OCCURRENCE, DISTRIBUTION AND ENVIRONMENTAL IMPACTS OF ORGANOCHLORINE PESTICIDE RESIDUES IN THE LAKE VICTORIA CATCHMENT: A CASE STUDY OF RIVER NYANDO DRAINAGE BASIN OF WINAM GULF IN KENYA

BY

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DECLARATION

This thesis is the original work of the author except where due references are made. It has not been submitted partially or wholly for the award of degree to this or any other institution of learning.

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DEDICATION

I dedicate this work to mummy's boys Friis and Yoweri

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ABSTRACT

A study was conducted in which 880 samples of soil, water, sediments, aquatic weeds and benthic macroinvertebrates were collected from 26 locations representative of the River Nyando drainage basin catchment area of 3450 km^2 and a total length of 170 km of the Lake Victoria Catchment over a period of two years. Soils from six farms were sampled in areas where maize, tea, sugar cane, coffee, rice and vegetables have been grown over the years. The objective was to investigate the impacts on the ecosystem health in relation to levels and distribution of oraganochlorine pesticides that have either been banned or are restricted for use in Kenya. The pesticides targeted were DDT, lindane, aldrin, dieldrin, heptachlor, endrin, endosulfan and methoxychlor. Pior to their ban or restriction in use, they had found wide applications in public health and agriculture for control of disease vectors and crop pests respectively.

Analysis of 48 soil samples revealed presence of all the targeted pesticides. Mean concentrations (μg/kg) recorded decreased in the order methoxychlor (138.97±1.517 μg/kg), total (∑) endosulfan (30.267±2.098μg/kg), ∑DDT (17.513±1.689 μg/kg), dieldrin (14.073±0.440 μg/kg), endrin (10.155±0.860 μg/kg), lindane (8.985±1.318 μg/kg) and ∑Heptachlor (0.681±0.021 μg/kg), respectively. The distribution showed that dieldrin was in use in vegetable farms in Kedowa area, tea farms in Nandi District and in Ahero rice paddies; while β-endosulfan was commonly used on tea farms in Nandi. Water analysis from the 26 sampling sites showed the highest mean concentrations were detected for methoxychlor (8.817±0.020 μg/L), ∑endosulfan (1.648± 0.04 μg/L), dieldrin (1.1561± 0.042 μg/L), endrin (0.281± 0.003 μg/L), ∑DDT (0.242±0.009 μg/L), ∑heptachlor (0.148±0.011μg/L) and lindane (0.144±0.006μg/L) respectively. The detected levels in sediments were considerably higher than those found in water in the order, methoxychlor (92.893±3.039 μg/kg), lindane (33.917±2.360 μg/kg), aldrin (26.676±0.981 μg/kg), dieldrin (23.62±4.810 μg/kg) and β-endosulfan, (10.502±0.800 μg/kg), respectively. The analysis of aquatic weeds recorded methoxychlor (39.641±3.045 μg/kg) as the highest residue concentrations, followed by aldrin (15.519±3.756 μg/kg). These higher levels may be as a result of continued use of the pesticide in the drainage basin. The levels of pesticides were higher in sediment, weeds and soil than in water.

The pooled results show that the targeted pesticides are still in use in the basin and could be impacting negatively on the ecosystem health of the area. A study of the composition of the benthic macroinvertebrates showed presence of four invertebrate phyla in River Nyando. These were Arthropoda, Mollusca, Plathelminthes and Annelida. A diversity of 16 families and eleven orders was recorded, with the order Ephemeroptera being abundant upstream followed by Hemiptera, Plecoptera and Trichoptera respectively. The downstream sections mainly the rice farming areas were dominated by Hirudinae (leaches) and Oligochaeta, suggesting that they are less sensitive to environmental pollution. Using Multivariate analytical techniques, Redundancy Analysis and Canonical Correspondence Analysis, correlation statistics showed that the occurrence of organochlorine pesticides strongly affects the distribution of the benthic macro invertebrates at all the sampling locations within the drainage basin. The high concentrations of pesticide residues were detected mostly in the soils and water from rice farms, these magnitudes were followed by those from tea farms. This implies that the rice farmers use most pesticides followed by tea farmers and there the proximity of the rice paddies to Lake Victoria could pose a greater impact to ecosystem health in the entire catchment than the upstream tea, sugar cane, maize and coffee farms owing to pesticide discharge; and this call for stringent management measures to be put in place to safeguard the environment.

