collected from the Lake and were labeled L_1S_1 to $L_{14}S_{14}$. Using the same sites for River Njoro a total of six sediment samples were collected and were labeled N_1S_1 up to N_6S_6 . Sediment samples were collected using an Ekman sampler.

2.4.2. PHASE II: RAINY SEASON

Samples were collected during the rainy season from the Lake, River Njoro, River Makalia and River Nderit. Only one sampling point was considered on River Nderit due to the presence of very little amount of water in a few places along the river.

2.4.2.0 Water Samples

A Macvuti sampler was used to collect water samples. A total of 15 samples were collected from the lake and stored in 1 litre capacity bottles. From River Njoro, a total of 6 water samples were collected from six sampling sites while from River Makalia 4 water samples were collected. One sample was collected from the mouth of River Nderit.

Labeling of these water samples was done as shown below: -

R.Njoro	labeled	$N_2W_1 - N_2W_6$
R.Makalia	labeled	$M_2W_1 - M_2W_4$
R. Nderit	labeled	D_2W_1
L Nakuru	labeled	$L_2W_1 - L_2W_{15}$

2.4.2.1 Sediment samples

Using an Ekman Sampler, sediment samples were also collected from the same sampling points as those from which water samples were collected.

From the lake 15 sediment samples were collected and were labeled as L_2S_1 up to $L_{15}S_{15}$. From river Njoro, 6 sediment samples labeled N_2S_1 to N_6S_6 were collected starting from the source to the mouth; while from River Makalia starting from the source to the mouth a total of 4 sediment samples were collected and labeled as M_2S_1 up to M_4S_4 . From river

Nderit one sediment sample was collected from near the mouth at Soy-sambu and was labeled as D₂S₁.

2.5 TREATMENT OF SAMPLES

2.5.0 Storage of samples

Immediately after each collection of the samples, they were stored under refrigeration at a temperature below 4°C. This was done to avoid any growth of micro-organisms. During sampling cool-boxes filled with ice cubes were used to store samples as soon as they were obtained and during transportation to the laboratory. After extraction samples were also stored at the same conditions to avoid any degradation; while awaiting analysis.

2.5.1 EXTRACTION OF PESTICIDES FROM THE SAMPLES

Both the water and sediment samples were extracted in triplicate using the following procedures.

2.5.1.0 Water Samples

The samples contained in the sample bottles were well mixed by shaking. After 350ml of the sample were measured transferred to a 500ml separating funnel that was rinsed with the mixed solvent into this funnel with the water sample, 60ml of 15% diethylether in hexane was added to the separating funnel. This was then mixed thoroughly by shaking for 5 minutes. The mixture was left to stand for 10 minutes to allow separation of the organic phase and the water phase.

The water phase was drained from the separating funnel into a 500 ml beaker and the organic phase carefully poured into a conical flask (250ml) containing anhydrous Na₂SO₄, (sodium sulphate) as a drying agent. The beaker that contained the drained water sample was rinsed with another 60ml of the mixed solvent, and the solvent used for a second extraction. A similar process was followed by draining the organic phase into the conical flask initially containing the other drained organic phase, and the extraction was repeated for the third time using another 60ml mixed solvent. After the extraction of the water sample three times, the organic phase was drained into a 250 ml volumetric flask. The Na₂SO₄ used for drying was then washed with 3 portions of hexane and

drained well into the volumetric flask. The dried organic phase was then concentrated to about 7mls in a water bath maintained at 45⁰C. The concentrated sample was then diluted to 10ml with hexane and subjected to gas chromatographic analysis.

2.5.1.1 Sediment Samples

To extract pesticides from sediment samples, the sediment sample was dried in an oven for two days at a temperature of 50⁰C. By reweighing the dried sample, complete drying was ensured after obtaining a constant weight. The dried sediment sample was then cooled and crushed using a pestle and mortar to fine powder. From this ground sample, 30gms were weighed and put in 100ml volumetric flasks and 60ml of the mixed solvent added. This was then shaken on a shaker for 3 hours continuously. After shaking the sample was filtered using Whatman number 1 filter paper. The residue was re-extracted two more times.

After filtration, the sample was then concentrated as in the case of the water samples and later diluted with hexane ready for analysis. The sample was then stored at a temperature of less than 4⁰C.

2.6 GAS CHROMATOGRAPHY

Gas chromatographic analysis of water and sediment samples was performed in triplicate. Before analysis of the analyte, a mixture of standards sample was run, this analysis was done by injecting 1 μ l of every sample at a time; i.e. 1 μ l of mixed standard, followed by 1 μ l of the unknown, and this was done throughout the chromatographic analysis.

In the analysis the electron capture detector (ECD) was used, which measures the loss of signal rather than a positively produced electric current. As the nitrogen carrier gas flows

through the detector, ^{63}Ni source ionizes the nitrogen molecules, forming slow electrons, which migrate to the anode under the fixed voltage i.e. cell voltage. When collected, the slow electrons produce a steady current amplified by the electrometer. The current will be reduced if a sample containing electron absorbing molecules is introduced. This loss in current is a measure of the amount of the compound, (McNair et al, 1968).

The ECD used in the analysis had a Minimum Detectable Limit (MDQ) ranging between 1.000ng to 0.001ng, (McNair et al, 1968).

CHAPTER THREE

3.0 RESULTS AND DISCUSSION

The analysis carried out on samples collected from Lake Nakuru and its feeder rivers, River Njoro, River Makaria and River Nderit has revealed that some organochlorine pesticides such as DDT, DDD, DDE, lindane, methoxychlor and heptachlor are still in use even after being banned in Kenya e.g. DDT, Lindane. Aldrin, Endrin and Endosulfan were not analysed due to the unavailability of standards.

It was found that organochlorine pesticide residues like the ones mentioned above are in sediments [like in table 1] and very little in the water samples. This is an indication that the organochlorine pesticides analysed are quite insoluble in water. They tend to be adsorbed on organic matter, mostly found in soils and in sediments. Although some water samples had significant amounts of pesticide residues as tabulated in table 7, most of them did not contain the residues. Those water samples detected to have trace amounts of organochlorine pesticides seem to have had suspended materials which could contain organic matter on which these pesticides residues were adsorbed.

3.1 SURVEY OF THE LAKE NAKURU CATCHMENT BASIN

A survey was carried out on the catchment basin of Lake Nakuru in April, 1999 before sample collection was done. This survey covered large-scale farms, small-scale farms, chemical firms dealing with pesticides and seeds and public health sectors in Nakuru. This was done to try and establish the range of chemicals in use within the Lake's catchment basin. Trade names are used to describe the types of chemicals in use with active ingredients in some cases. Out of this survey the following pesticides were found to be used in significant amounts.

Copper oxychloride, [used together with lindane for seed dressing and also during planting] while Mamba and Avadex are used during planting; Graphosite is used during ploughing.

Rindomil, tilt Bacteria Mc, Ambush used when young plants are infected by pests, Round-up, Sting, Touch down used before planting.

Mistron, Stelldone, Delnar, Stomp, Triflan, Karate, Dynamic, Kethane, (dicofol, a metabolite of DDE) Mitac, Apollo, orthene which are used between April and August on the soil during cultivation. This is during growth of plant.

Among the fungicides used, are meltabox, Nimrod, rubigan, Benlet, Newstar, samprol, scakar, Benled, Rovmal among others used between March and April. During preparation of the soils/farms.

Others are Arto combi, Punch c, Azocord, Ariane used between March and August. Others are Talstar, Maytril, Metasytox, impact, swing, silvacor, Bevelon. In seed dressing, lindane, Raxit, Copper oxychloride, Vitavax, Bucril M.c are used, while some of the herbicides used include Arien, Supper, Puma, Pasagran, Laso atrazine, zencor, Laddok; which are used between May and August at 3-4 leaves on the crops.

On livestock among others, we have almateix, ortriatix, Nilzan, Valbazen, Noromectin, Ivonienc, Noromectic which are used on a weekly basis.

In flower farms, chemicals like Temik, Dynamic, Trigard, Fluorescent Chrasal AVB and LUB are used. Others include Dimethoate, Nissorun 10EC, Plyram DF and methyl bromide. Others are pentac, Mitac, Agral 90, Fotiard, antracl, Rufast 150 EC among others.

Survey of some firms was inadequate since information was not fully provided, therefore not all chemicals in use were documented e.g. in Rodent and Storage

Pest Control where Phostoxin, Detia degesch, methobromide were given with others like termidor 25EC.

Another like Actellic Super, is used in companies. Others in this group include Ambush CY, Aldrex 48 EC, Feritrothion 50% EC, Murtano, Vitaflo, Vitavax 200 FF.

From this survey it can be seen that a large number of chemicals are in use within this catchment basin.

Also learnt from this survey is the mode of disposal of empty containers, where most are thrown away while a few are burnt. Therefore it can be realized that disposal of containers could cause an increase in the extent of pollution because rainwater can wash these chemicals out into the environment causing contamination.

Also worthy noting is the mode of application. Basically, farmers use manual spraying, Drip lines, Nap-sack sprayers used on small-scale farms, use of ground and tractor mounted boom sprayers. Aerial spraying, use of Dips e.g. in livestock, use of central system for spraying of animals. From these modes of application, it can be seen that chemicals may move kilometers away from points of application, hence finding their presence in places far away e.g. in the Lake.

3.2 QUANTITATIVE ANALYSIS

The following are the results obtained from the analysis carried out during the period between April and December 1999.

3.2.0 Results: Determination of Pesticide Concentration. (Calculation)

Determination of pesticide concentrations were done using the area [counts] of both the samples and their standards.

Determination of pesticide concentrations was done using the method found in standard methods (Arnold, 1980) where the area counts for both sample analysed and the standard were used. The pesticide concentration was done by direct comparison to a single standard where the injection volume and response were within 10% of those of the sample pesticide of interest.

To calculate the concentration of pesticide [in ppb] found in water samples in ppb, the following equation was used;

$$\text{ng/ml (ppb)} = \frac{A \times B \times C \times D}{E \times F \times G}$$

Where:

- A = ng standard pesticide
- B = Area count of sample
- C = Extract volume, μl
- D = Dilution factor
- E = Area count of standard
- F = Volume of extract injected, μl and
- G = Volume of sample extracted, ml

Calculation of the concentration of pesticides in sediments in ppb(ng/g);

Was calculated as below.

$$\text{ng/g(ppb)} = \frac{A \times B \times C \times D}{E \times F \times G}$$

- A = ng standard pesticide
- B = area count of sample
- C = Extract volume, μl
- D = dilution factor
- E = area count of standard
- F = Volume of extract injected, μl , and
- G = mass of sample extracted, gms.