ABBREVIATIONS

AAK	Agrochemical Association of Kenya
ATSDR	Agency for Toxic Substances and Disease Registry.
BHC	Benzene Hexachloride
BEA	British East African
CNS	Central Nervous Systm
DDD	1,1 Dichloro-2.2-bis (4-chlorophenyl) ethane
DDE	1,1 Dichloro-2.2-bis (4-chlorophenyl) ethylene
DDT	Dichlorodiphyl-1,1,1-trichloroethane
DMDE	p,p-dimethoxy dichloroethene
DO	Dissolved Oxygen
dw	Dry weight
EAC	East African Community
EMCA	Environmental Management and Coordination Act
ERA	Ecological Risk Assessments
ERSE	Economic Recovery Strategy on Employment
EU	European Union
FAO	Food and Agricultural Organization
FDA	Food and Drug Administration
GC	Gas Chromatography
GEF	Global Environment Facility
GMC	Genetic Modified Crops
GMO	Genetic Modified Organism
GUP	General Use Pesticide
HCH	Hexachlorocychlohexane
HCl	Hydochloric acid
IARC	International Authority for Research on Cancer
ICRAF	International Centre for Research in Agroforestry
IPCC	Inter-governmental Panel on Climate Change
IPM	Integrated Pest Management

IUPAC	International Union of Pure and Applied Chemistry
JMPR	Joint FAO/WHO meeting on Pesticide Residue
KARI	Kenya Agricutural Research Institute
KCBS	Kenya Central Bureau of Statistics
KGGCU	Kenya Grain Growers Cooperative Union
LD	Lethal Dose
LOAEL	Lowest Observed Adverse Effect Level
LOI	Loss of weight on Ignition
LVEMP	Lake Victoria Environmental Management Project
LVFO	Lake Victoria Fisheries Organization
LVFRP	Lake Victoria Fisheries Research project
LVWR	Lake Victoria water Resources
MCL	Maximum Contamination Level
MDE	Methoxy Dichloro Ethane
MoALD & M	Ministry of Agriculture and Livestock Development
NAL	National Agricultural Laboratory
NEA	National Environmental Authority
NEMA	National Environmental Management Authority
NIP	National Implementation Plan
NLM	National Library of Medicine
NOAEL	No Observed Adverse Effects Level
OCP	Organochlorine Pesticides
OSHA	Occupational Safety and Health Administration
PCB	Polychlorinated Biphenyl
PCPB	Pest Control Products Board
POPs	Persistent Organic Pollutants
PRA	Participatory Rural Appraisal
PRSP	Poverty Reduction Strategy Paper
TN	Total Nitrogen
TP	Total Phosphorous

TSS	Total Suspended Solids
UNEP	United Nations Environmental Programme
UNESCO	United Nations Educational Scientific and Cultural Organization
US-DHHS	United States Department of Heath and Human
US-EPA	United States Environmental Protection Agency
WHO	World Health Organization

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER ONE

1.0 INTRODUCTION AND LITERATURE REVIEW

In many African countries Kenya included, agriculture is considered to be the key to economic development. Although the commercial use of natural resources often makes an important contribution to many national economies (Darkoh 2003), agro-intensification has led to negative impact on the surrounding environment in many parts of the world (Wilson and Tisdell, 2001). The challenge for future food production in Africa is therefore to intensify the agricultural production without decreasing the capacity of the environment to supply the population with other ecosystem services. Agriculture has been a mainstay of the Kenyan economy. It is the basis for food security, for economic growth, employment creation and foreign exchange generation. Most Kenyan industrial and manufacturing firms are agro-based. The development strategy depends on agriculture and industry. Most of the agricultural production in Kenya comprises mixed farming, i.e., crop and livestock farming. Agriculture accounts for 60% of Kenya's foreign exchange earnings and provides raw materials for the industries (NIP, 2006). Hence there is tendency towards the use of chemicals especially fertilizers, veterinary chemicals and pesticides.

Agricultural production systems in the non-arid areas are more intensive than those in semi-arid areas. Maize is the staple food crop in Kenya, while dry beans are the most important legume crop. Coffee, tea, and sugarcane are the major commercial crops. It is in agricultural sector that chemicals are most used and in which waste biomass is generated that is burnt in the open. Coffee production constitutes a major use of pesticides, while tea production is a major user of fertilizers (NIP, 2006). Rapid expansion of the agricultural sector has resulted in increased demand for agro-chemicals. Pesticides have become integral part of agricultural, livestock and public health pest interventions. Their use is increasing in the tropical regions such as Africa because of greater awareness of the benefits in an environment that promotes the growth and development of pests and diseases. However, increasing evidence suggests pesticides have intrinsic public health and environmental risks during their production, import, use, disposal and degradation in the environment. Many pesticides used in all societies have been associated with toxicity and others are suspected to be carcinogenic, mutagenic, endocrine disruptors etc. These pesticides (and many others chemicals with similar properties), while posing minimal or no direct acute (except at high concentrations or against use instructions) or chronic threats to animals, still pose an indirect threat by interacting with endocrine system of organisms (Colborn, 2004).

Despite the reported rapid degradation of pesticides in tropical climate soil (Wandiga et al, 1996 (a)), marine (Mbuvi, 1997) and fresh aquatic environments (Wandiga et al., 1996(b); Bereket, 2000), the potential for bioaccumulation and bio-concentration of those pesticides (Munga, 1985) poses serious ecological and health concerns for the environment. Pesticide leaching or drainage from cultivated land into the surface waters and underlying ground water are a source of pollution because of their environmental mobility and persistence. Organic substances, pesticides and industrial solvents originating primarily from industries and agricultural fields are released into the environment through the urban and agricultural run-off, atmospheric fall out and industrial waste waters (UNEP, 1991). These organic compounds are also found in substances for domestic use, such as household solvents and aerosol containers. Because these compounds are commonly used, their rate of dispersal into the environment is correspondingly high (UNEP, 1991).

1.1 Kenya's National Development Plans

Kenya's development planning process can be traced to the 7th National Development plan of 1994-1997. Subsequently National Development Plans and other policy papers, including Poverty Reduction Strategy Paper (PRSP) and the Economic Recovery Strategy on Employment and Wealth Creation, have provided the required policy platforms for increased involvement of stakeholders, especially local communities, in decision-making for environmental and natural resource protection. The 9th National Development Plan (2002-2008) provides a more fundamental approach to environmental management and is emphatic about the need to develop and incorporate environmental economics and natural resources accounting into the National Accounting System (NIP, 2006).

The Poverty Reduction Strategy Paper (PRSP) highlights that "Conservation, sustainable utilization and management of the environment and natural resources, especially land, water and forests" is an integral part of national planning and poverty reduction efforts. The PRSP also states that *"in order to improve environmental management and conservation, the government and other stakeholders will create awareness of environmental costs and benefits"* The use of chemicals is an essential means of achieving economic and social development in Kenya. To make such development sustainable, the benefits of chemicals must be maximized and their adverse health and environmental impact effects minimized. Kenya has an active and growing programme to help stakeholders build their capacities to manage chemicals safely. The general approach is to provide awareness, legal and policy framework and training in key chemical safety elements, usually in support of the relevant conventions such as the Rotterdam Convention on pesticides and Individual Chemicals in international trade or Stockholm Convention. United Nation Environmental Programme (UNEP) Chemicals is currently assisting Kenya to develop the Stockholm Convention national implementation plan through Global Environment Facilities (GEF)-founded enabling activities (NIP, 2006).

Pesticides are now used on global scale, but less is known about their effects in the African continent (Abate, 2000). So far point sources such as pesticide storage facilities have been considered to be a bigger threat to the environment than the diffuse use in agriculture (Kylin et al., 2005, NIP, 2006). In Kenya, a few studies regarding pesticides have been reported residue levels in various matrices. Not much is known about the pesticides use and effects on the environment in small and large-scale agro-ecosystem, which are employing the majority of the work force and covering a major part of the arable land.