After this was done, the mean concentration of each triplicates was determined. This was achieved as follows:-

$$X(\text{ppb}) = \frac{\sum x_i}{3}$$

Where X_i = Concentrations of the triplicate samples extracted per each sample collected (ppb)

X = Mean per each sample collected and analysed (ppb)

After obtaining X (ppb) per each sample, which contained the pesticide residue, this represented the concentration of pesticide residue in the sample contained. Further, considering each pesticide residue, a mean of each of them was determined as they appeared at different sampling sites. This is shown in the tables below (Results);

3.2.1 Determination the mean concentration of the pesticide residues, ppb.

Each sample collected was analyzed in triplicate. This gave a triplicate of results per every pesticide residue detected in a sample. From these three readings, an average value of concentration was determined, giving the concentration of each pesticide residue per a given sampling point. The maximum concentration given in the tables is the highest average concentration calculated per pesticide residue, for a given inlet/lake. To determine the mean concentration of each pesticide residue, the sum of all the concentrations for each pesticide residue (water or sediment) per an inlet or lake, was divided by the total number of samples collected [n] from the source(river, lake or sewage release area).

3.3 TABLES OF RESULTS.

NOTE: The concentration of pesticide residues in all the tables here under had an error of between 4% and 7% Relative Standard Deviation.

Table 1: Mean concentrations of organochlorine pesticide residues in sediments from Lake Nakuru, April 1999.

Pesticide residue	Mean Conc. (ppb)	No. of Samples Detected n=14	Maximum Concentration (ppb)
DDD	121.8	1	1705.6
DDE	246.0	2	3444.4
DDT	ND	0	-
γ -BHC	947.5	6	5132.0
Heptachlor	156.7	1	2194.4
Methoxychlor	ND	0	-

No organochlorine pesticide residue was detected in lake Nakuru and river Njoro water samples during the dry season; April, 1999.

Table 2: Mean concentrations of organochlorine pesticide residues in sediment from river Njoro, April 1999.

Pesticide residue	Mean Conc. (ppb)	No. Of Samples Detected n=7	Maximum Concentration(ppb)
DDD	ND	0	-
DDE	103.2	1	722.2
DDT	ND	0	-
γ -BHC	333.3	1	2333.3
Heptachlor	396.8	2	2777.8
Methoxychlor	34.8	1	24

Table 3: Mean concentration of organochlorine residues in water from Lake Nakuru, September 1999.

Pesticide residue	Mean Conc. (ppb)	No. Of Samples Detected n=15	Maximum concentration (ppb)
DDD	6.8	2	80.3
DDE	ND	ND	-
DDT	36.9	2	427.1
γ -BHC	5.7	2	54.8
Heptachlor	ND	0	-
Methoxychlor	13.2	1	198.6

Table 4: Mean concentration of organochlorine residues in Sediments from Lake Nakuru, September 1999.

Pesticide residue	Mean Conc. (ppb)	No. Of Samples Detected n=15	Maximum concentration (ppb)
DDD	ND	0	-
DDE	42.6	1	638.9
DDT	835.3	3	7933.3
γ -BHC	235.2	2	3327.8
Heptachlor	ND	-	-
Methoxychlor	ND	-	-

Table 5: Mean concentrations of organochlorine pesticide residues in sediments from river Makalia in September 1999.

Pesticide residue	Mean Conc. (ppb)	No. Of Samples	Maximum concentration (ppb)
		Detected n=4	
DDD	1175.0	1	4700.0
DDE	627.8	1	2511.1
DDT	ND	0	-
γ -BHC	ND	0	-
Heptachlor	ND	0	-
Methoxychlor	369.4	1	1477.8

No organochlorine pesticides were detected in river Makalia's water samples.

Table 6: Mean concentrations of organochlorine residues in water from R. Njoro.

Pesticide residue	Mean Conc. (ppb)	No. Of Samples	Maximum concentration (ppb)
		Detected n=7	
DDD	ND	0	-
DDE	ND	0	-
DDT	13.6	1	95.4
γ -BHC	ND	0	-
Heptachlor	ND	0	-
Methoxychlor	633.4	1	4433.5

Table 7: Mean concentration of organochlorine pesticide residues in sediments from river Njoro.

Pesticide residue	Mean Conc. (ppb)	No. Of Samples Detected n=7	Maximum concentration (ppb)
DDD	246.9	1	1728.0
DDE	313.2	3	1346.7
DDT	531.9	1	3723.7
γ -BHC	1.3	1	9.0
Heptachlor	ND	0	-
Methoxychlor	ND	0	-

No organochlorine pesticide residues were detected in water samples collected from river Nderit.

Table 8: Mean concentration of organochlorine pesticide residues in sediments from river N derit.

Pesticide residue	Mean Conc. (ppb)	No. Of Samples Detected n=2	Maximum concentration (ppb)
DDD	ND	0	-
DDE	3127.8	1	6255.6
DDT	ND	0	-
γ -BHC	ND	0	-
Heptachlor	ND	0	-
Methoxychlor	ND	0	-

3.3.0 DATA CORRELATION

Correlation coefficient was used to determine the significance of the results obtained. The following results were obtained:

	R^2
Dry season: Lake/ R. Njoro sediment samples.....	0.9987
Wet season: Lake/R. Njoro sediment samples.....	0.6992
Lake/ R.Njoro water samples.....	-0.1183
Lake/R. Makalia sediments.....	0.4790
Lake/R.Nderit sediments.....	-0.2114

Where R^2 is the correlaton coefficient.

The above values show that the above rivers are significant as sources, since their correlation coefficient lie between -1 and 1 . Therefore, the rivers are the possible sources of the organochlorine pesticides. R. Njoro shows a higher correlation (0.9987 dry season and 0.6992 wet season) than R. Makalia and R. Nderit. Thus river Njoro can be considered as the major source of lake Nakuru pollution.

Recovery studies were not carried out.

3.3.1 LAKE WATER SAMPLES: DRY SEASON (April,1999)

Samples collected during this period showed no presence of organochlorine pesticide residues in the water samples collected from the lake. This indicates that during the dry season the lake's water is polluted to a lesser extent by the organochlorine pesticides. There is no water or runoffs to translocate pesticide residues in the soil from the point sources to the lake, despite the use of the pesticides even at this time of the year. Since some organochlorine compounds degrade at high temperatures (180°C), some seem to have degraded during the dry season hence their absence in the water samples.

3.3.2 LAKE WATER SAMPLES: WET SEASON (Sept, 1999)

Unlike the dry season, samples collected during this period contained significant amounts of the Organochlorine pesticide residues under study. From table 3, it is evident that DDT has the highest concentration with a mean concentration of 36.9 ppb within a

range of 0-427.1 ppb. That is two samples out of six were detected to have DDT. Heptachlor and DDE were not detected in the lake water samples while DDD and Lindane had mean concentrations of less than 10 ppb. Heptachlor is known to degrade faster in moist soils and in water; with a half-life of 9-10 months in soils (Wandiga, 1995).

There is evidence that during the wet season the Lake is much more polluted with organochlorine pesticide residues than during the dry season. This can be correlated to activities around the lake's catchment basin, of Makalia, Nderit, Njoro where most farming activities are carried out during the wet season e.g. wheat farming, barley farming, floriculture. Livestock farming is also carried out in the catchment area with prevalence of dipping and spraying of livestock e.g. near Kilo along River Makalia, River Njoro, and spraying of livestock. Other crops planted in small-scale farming include maize, beans, Irish potatoes, fruits like oranges and citrus; which make use of pesticides.

During wet season the rain water act as a media for transportation in drainages or leaching. Thus, the pesticides are transported kilometers away from their sources to the lake.

3.3.3 LAKE SEDIMENT SAMPLES: DRY SEASON, (April,1999).

Analysis carried out on Lake sediment samples collected during this period indicate the presence of pesticide residue in a few sediment samples i.e. Table I shows that DDD and DDE, degradation products of DDT were detected with mean concentrations of 121.8 ppb and 246.0 ppb respectively. Heptachlor and Lindane were also detected with mean concentrations of 156.7 ppb and 947.5 ppb respectively. DDT and methoxychlor were absent in the sediment samples

It is Important to note that most of the water samples collected during the dry season were clearer as compared to those collected during the wet season, thus carrying more suspended matter.

3.3.4 LAKE SEDIMENT SAMPLES: WET SEASON (Sept, 1999)

From Table 4, DDE, DDT and Lindane were detected with mean concentrations of 42.6ppb, 835.3ppb, and 235.2ppb respectively, while DDD, methoxychlor and heptachlor being absent. Looking at the mean concentrations, DDD levels seems to have gone down, comparing with DDD concentration detected in dry season (April, 1999). While DDD is absent in September's samples, DDT which was absent in April 1999, has been detected to be 835.3 ppb. There is an indication that fresh DDT could have been added into the lake during the wet season through rain water runoffs. Also seen to be present is lindane with a mean concentration of 235.2ppb. This can be related to the activities found in the catchment area e.g. livestock keeping which uses lindane among other pesticides. Also maize seeds which are preserved by lindane, are in use in the wet season. As the rains start, the water run-off tends to sweep this chemicals from the fields of application. Also the sewage release into the lake could be one other sources as all seed firms in Nakuru town release their waste water into the Lake. It is indicated that sewerage release to the lake could be one source of enhanced lindane concentrations in the lake as evident from the results of table 10.

Also worthy noting, is the domestic pest control e.g. cockroaches, malaria parasites, rodents. From the survey carried out before the on-set of the sampling, it was revealed that pesticides of the organochlorine group are in use; and the containers are usually thrown all over after use, that is there is no specific disposal area for most domestic used pesticide containers. This is another source of the organochlorine

pesticides found in the Lake. The fumigation processes in Go-downs or warehouses in the town and the industries within the catchment area is a possible source of pesticides in the lake transported through runoffs of rain water and leaching.

3.3.5 RIVER MAKALIA WATER AND SEDIMENT SAMPLES: DRY SEASON. (April, 1999)

The river was not sampled in April since it was almost dry. Some parts were only having dry sediments with no water flowing.

3.3.6 RIVER MAKALIA SEDIMENT SAMPLES: WET SEASON. (Sept, 1999)

From the analysis carried out on R. Makalia samples, it is observed from Table 5 that DDD had the highest mean concentration of 1175.0 ppb. DDD could be under use as a mosquito larvicide (Hassall, 1982). Methoxychlor which was detected with a concentration of 369.4 ppb could also be used to combat mosquito larvae, houseflies and in dairy barns especially for veterinary services. It is clear from the survey that livestock keeping is one of the major activities in the lake's catchment area. Though methoxychlor is present in this river at higher concentration (table 5), it was detected in the lake at lower concentration in water samples (13.2 ppb) as shown in (table 3), while in sediment samples, it was not detected at all (table 4). This is so because methoxychlor is highly degradable, so it seems to have degraded. DDE which is a degradation product of DDT has a mean concentration of 627. ppb, which is basically a degradation product of DDT. It is shown to be absent in the lake. Hence we can conclude that river Makalia is one of the sources of DDD, and that Methoxychlor does not reach the lake possibly due to the metabolism of DDE to dicofol. Hence the absence of it in the lake.