1.1.1 Current status of pesticides imports in Kenya

Kenya does not have pesticide manufacturing facilities; fully formulate and/or active ingredients are imported and the formulated for use. Approximately 8,370 tones of pesticides were imported into the country in 2005 (AAK, 2005). More insecticides were imported in comparison to other pesticides. The data is based on applications for the import of pest control products for the commercial purposes approved by Pest Control Products Board. These quantities exclude quantities imported by the Ministry of Agriculture for commodity aid and grants programs (AAK, 2005). Primarily, firms in the agrochemical industry have been responsible for pesticide distribution in Kenya. The principal importers before 1963 include Mackenzie Kenya ltd, BEA Corporation (affiliated with Oversea Trading Organization) and Kenya Grain Growers Cooperative Union (KGGCU), (Mbatha, 1988). After 1963 (post-independence), most of the large firms were sold out, and consequently, the distribution of pesticides involved more firms and became more complex. Representatives of oversea pesticide manufacturer are now involved in the importation of pesticides. They additionally serve as principal distributors, supplying to the stockist shops in the country.

1.2 Pesticides regulations in Kenya

Public Health Act, Cap 242, of 1921 was passed by the colonial government and Parliament Act, Cap 358 of 1937 prescribes various preparations for destroying ticks. These preparations are still retained in law though several amendments have modified the original prescription. Poisonous substance ordinance of 1954 provided for protection of employees against risks of poison by certain substances used in agriculture for matters incidental thereto and connected therewith. Pharmacy and poison Act of Parliament of 1957 aims to incorporate provision of the law to provide for control of profession of the Pharmacy and trade in drugs and poisons. Included in this Act was the control of the profession of pharmacy and trade in drugs and poisons with additional rules on the selling and labeling of poisons, including pesticides.

For Food, Drug and Chemical Substance Act, Cap 254 of 1965, pesticides were given particular attention, the term "Chemical Substance" was defined to refer to any substance or mixture of substances prepared, sold or represented for use as germicide, disinfectant, insecticide, rodenticide, antiseptic, pesticide, vermicide or detergent. For the first time, it also set tolerant levels (ppm) for pesticides in food stuffs. This law has neither been amended since then nor has its implementation been effective. The protection of workers in the work place has not been left outside the ambit of legal protection. The Occupational Safety and Health Act (OSHA) 2007 section 44/1 requires that a written notice should be addressed to the Director of Occupational Health and Safety Services for the approval before occupying a work place; such a detail include nature of work, harzards and the control measures in place. In addition, the harzardous Substances Rules L.N 60 of 2007 provides that all harzadous substances at workplaces should be handled safely.

Importation of pesticides is covered under the Pest Control Products Act Cap 346 of 1982 L.N 146/1984 and 125/2006 which regulates importation so as to ensure that unwanted, obsolete, expired or banned pesticides are not imported into the country as well as regulate quanties that are imported. There exist control mechanisms for entry of public health pesticides into the country, which includes collaboration with customs departments and other enforcement agencies. This is done through issuance of import permits as well as having PCPB inspectors at ports of entries. Formulation and repacking of pesticides is covered under the Pest Control Products Acts Cap 346 of 1982 L.N 145/1984 and 124 of 2006 whose aim is to protect and guard against contamination of the environment. It also ensures that the products are formulated and repacked under safe conditions. Safety and health of workers is further covered under the harzadous Substance Rules L.N 60 of 2007 as well as OSHA 2007 Sec 7 which provides for control measures to prevent exposure to hazardous substances during formulation and packaging. However protection of workers and adherence to use of protective gears is lacking and cases of exposures have previously been reported.

Another important component is storage and transport of pesticides. The Pest Control Product Act Cap 346 of 1982 L.N 145/1984 and 124/2006 covers storage only. It aims at ensuring that products are stored under safe conditions that will not compromise the quality of the products, safety of the environment and user's health. In addition, OSHA 2007 Sec 83/3 also provides for safety in transportation and storage so as not to cause ill effects to any person or environment. Distribution of pesticides is covered under the Pest Control Products Act Cap 346 of 1982 L.N 145/1984 and 124/2006 aims at ensuring that products are only distributed through lincensed dealers. An important aspect of waste management includes disposal of pesticide containers, which is covered under Pest Control Acts Cap 346 of 1982 L.N 126/1984. The act aims at ensuring that the products are disposed off in an environmentally sound manner. In support, OSHA 2007 Sec 83/4 mandates the employer to provide suitable system for safe collection, recycling and disposal of chemical waste, obsolete chemicals and empty containers. In addition, the Environmental Management and Coordination (waste mangement) Regulations L.N 121 provides operational guidelines for facilities lincensed to dispose harzadous waste such as pesticides. The National Environment Managenment Authority (NEMA) is in the process of drafting Environment Managenment Coordination (Toxic and Harzadous Chemicals) regulations.

Licensing provision under the Pest Control Products Act Cap 346 of 1982 L.N 128/1982 ensures that premises that deal in pesticides should store the pesticides safely without dangers of contaminating the environment and be equipped to handle emergencies such as spillages and poisoning. Control of labeling is covered under Pest Control Products Act Cap 346 of 1982 L.N 89/1984 and 127/2006 (PCPB, 2007). It aims at ensuring that lebels have sufficient and legible information on use instructions, precaution, disposal, toxicology and limitation. In addition, OSHA No. 15 of 2007 provides that material data sheet (MDS) are provided and available to employee, as well as requirements that hazardous materials have 'special' labeling with clear information, instructions for safe handling, incase of spillage or accidental exposure.

To control unauthorized use of pesticides, the Pest Control Products Act Cap 346 of 1982 L.N 126/1984 and 89/1984 aim at ensuring that only products of proven efficacy, safety, merit and economic values are available to consumers. The control of pesticide advertisements is covered under the Pest Control Product Act Cap 346 of 1982 L.N 89/1984 and 126/2006 which ensure that advertisements are not erroneous, misleading or deceptive. However these regulations have inadequate details. Pest control operators are lincensed under the Pest Control Products Act Cap 346 of 1982 L.N 124/1984 which aims at ensuring that only qualified and competent professionals handle highly hazardous pesticides. Regarding control of the quality of pesticides, Pest Control Products Act Cap 346 of 1982 L.N 124/1984 aims at ensuring that only products of proven quality as per their registration are availed to the users. The PCPB under the Act is mandated to undertake the safety of the Pest control products that are registered, and that includes pesticide residues in the products and environment. For purposes of registration, residue data is provided along with pre-harvest, withdrawal and reentry intervals as a requirement for safety of the products. Currently, the PCPB is not undertaking residual trials to confirm the data in the local environment nor are the residuals in the final produce being monitored (PCPB, 2007). Other legislative laws passed by parliament which have a bearing on pesticide use, distribution, and control including the Agriculture Act, Cap 318, the Fertilizer and Animal Food Stuffs Act Cap 345 of 1995; Forest Act Cap 385; the Plant Protection Act, Cap 324 of 1995, the Water Act , Cap 389 of 2002 and EMCA Act 1999. Although in some of these acts pesticides are not specifically mentioned, it is clear that to fulfill Act's objectives the control of pesticide may be invoked.

The practice in Kenya has been for the Parliament to pass sectional laws for the regulation and control of environmental matters. National Environmental Management Authority (NEMA) created in 1999 is the coordinating body on environmental issues in Kenya now. The most comprehensive law regulating pesticides is the Pest Control Products Act which came into law in 1983. It was established to regulate the importation, exportation, manufacture and distribution of products used to control pests and of the organic functions of pesticides on plants and animals. The Act established a Pest Control Products Board (PCPB) which became operational in 1984.

1.3 Fate of Pesticides in the Environment

In the environment, pesticides are subjected to a variety of transport and transformation processes. The rates of these processes can have profound influence on the exposure of animals and plants to these chemicals.

1.3.1 Transport processes

These refer to physical movement of a pesticide from the site of application to un-intended place. The processes, which include advection, volatilisation and leaching, act as the pesticide contamination routes into surface water, air and ground water.

1.3.1.1 Advection

Advection (run-off or mass flow) is transportation of pesticide either in the dissolved form or associated with suspended materials in flowing water (Harris, 1995). It is the most important route, which occurs intermittently when water accumulate faster than it can infiltrate the soil. In most cases run-off mixes with streams and rivers before flowing into lakes or marine coastal areas. Pesticides in the soluble form associated with run-off water are harmful and can cause direct injury to non-targeted organism. Even those that are adsorbed to suspended particles can be detached and thus become equally harmful (Harrison, 1990).