3.3.7 RIVER MAKALIA WATER SAMPLES: WET SEASON.

(September, 1999)

No organochlorine pesticide was detected in R. Makalia's water samples. As seen before, most of these pesticides are not soluble in water. Depending on how much organic matter is suspended in water, the amount of these pesticides is related to it, since they are insoluble in water but are mostly adsorbed onto organic matter, hence being suspended in water.

3.3.8 RIVER NDERIT WATER AND SEDIMENT SAMPLES: WET SEASON.(SEPT,1999).

Sampling from river Nderit was done during the wet season. There was no water flowing in the river in April 1999. There was no organochlorine pesticide residue present in river Nderit water samples. From Table 8, it can be seen that only one organochlorine pesticide residue was detected in river Nderit i.e. DDE, which had a mean concentration of 6255.6ppb. DDE is also present in the lake sediment samples (table 4) hence Nderit river could be a possible source of the DDE pesticide residues found in the Lake, since DDT was detected at the mouth and along the river.

3.4 Current status of the lake

From the foregoing discussion it is evident that the status of the lake is not better than 1995 as can be seen from Table 1. The lake is quite polluted by organochlorine pesticide residues much more than in 1995 and 1975. The highest levels of organochlorine pesticide residues detected in the lake are as tabulated below: -

Table 9 - Summary Table (1999)

Organochlorine Pesticide Residue	Highest Mean Concentration (ppb) detected (sediments)	
	1999	1995
DDD	1175.0	1.5
DDE	3127.8	1.64
DDT	835.3	4.26
Heptachlor	396.8	ND
Lindane	333.3	706.0

This is a combined review of pesticides detected within the two phases/seasons of the year. This indicates that DDT and its metabolites; DDD and DDE, are the greatest pollutant of the lake followed by heptachlor, while Lindane is the least pollutant of the lake. This can be compared with results obtained by Thampy (1995) from Table 1.

Also worthy noting about the status of the lake is the fact that the most polluted part of the lake is the sediment, (tables 1 and 4). Most pollutant of the lake i.e. organochlorine pesticides were detected in the sediments. To be noted also are the most polluted parts of the lake. The sections of the lake (sites) that have been found to be highly polluted include the following: -

Table 10

Lake Site	(UTM)	Type of OCs pollutant	Concentration (ppb)
Presidential pavillion shore	9962525	DDE	246.0
Kambi ya Nyuki/Mouth of Njoro	9963744	DDE	2.2
Drums Lakeshore Sarova	992729		2.8
Mouth of R. Njoro/Kambi ya Nyuki	9963744	Lindane	947.5
Sewarage release/ Area	9965404	DDD	21.6
		DDT	126.3
		DDE	18.3
Mouth of Nderit(South shore below Euphobia forest)	9957626	Lindane	54.8
		DDT	4427.8
Sarova drums	992729	DDD	80.3
NKR/3		DDT	142.8
Kambi ya Nyuki	9965008	DDT	54.0

This is a summary of the polluted areas, which covers both the two seasons, wet and dry. The same can be considered for the three rivers sampled, showing pollutants present.

Table 11

River	OCs Pollutants	Concentration (ppb)
R. Njoro	DDT	1950.6
	DDE	1346.7
	DDD	1728.0
	Lindane	2333.3
	Heptachlor	2777.8
	Methoxychlor	4433.5
R. Makalia	DDD	4700.0
	DDE	2511.1
	Methoxychlor	1477.8
R. Nderit	DDD	ND
	DDE	6255.6

From these two tables; 9 and 10, it can be seen that mostly DDE, DDD, DDT, Lindane and methoxychlor are the major pollutant pesticide residues in the lakes. Comparing these results with those obtained in 1995 (Thamby et al, 1995), where Lindane (706.0 ppb mean concentration) was detected, in 1999, the level or mean concentration of Lindane has increased to 947.5 ppb, which is used along with copper oxychloride for seed dressing. Therefore, its presence in the lake's sediments reveals the continued use of Lindane in the Lakes environs.

Considering the half-life of Lindane (1.2 years), it implies that fresh Lindane is possibly being added into the environment. Similarly DDT with a half-life of about 5 months in the tropics (Wandiga, 1995), is still in use as it has been detected in the lake samples analyzed. Wandiga 1995 and Thamby et 1995 obtained the samples at the same points from where analysis was carried out in 1999.

CHAPTER FOUR

4.0 CONCLUSION AND RECOMMENDATIONS

Considering the table 10 and 11, it is possible to determine the likely sources of the organochlorine pesticides found in lake Nakuru. Samples from the three rivers show that DDD and DDE are found to be prevalent with Lindane and heptachlor detected particularly in river Njoro. These rivers which discharge their water into the lake, seem to be the major entry points of the pesticides to lake Nakuru. From the town sewerage, it can be noticed from table 10 that it discharges DDD and DDE into the lake, which are degradation products of DDT.

This therefore reveals that the town sewerage contains DDT, which seems to degrade to give DDD and DDE. DDT is used to kill mosquito larva in the municipality of Nakuru, whenever there is an outbreak. From the description of the study area, it is revealed that the catchment area is heavily agricultural. Farming around the lake involves growing of maize, wheat, barley and horticultural crops as another activity. The catchment area is also known for its livestock keeping. The area has many herds of cattle, which are dipped weekly, or fortnightly with pesticides. River Njoro for instance is bordered with flower farms, wheat and barley, livestock keeping and the vegetable canning factory near Egerton. All these involve the use of pesticides, which are then washed away by rain into the river.

As indicated in the survey seed dressing is done using Lindane and copper oxycyhalothrin, and since intensive farming is done around river Njoro, the seeds are dressed with Lindane especially barley, maize and wheat seeds which is also a crop cultivated around river Njoro. Once planted, containers are disposed off while the chemicals are washed out, finding their way into the river and eventually into the lake.

Considering river Njoro, analysis of sediment samples indicate the enrichment of sediments with organochlorine pesticide residues at the mouth of the river. For example,

samples collected from sites along R. Njoro i.e the mouth (Lindane 9.0 ppb, DDE 183.8 ppb), Technology gauge (DDE 661.9 ppb), Mogoon (DDE 1346.7 ppb, DDD 1728.0ppb), [tables 7] indicate enrichment of the sediment samples with the pesticides; especially with Lindane, DDT and its analogues; DDD and DDE. Relating this sampling sites to the activities around them it is worthy noting that crop and livestock farming are sources of most of these pesticides. For instance from the survey carried out on the catchment basin, it was revealed that in livestock farming there is use of lindane. Thus farming activities form a major source of pollutants in river Njoro and hence, the lake. Looking at a map representing the lake and its catchment area, it can be seen that river Njoro is surrounded by farming as the major activity, meaning that chemicals are in use in this area.

Farming and ranching activities also surround river Nderit. Thus farming which is done on both small and large-scale poses as a major source of organochlorine pollutants, which find use in the prevention of pests both in farms and on livestock. River Nderit is shown to discharge DDE as the only pollutant of which is a degradation product of DDT. Since DDT has a shorter half-life of between 3 - 9 months (Wandiga, 1986), it seems DDE is formed after DDT's degradation. River Nderit is therefore also a portal entry of DDT and DDE into the lake. River Makalia discharges DDD, DDE and Methoxyclor with DDD having the highest concentration, (1175.0ppb).

Considering the results obtained from this study area, it is worthy noting that the lake is polluted by organochlorine pesticides which find their way there through the rivers Njoro, Makalia and Nderit, and the town sewerage. Comparing the levels of the pesticides obtained from the study with their corresponding exposure limits, (Table VIII), the levels are high enough to affect the fauna found in the lake. Further studies on these pollutants is important since the lake's fauna are at a risk of contamination and even death due the pesticides effect. Although the exposure limits are based on human beings, the rivers feeding the lake which have been shown to be polluted pose a great danger to human and the livestock and further to the fauna, as they utilize the rivers water.

4.1 Recommendations

The following recommendations could assist to reduce contamination of the Lake by the organochlorine pesticides analysed in this research. Since some of the organochlorine pesticides seem to have longer half-lives i.e. high persistence, alternative pesticides need to be used to reduce the rate of pollution. Thus less toxic pesticides should be developed and used instead of DDT, which even at very low levels is a carcinogenic pesticide.

Another recommendation is on digesters. More stage digesters could be located along the Njoro town sewerage system. They should also be well treated before discharging the waste to the lake. This would reduce the lake's contamination.

The firms and industries around Lake Nakuru should also treat their wastes before discharging them to the sewerage system especially firms dealing with seed dressing e.g. of maize, which deal with domestic pest control. This can be achieved through enforcement of the Environmental Act, the Factories Act, and the Water Pollution Act.

Considering domestic sources of contaminants, proper disposal measures of used containers and their treatment should be exercised. Firms dealing with domestic pest control should ensure that their containers are properly cleared and proper disposal measures followed; Pesticide residues in these containers may be hazardous to human beings, livestock and wildlife.

Storage of pesticides should be carefully done to avoid spillage or misuse which can otherwise cause contamination and pollution to the environs.

Contamination from ranches or livestock can be reduced i.e. lindane contamination; can be reduced by spraying the animals in designated areas where proper treatment of the waste can be carried out before discharging the waste to the lake or the rivers.

Awareness of pesticide regulations should be ensured since there are still deficiencies, loopholes and gaps of many of the pesticide registration systems especially in Africa. Efforts should therefore be made to ensure that laws governing the control, supply and use of pesticides are reviewed. This may assist in reducing hazards to non-target species.

Sources of information on pesticide use should be augmented and maintained by means of research in order to allow use of pesticides to be selected correctly. Such information can easily be made available to farmers in rural areas through extension officers, non-governmental organizations representatives of chemical companies and public media.

A system for the disposal of obsolete expired chemicals should exist in Kenya.

Proper classification, labeling and instructions on pesticide use should be well documented.

Pesticide information centre with a data bank on pesticide use, storage and disposal should be set up.

A further survey on other inlets to the lake could be of great importance to try and establish more of the sources of contaminants to the lake. Studies of chemicals in use within the catchment could be carried out, especially to try and find out the chemicals sold to the farmers around the lake i.e from the shops/shelves.

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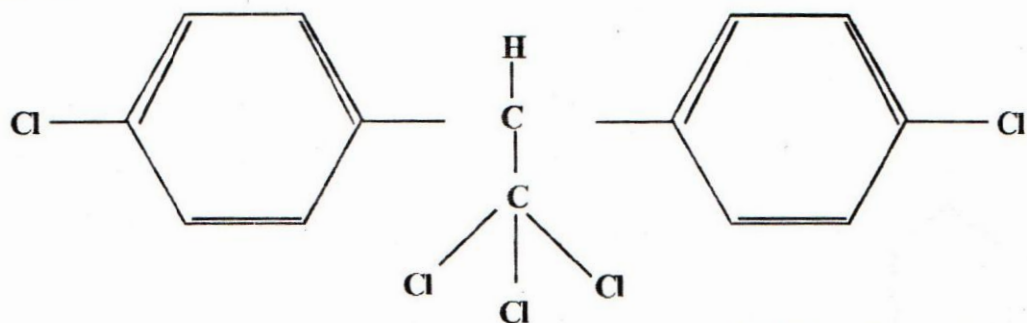
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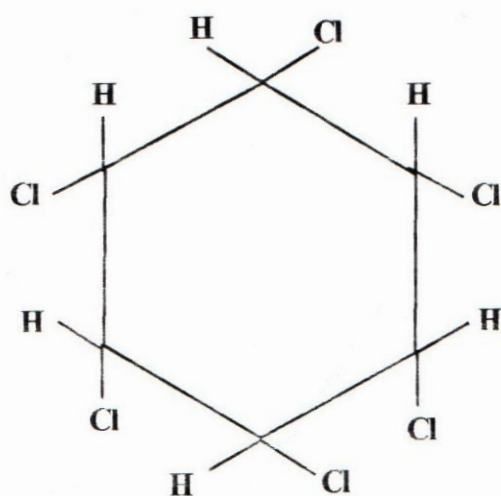
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Appendix 2

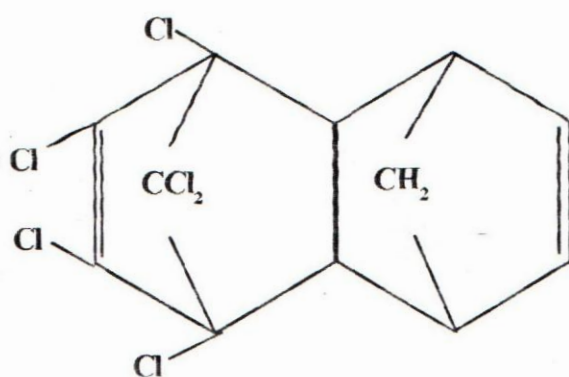
The Organochlorine Pesticide families



DDT family eg DDT.

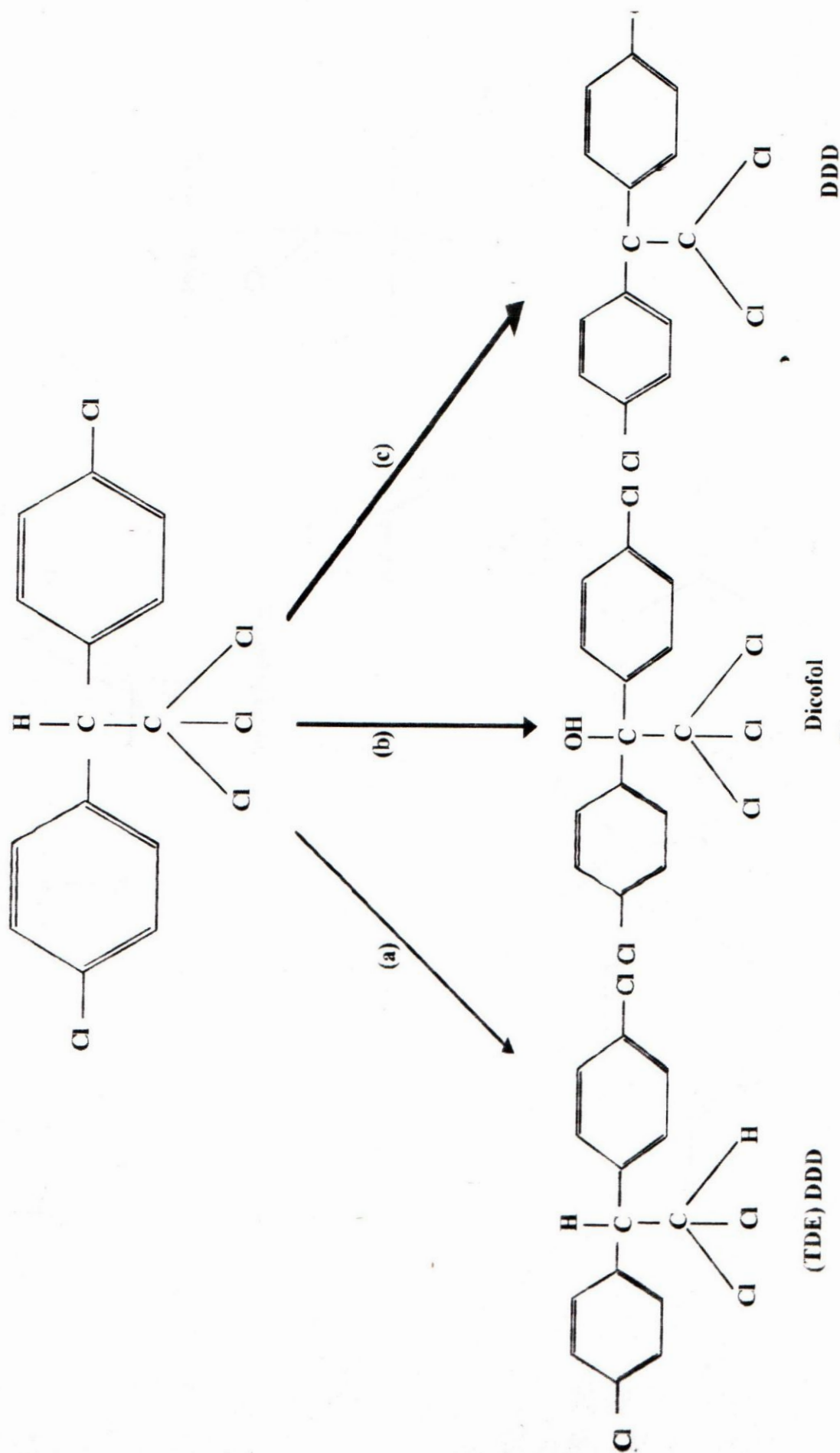


BHC family (Only γ -BHC)