1.3.1.2 Drifting and Volatilization

Drifting refers to process of carrying pesticide by wind from one point to the other. This process mostly takes place during application and is highly dependent on mode of application and weather. For example, applying pesticides without consideration of good application procedures such as meteorological conditions will result in drifting. The negative impacts of drifting to the environment include harming non-targeted organisms, polluting nearby water bodies and even contaminating the applicator (FAO, 1988). Volatilization is the process where a chemical is transported from wet or dry surfaces into the atmosphere. The process is governed by the various inherent properties of the chemical and environmental factors. The properties of the chemicals such as solubility vapour pressure and molecular structure influence volatilisation while the volatilisation rates are governed by environmental factors such as wind speed, temperature and soil texture (Linde, 1994).

1.3.1.3 Leaching

Leaching of pesticide residues is the movement of water with dissolved pesticides residues through the soil. The process occurs when soluble pesticides accumulate in amounts that overwhelm the soil's ability to adsorb and degrade them (Harrison, 1990). The situation may be brought about by the repeated releases of small quantities of pesticides. The potential for pesticides to leach depends, in part, on chemical and physical properties of the pesticides and that of soil. A pesticide that is persistent, very soluble and hydrophilic is likely to leach because it remains in soil solution for long time before being degraded and cannot be held strongly to the soil particles. Soil which is porous and with low organic matter favours the leaching process whereas soil with fine and compact soil structure and high organic matter content resists leaching, mostly because of its effect on pesticide adsorption. Much leaching of pesticides which in most cases is a result of non-observance of good pesticide application procedures leads to ground water contamination (Sorenson *at al.,* 1994). Heavy and repetitive application of pesticides may result in leaching and hence contamination of the ground water which may be used as a source of drinking water.

1.3.2 Retention Processes

Pesticide retention is the ability of soil or sediment matrices to hold pesticide to their surfaces. It is therefore, a major factor in the transportation, partitioning and eventual degradation of pesticides in the environment (Linde, 1994). The retention ability is expressed by adsorption and desorption processes which inturn are governed by the characteristics of the soil/sediments (sorbent), the chemical nature of the pesticide (sorbate) and the climatic factors such as rainfall, temperature, sunlight and wind. The sorbent parameters that are most responsible for adsorptive capacity are organic matter content, particle size, pH of soil and salinity of estuarine sediments. Other parameters that may have an impact on adsorption/desorption of a particular chemical are moisture content, effective cation exchange capacity and content of amorphous iron and aluminium oxide (Di Toro and De Rosa, 1991). Among the properties of contaminants, solubility plays a key role in adsorption/desorption of the pesticides (Di Toro and De Rosa, 1998). When a pesticide enters the environment, some of it will stick to soil particularly to organic matter and some will dissolve and mix with water between the particles. In aquatic bodies, pesticides that are non-polar tend to be pushed out of water to the sediments making their concentrations decrease rapidly in water column (Linde, 1994).

1.3.2.1 Biota uptake

Uptake by biota is the process in which pesticides are transported into and within the biota structure. The uptake process can be separated into two distinct pathways: Active uptake through feeding for animal biota and sorption by the root by plants, and passive up-take which is a result of direct contact between biota and pesticides (Burner *et al.*, 1997). Depending on the properties of the pesticides and biota characteristics, ingested pesticide may be degraded, accumulated within the organisms or passed through to the other organisms and the environment (Brown *et al.*, 1997). The accumulation of pesticide residues within the organism body is highly influenced by the fat content of the organism and the lipophilicity of the pesticide. This accumulation trend has been found to increase from low to high trophic levels owing to prey-predator relationships (Tanabe *et al.*, 1994). Since fat content in plants is negligible, bioaccumulation is not significant. However the up-take by plants can have severe consequences through the food chain if the pesticide is translocated into a section of the plant that will subsequently be harvested and eaten raw (Burner *et al.*, 1997).

Bioaccumulation is of more environmental and public health concerns since the residues accumulate in organisms' fats to the levels that may be harmful to organisms themselves. The comprehensive study of the acumulative persistent pollutants has shown that some of these chemicals can disrupt normal endocrine physiology in organisms. Man and other predator species occupy the highest level in the food chain and therefore the most vulnerable. The elevated levels of pesticide residues and their long-lives in animal tissues have led to adverse effects on health, such as carcinogenicity, mutagenicity and endocrine disruption as well as the claimed worldwide decrease in human sperm count (Juhler *et al.*, 1999).