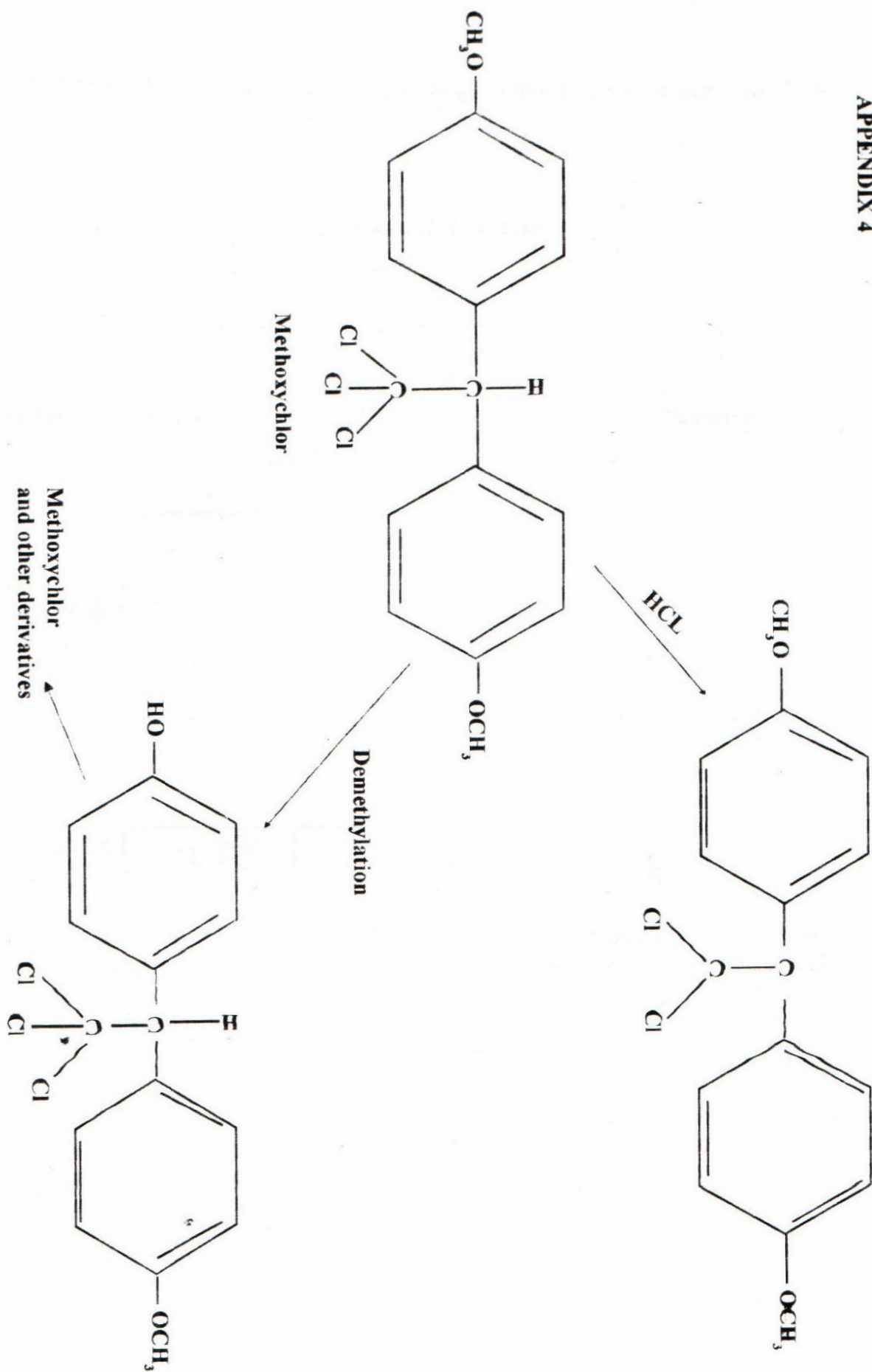


Chlorinated Cyclodiene family eg aldrin

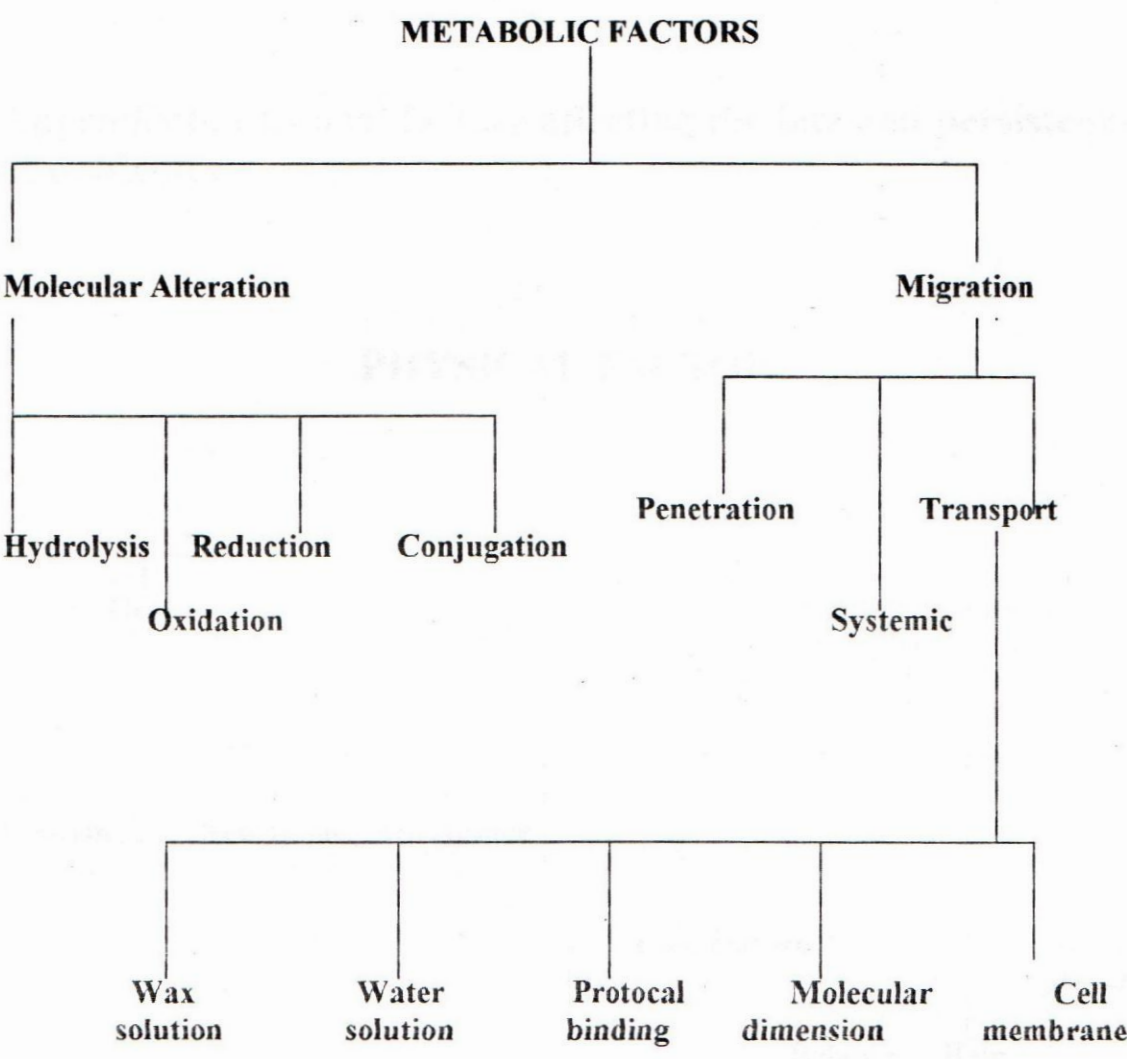
APPENDIX 3
Metabolism of DDT.



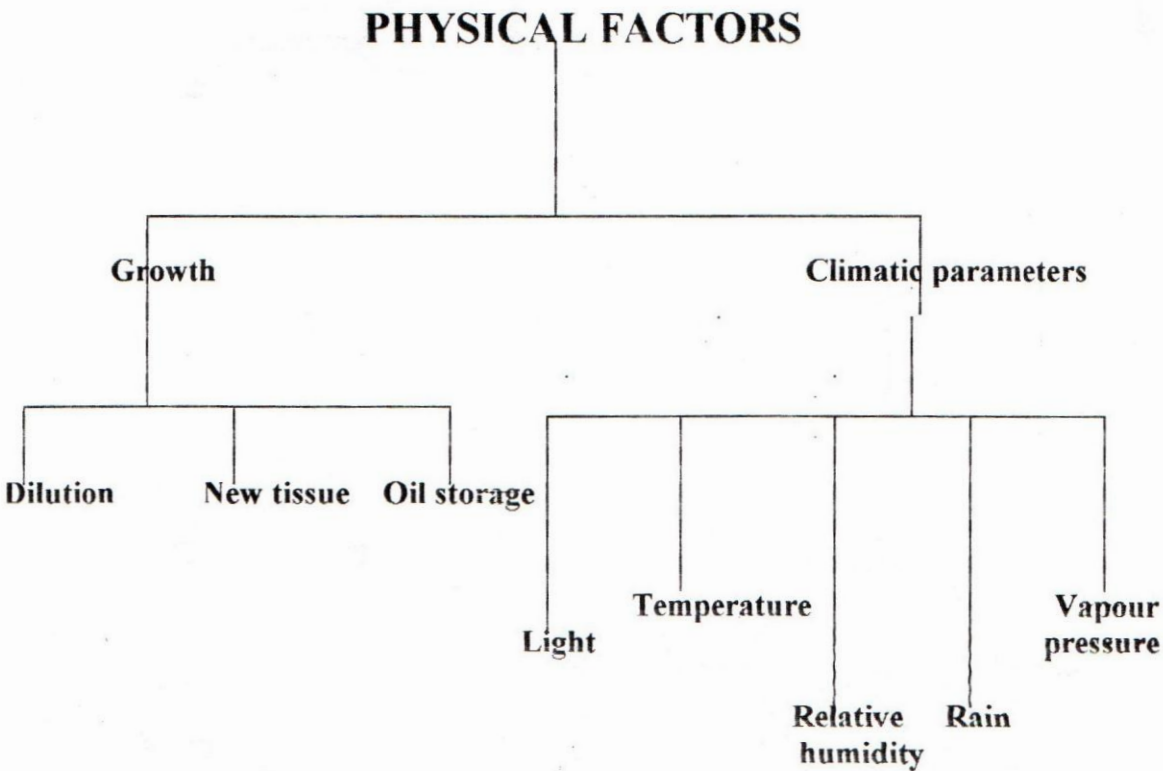
APPENDIX 4



APPENDIX 5: Metabolic factors affecting the fate and persistence of pesticides

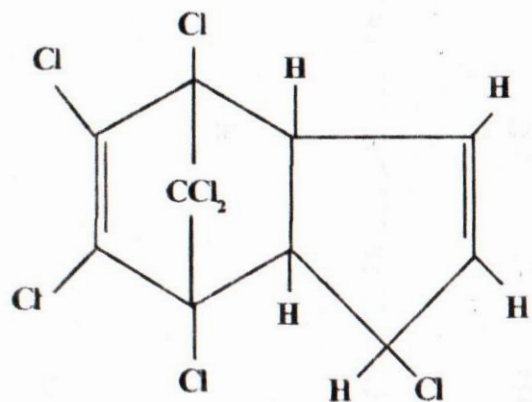


Appendix 6: Physical factors affecting the fate and persistence of pesticides.

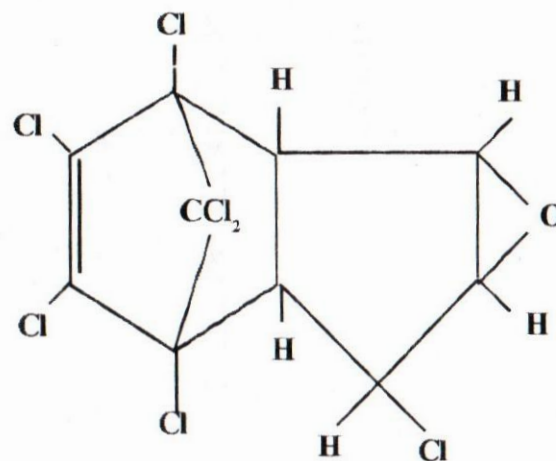


APPENDIX 7

Epoxidation of aldrin in plants, soils and animals.

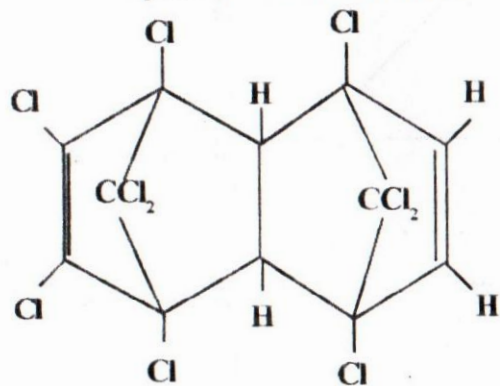


Heptachlor

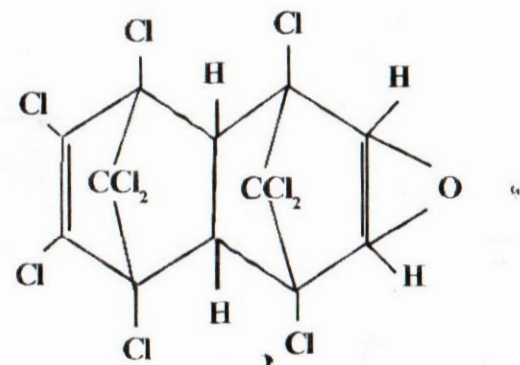


Heptachlor Epoxide

Epoxidation of aldrin in plants, soils and animals.

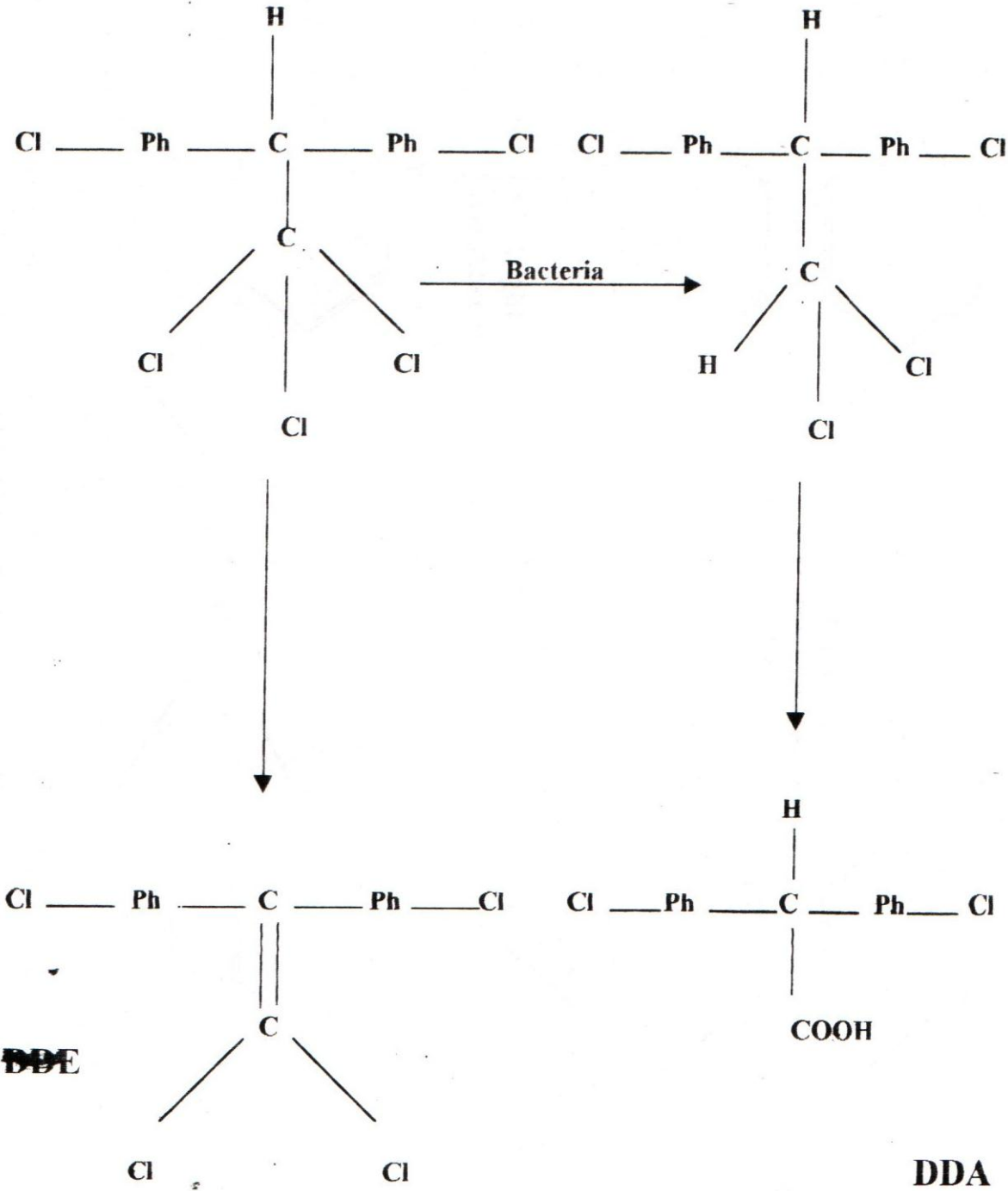


Aldrin

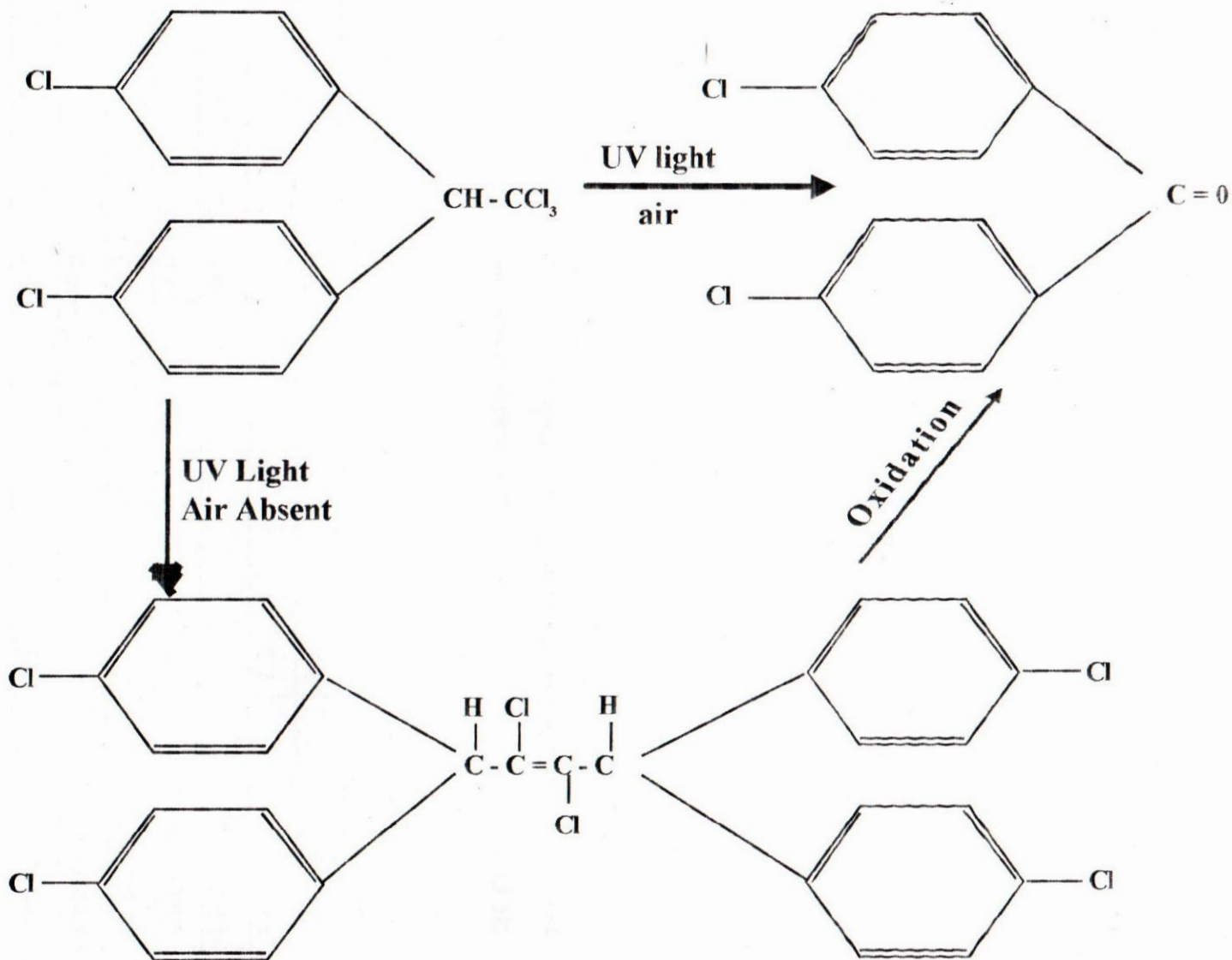


Dieldrin

APPENDIX 8: Metabolism of DDT in the soil



APPENDIX 9



Effect of ultraviolet light on air on DDT decomposition

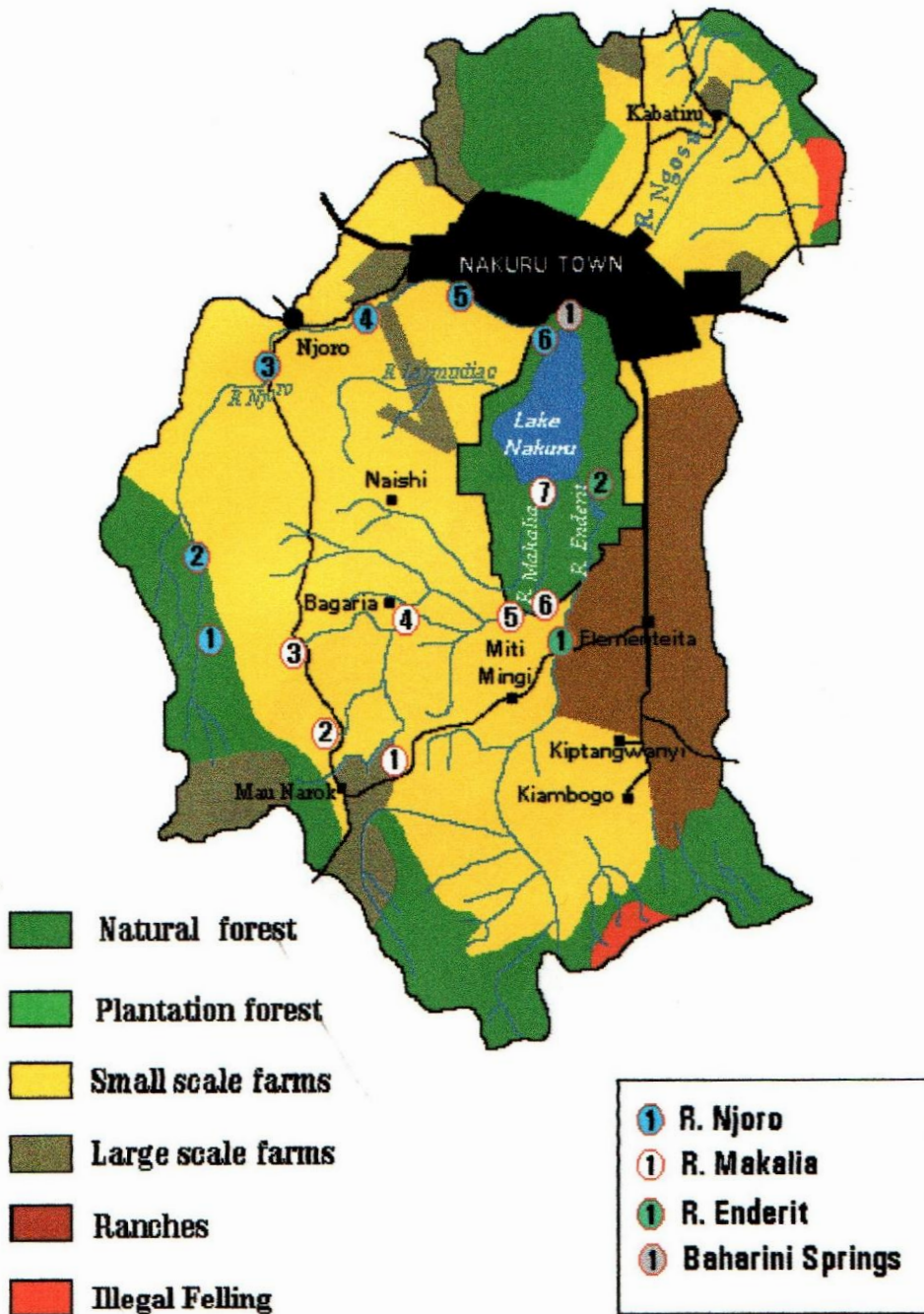
APPENDIX 10

THE PERSISTENCE OF ORGANOCHLORINE INSECTICIDES IN TEMPERATE SOILS (EDWARDS 1973)