1.3.2.2 Transformation/ Degradation

Degradation is the transformation of pesticide molecules to other compounds (metabolites) not necessarily simpler and less toxic compared to parent molecule (Burner *et al.*, 1997). Some of the formed metabolites are more toxic and persistent than the parent molecules. Pesticides such as the toxic heptachlor and chlordane, respectively, degrade to heptachlor epoxide and oxychlordane, which are more toxic (Plimer, 2001).

The degradation mechanisms can be categorized into abiotic and biotic classes. An abiotic degradation mechanism includes chemical processes and photolysis and there is no involvement of organisms. Chemical degradation occurs when pesticides react with other chemicals from the surrounding environments. One of the most common chemical degradation processes of pesticides is hydrolysis, a process in which the pesticides react with water. Many organophosphates and carbamates are particularly susceptible to hydrolysis. Photolysis (photodegradation) is the breakdown of pesticides by light, particularly sunlight. The breakdown occurs on foliage, on the surface of soil and in air (Brown *et al.*, 1997).

Biotic degradation is the breakdown of pesticide and involves participation of biological organisms either by microbial attack or biological metabolism. Most microbial degradation occurs in soils and is highly dependent on microorganism populations. The degradation accelerates and becomes faster under soil conditions favouring microbial activities. These conditions include warm temperatures, favourable pH levels and adequate soil moisture, aeration and high organic matter contents. The organisms that participate in microbial degradation are fungi, bacteria, and other microorganisms that use pesticides as food substrate (Mbuvi, 1997).

1.4 The Lake Victoria Catchment

Lake Victoria is the second largest fresh water lake in surface area in the world. It is second only to Lake Superior in North America and has the world's largest freshwater fishery. The introduction of the Nile perch in 1954 which has thrived remarkably well largely support an economically and socially important export fishery for the reparian countries (LVEMP, 2001). The lake basin supports about 30 million people living in five countries and it exports critical quantities of water downstream and fish to the global market. It is boarded by Tanzania, Kenya and Uganda and although not riparian, Burundi and Rwanda also lie within the Lake Victoria drainage basin.

Lake Victoria stretches 412 km from north to south between latitude 0° 30′ N and 3° 12′ S and 355 km from west to east between longitude 31° 37′ W and 34° 53′ E. It is situated at an altitude of 1,134 m above sea level and has a volume of 2,760 m^3 and an average and maximum depths of 40 m and 80m repectively. The lake is a home to numerous small and large communities along its edge. It has a total area of 68,800 km^2. 6 %, 51% and 43% of this area is in Kenya, Tanzania and Uganda respectively. The lake contains numerous Islands (Sesse or Kalangala and Buvuma in Uganda, Ukerewe in Tanzania and Rusinga in Kenya) and many smaller ones. It has a highly indented shoreline estimated to be 3,460 km long and its flushing time (volume/average outflow) is 138 years and a residence time of 21 years (LVEMP, 2003). Because of its long retention time, pollutants entering the lake remain in it for a long time. The lake has a wide drainage area of slightly over 193,000 km^2 in five countries including Rwanda and Burundi. It is the source of the White Nile and therefore an important asset for all the countries within the Nile River Basin (LVEMP, 2003). The lake and its drainage basin is a basic source for development with numerous capacities for domestic water supply, hydro-electricity.

fishing, irrigation, industrial water supplies, livestock development, amenity and conservation (Vidaeus *et al.*, 1992).

Various user conflicts exist within the Nile Basin countries. The biggest conflicts are the use of the lake as a depository for waste and sewage, as quite a few industries and municipalities do, and as a source of drinking water as well as for fishing. All land uses in the catchment in one way or another, affect the quality of the lake's water and that of its tributaries. For example, expanded agriculture and deforestation within the basin has resulted in higher sedimentation, nutrient build up and pesticide loading (Vidaeus *et al.*, 1992).