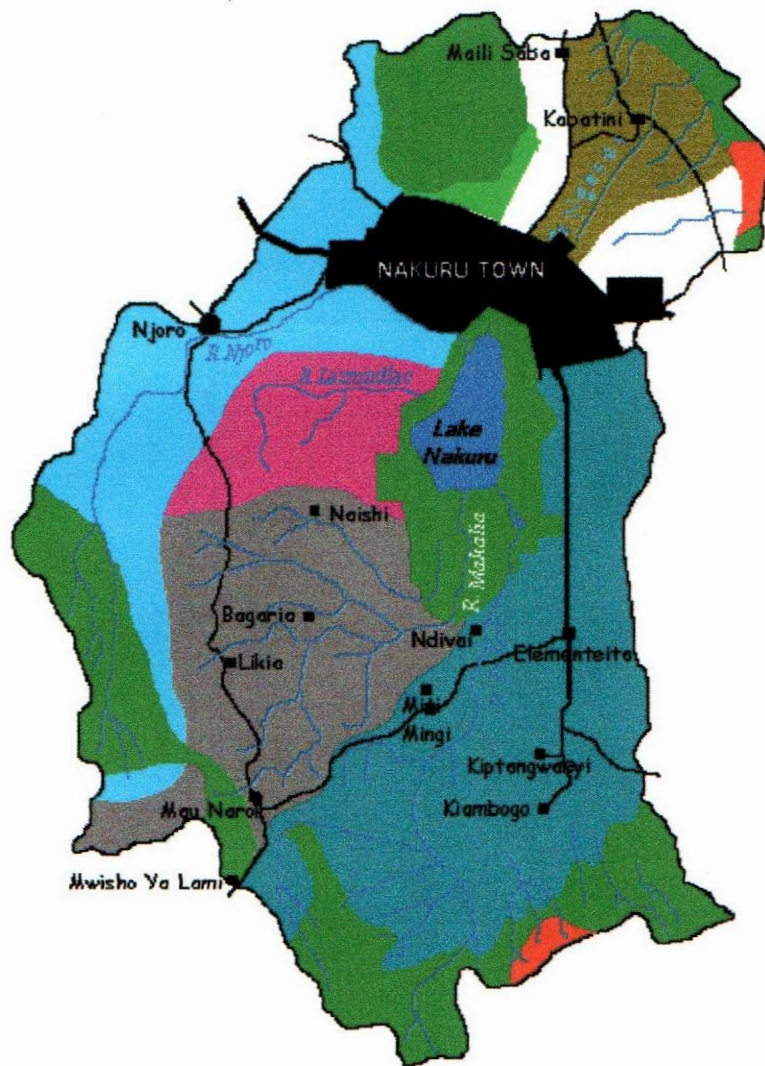
INSECTICIDE	HALF-LIFE IN SOIL (YEARS)	95% DISAPPEARANCE(YEARS)
Aldrin	0.3	0.3
Isobenzan	0.4	4.0
Heptachlor	0.8	3.5
Chlordane	1.0	4.0
Lindane	1.2	6.5
Endrin	2.2	7.0
Diedrin	2.5	8.0
DDT	2.8	10.0

REF: Edwards, C.A., 1973, Pesticides residues in soil and water environment
pollution by pesticides. Plenum Press. London.

LAKE NAKURU CATCHMENT BASIN - SAMPLING SITES (1997 - 99)



RIVER BASINS LAKE NAKURU CATCHMENT



- R. Ngosur
- R. Njoro
- R. Larmudiac
- R. Makalia
- R. Enderit
- Forests

APPENDIX 13

N₂S₆ - SEDIMENT SAMPLE
FROM R. NJORD
1 ml.

10/12/79

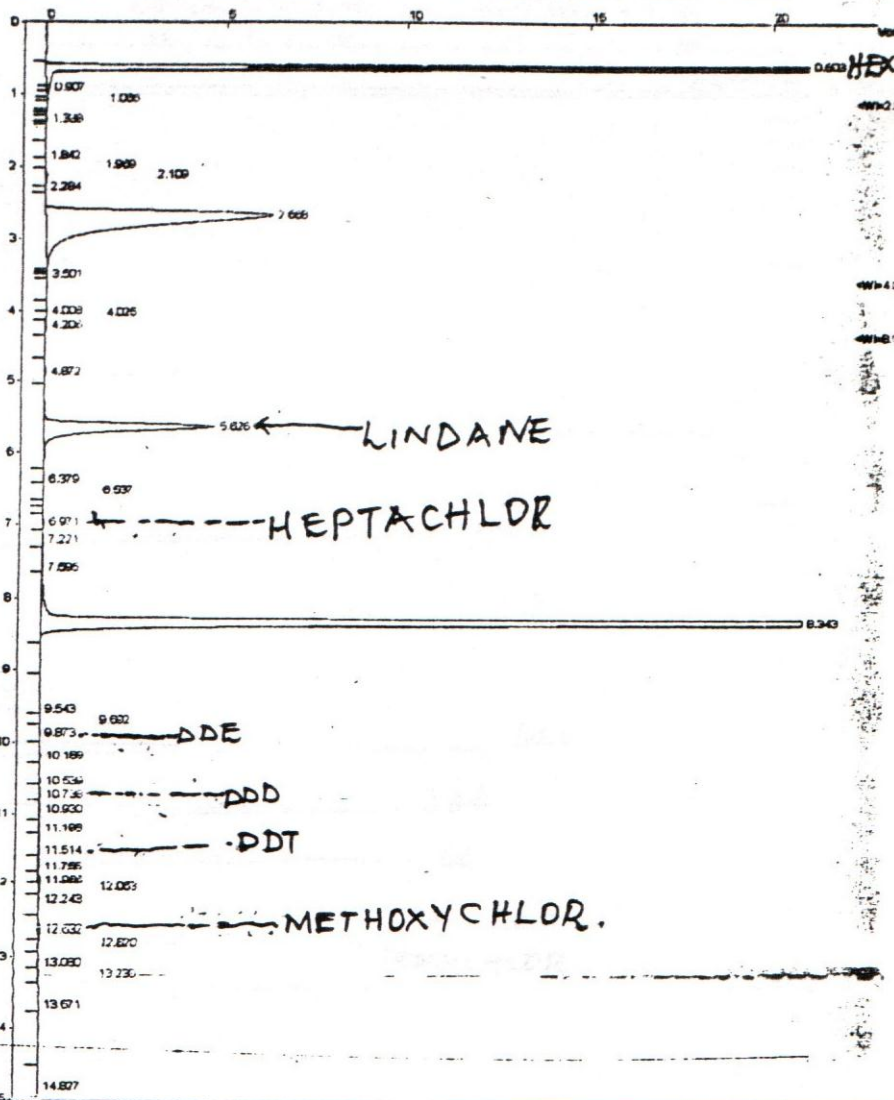
Run File : C:\STAR\MODULE16\STAR857.RUN
Method File : C:\STAR\ECD.MTH
Sample ID : Manual Sample

Injection Date: 10-DEC-79 9:43 PM Calculation Date: 10-DEC-79 9:59 PM

Operator : Dr. MAVURA Detector Type: ADCR (10 Volts)
Workstation: ACER Bus Address : 16
Instrument : VARIAN 3400CX Sample Rate : 10.00 Hz
Channel : A = A Run Time : 15.002 min

***** Star Chromatography Workstation ***** Version 4.5 *****

Chart Speed = 1.39 cm/min Attenuation = 9916 Zero Offset = 24
Start Time = 0.000 min End Time = 15.002 min Min / Tick = 1.00



Peak No.	Peak Name	Result ()	Time (min)	Offset (min)	Area (counts)	Sep. Code	Width (sec)	Status Codes
1		0.2512	0.803	0.000	2373824	EV	0.1	
2		0.4331	0.855	0.000	2421851	VR	0.6	
3		0.0131	0.907	0.000	3360	TC	0.0	
4		0.0062	1.036	0.000	1562	PR	0.0	
5		0.0162	1.336	0.000	4156	EV	1.1	
6		0.0236	1.840	0.000	7546	EV	0.0	
7		0.0136	2.284	0.000	4156	VV	0.0	
8		0.1237	3.501	0.000	31467	VV	0.0	
9		0.0084	4.008	0.000	31467	VP	0.0	
10		0.2884	4.206	0.000	6535815	PR	1.1	
11		0.0044	4.872	0.000	1137	TP	0.0	
12		0.0196	5.826	0.000	5027	EV	0.0	
13		0.0203	6.376	0.000	5220	VV	0.0	
14		0.0275	6.971	0.000	27049	VR	0.0	
15		0.0556	7.221	0.000	3219532	EV	0.0	
16		0.0128	7.596	0.000	3643910	VP	0.0	
17		0.0196	8.000	0.000	3386	PV	0.0	
18		0.1024	8.500	0.000	3386	VR	0.0	
19		0.1044	9.000	0.000	26796	VV	0.0	
20		0.2302	9.500	0.000	550555	VV	10.0	
21		0.0326	9.800	0.000	8373	VR	19.0	
22		0.0130	10.100	0.000	4108	VV	0.0	
23		0.0373	10.400	0.000	9699	VV	0.0	
24		0.0403	10.700	0.000	10399	VV	20.0	
25		0.0443	11.000	0.000	11236	VV	0.0	
26		0.0430	11.300	0.000	11236	VV	0.0	
27		0.0821	11.600	0.000	11236	VV	0.0	
28		0.0821	11.900	0.000	11236	VV	0.0	

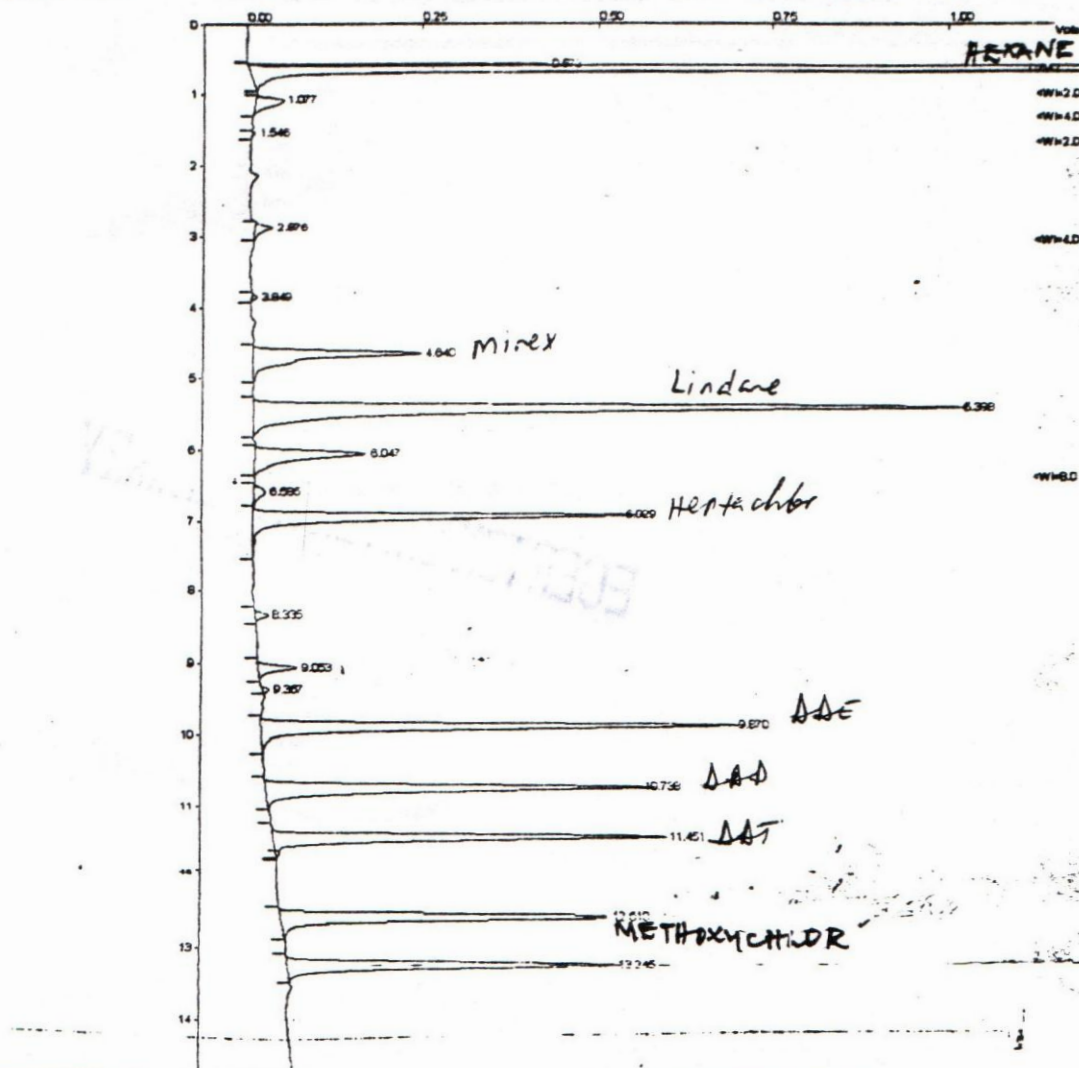
Run File : C:\STAR\MODULE16\STAR056.RUN
Method File : C:\STAR\ECD.MTH
Sample ID : Manual Sample

Injection Date: 10-DEC-99 10:08 PM Calculation Date: 10-DEC-99 10:24 PM

Operator : Dr. MAVURA Detector Type: ADCB (10 Volts)
Workstation: ACER Bus Address : 16
Instrument : VARIAN 3400CX Sample Rate : 10.00 Hz
Channel : A = A Run Time : 15.002 min

***** Star Chromatography Workstation ***** Version 4.5 *****

Chart Speed = 1.39 cm/min Attenuation = 512 Zero Offset = 5%
Start Time = 0.000 min End Time = 15.002 min Min / Tick = 1.00



Peak No.	Peak Name	Result ()	Ret. Time (min)	Time Offset (min)	Area (counts)	Sep. Code	Width 1/2 (sec)	Status Codes
1		0.2121	0.572	0.000	15797	EV	0.4	
2		23.0689	0.615	0.000	1717824	VV	1.4	
3		34.8686	0.642	0.000	2596672	VP	3.5	
4		0.4561	1.077	0.000	33965	BB	7.7	
5		0.0198	1.546	0.000	1476	BB	2.0	
6		0.0164	2.876	0.000	16117	BB	5.3	
7		0.0362	3.846	0.000	2693	BB	3.6	
8		0.4690	4.649	0.000	183571	BB	5.8	
9		1.7926	5.368	0.000	729781	BB	5.1	
10		1.7926	6.047	0.000	133493	BB	7.3	
11		0.1892	6.056	0.000	14086	EV	8.7	
12		4.4292	6.096	0.000	329845	VB	5.2	
13		0.1273	6.336	0.000	9481	BB	4.7	
14		0.4364	9.053	0.000	32648	VP	5.4	
15		0.0483	9.367	0.000	3594	VP	0.0	
16		5.3730	9.870	0.000	400129	BB	5.2	
17		4.7601	10.736	0.000	354463	BB	5.7	
18		4.4113	11.451	0.000	328513	BB	5.3	
19		3.4383	12.245	0.000	256054	BB	4.9	
20		3.8498	13.245	0.000	286700	BB	5.5	
Totals:		100.0001		0.000	7447050			

Total Unidentified Counts : 7447046 counts

Detected Peaks: 21

Reported Peaks: 1

Identified Peaks: 0

APPENDIX 15

N₂W₅
WATER SAMPLE FROM R. NJORO.

11/12/99

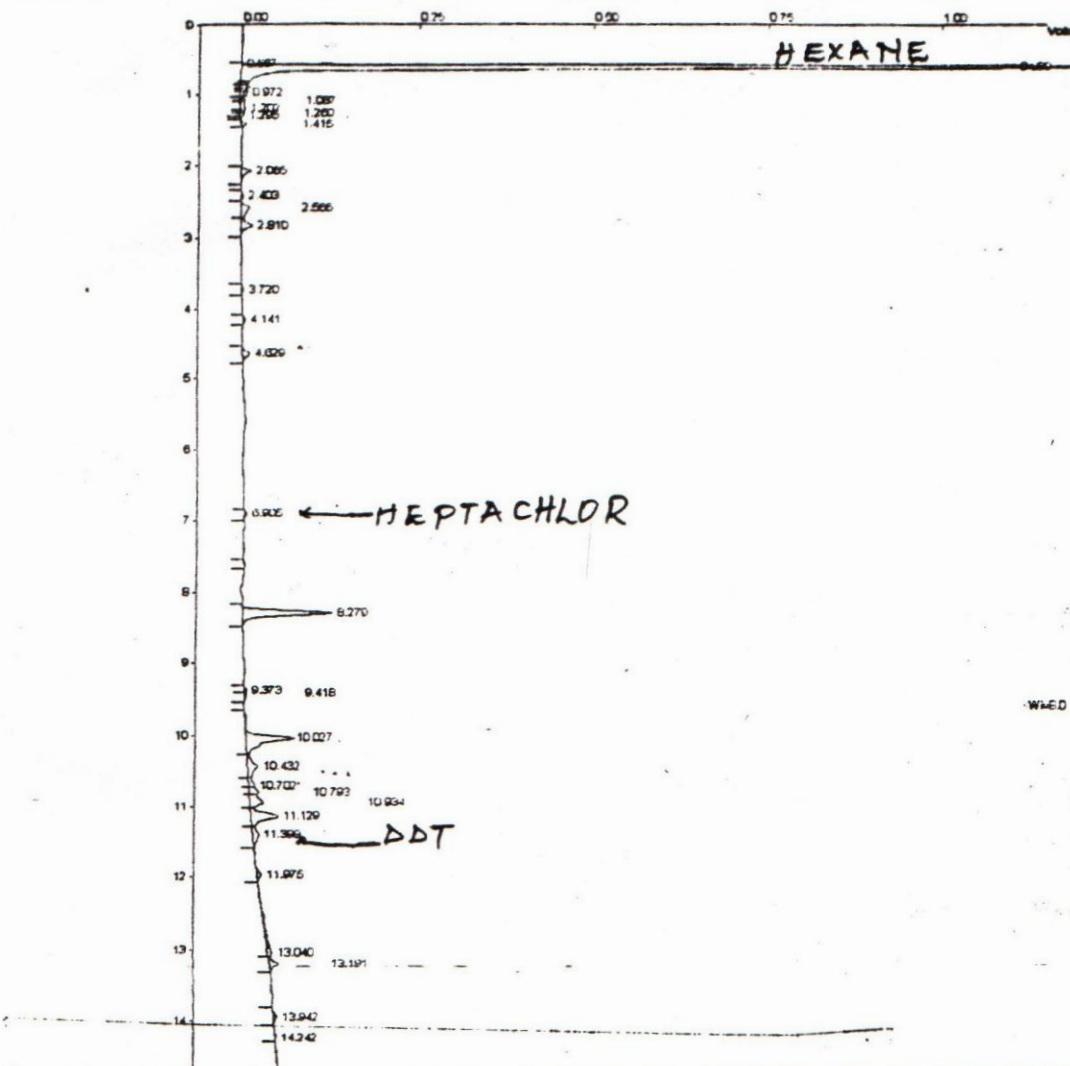
Title :
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Method File : C:\STAR\ECD.MTH
Sample ID : Manual Sample

Injection Date: 06-DEC-99 6:40 AM Calculation Date: 06-DEC-99 6:55 AM

Operator : Dr. MAVURA Detector Type: ADCE (10 Volts)
Workstation: ACER Bus Address : 16
Instrument : VARIAN 3400CX Sample Rate : 10.00 Hz
Channel : A = A Run Time : 15.002 min

***** Star Chromatography Workstation ***** Version 4.5 *****

Chart Speed = 1.39 cm/min Attenuation = 512 Zero Offset = 5%
Start Time = 0.000 min End Time = 15.002 min Min / Tick = 1.00



Peak No.	Peak Name	Result ()	Ret. Time (min)	Time Offset (min)	Area (counts)	Sep. Code	Width (sec)	Status Codes
1		1.00276	0.000	0.000	196111	EV	0.5	
2		0.07006	0.000	0.000	159206	VP	1.8	
3		0.07433	0.000	0.000	16722	TF	0.0	
4		0.17555	0.000	0.000	38448	TF	0.0	
5		0.08006	0.000	0.000	13663	TF	0.0	
6		0.08555	0.000	0.000	13441	TF	0.0	
7		0.28333	0.000	0.000	63745	BB	0.0	
8		0.07774	0.000	0.000	1741	BV	0.0	
9		0.4311	0.000	0.000	3656	VV	0.0	
10		0.4470	0.000	0.000	10027	VE	0.0	
11		0.07006	0.000	0.000	10000	BB	0.0	
12		0.07006	0.000	0.000	10722	BB	0.0	
13		0.07006	0.000	0.000	63446	BB	0.0	
14		0.07006	0.000	0.000	17855	BB	0.0	
15		0.07006	0.000	0.000	63446	BB	0.0	
16		0.07006	0.000	0.000	14600	EV	0.0	
17		0.07006	0.000	0.000	10000	VE	0.0	
18		0.07006	0.000	0.000	47855	BV	0.0	
19		0.07006	0.000	0.000	13556	VV	0.0	
20		0.07006	0.000	0.000	13556	VV	0.0	
21		0.07006	0.000	0.000	13556	VV	0.0	
22		0.07006	0.000	0.000	13556	VV	0.0	
23		0.07006	0.000	0.000	13556	VV	0.0	
24		0.07006	0.000	0.000	13556	VV	0.0	
25		0.07006	0.000	0.000	13556	VV	0.0	
26		0.07006	0.000	0.000	13556	VV	0.0	
27		0.07006	0.000	0.000	13556	VV	0.0	
28		0.07006	0.000	0.000	13556	VV	0.0	
29		0.07006	0.000	0.000	13556	VV	0.0	
30		0.07006	0.000	0.000	13556	VV	0.0	
31		0.07006	0.000	0.000	13556	VV	0.0	
32		0.07006	0.000	0.000	13556	VV	0.0	
33		0.07006	0.000	0.000	13556	VV	0.0	
34		0.07006	0.000	0.000	13556	VV	0.0	
35		0.07006	0.000	0.000	13556	VV	0.0	
36		0.07006	0.000	0.000	13556	VV	0.0	
37		0.07006	0.000	0.000	13556	VV	0.0	
38		0.07006	0.000	0.000	13556	VV	0.0	
39		0.07006	0.000	0.000	13556	VV	0.0	
40		0.07006	0.000	0.000	13556	VV	0.0	
41		0.07006	0.000	0.000	13556	VV	0.0	
42		0.07006	0.000	0.000	13556	VV	0.0	
43		0.07006	0.000	0.000	13556	VV	0.0	
44		0.07006	0.000	0.000	13556	VV	0.0	
45		0.07006	0.000	0.000	13556	VV	0.0	
46		0.07006	0.000	0.000	13556	VV	0.0	
47		0.07006	0.000	0.000	13556	VV	0.0	
48		0.07006	0.000	0.000	13556	VV	0.0	
49		0.07006	0.000	0.000	13556	VV	0.0	
50		0.07006	0.000	0.000	13556	VV	0.0	