1.4.1 Pollution of Lake Victoria

Kenya has the highest number of rivers, streams and other water systems draining into Lake Victoria compared to Uganda and Tanzania. Most of the rivers draining the lake basin meander in broad shallow valleys through Kenya's major agro-based industrial belts, carrying rain runoff waters, treated and untreated industrial and domestic discharge, various types of Municipal waste, soil and other pollutants. Bad agricultural practices like cultivating on slopes adjacent to rivers and on river beds have caused massive soil erosion. As a result of this, the rivers in Lake Victoria catchments are carriers of both sediments and nutrient loads chocking the lake.This has created a significant pollution problem that threatens the exploitation of the water resources for national development. Since the rivers draining into Lake Victoria have unacceptable water quality levels, the overall water quality status of the lake and of its waterways are therefore affected and utilization of these water for development is subdued (Calamari *et al.*, 1995). These water systems also carry huge quantities of raw sanitation effluents from the lake basin. The Kenyan rivers flowing into the lake contribute mean total volume of 7.3-billion m^3 water/year

(Calamari *et al.*, 1995). The main ones are Sio, Nzoia, Yala, Sondu-Miriu, Nyando and Gucha/Migori; between them are many minor streams. All these rivers tend to flood in concert, having catchments in high rainfall zones with a prolonged dry season in January and February and the wet season runs from March to December, however this pattern is changing. A number of these rivers namely Yala, Nzoia, Nyando and Gucha form extensive swamps on the lakeshore. The overall catchment area covers over 67,000 km^2 in Kenya.

Owing to the topographic nature, Tanzania, which has the largest share of the lake, has limited river drainage systems into the lake (Calamari *et al.*, 1995). Most of Tanzanian rivers are merely seasonal. The most prominent being Isanga, Kalutangi, Simiyu, Mbalageti, Bariadi and Grumetti. All these drain the semi-arid plains of central Tanzania where there are insignificant agricultural and industrial activities and only one industrial area, in Mwanza town. Mwanza like all other municipalities in the lake basin empties its untreated waste into the lake thereby contributing to pollution. In Tanzania the land mass south of the lake is mainly a plain savannah with gentle, relatively flat topography receiving little rain compared to Kenya and Uganda where the topography slopes away from the lake. The only river, which constitutes a major drainage system for Tanzania, Uganda, Rwanda and Burundi, is the Kagera River which emanates from the Ruwenzori Mountains.

Uganda, which could have contributed an equally large percentage in the pollution process because of its highly agricultural and industrial lands in the central to the southern regions, has no major drainage river systems into the lake except for City of Kampala which has a man-made drainage channel (Nakivubo) that empties waste into the lake. Even rivers like Malaba among a myriad others within the country, either drain into the Lake Kyoga or other smaller lakes like Albert. Edward and George. This phenomenon is owed to the land topography, which tends mostly to veer away from Lake Victoria (Calamari *et al*., 1995).

1.5 The Winam Gulf

The Committee for Inland Fisheries of Africa (CIFA) sub-committee meeting held in Mwanza in 1989 noted the pollution problems in Kenya's side of Lake Victoria since the catchment basin is large with six major rivers draining pollutants into the lake. Winam Gulf was noted to be the most polluted catchment area (Calamari *et al*., 1995) within the lake basin. Winam Gulf catchment comprises the North and Southern Lakeshores and the Nyando and Sondu-Miriu River basins with a total area of 11.994 km^2. The Northern and Southern lakeshores comprise of seasonal rivers. Because of the CIFA concerns, it would be important to focus on the pollution status of the Winam Gulf and its catchment.

1.5.1 Climate of Winam Gulf

The climate of the Winam Gulf basin is characterized by two distinct seasons, the rainy and dry seasons. The long rainy season runs from March to May while the short rainy season from October to December. The dry seasons are January to February and from June to September. Average annual rainfall in the catchment area is 1300 mm, ranging from 1000 mm, along the lakeshore basin to over 1800 mm on the eastern Sondu -Miriu basin. Overall, the central part of Nyando catchment receive annual rainfall ranging from 1400 mm to 1500 mm. Rainfall increases north wards and southern towards the Nandi escarpment and Nyando-Sondu divides (Calamari *et al*.,1995).

1.5.2 The Lake Shore Basin

The lakeshore basin is a relatively dry area with small seasonal rivers draining it. The Northern Lakeshore consists of Awach- Seme. Kibos. Nyamasaria and other seasonal rivers. Its sub-basins are Kibos, Asembo-Kisumu and Kadimu-Uyoma. The Southern sub-basin has the following Awach-Kibuon. Awach Tende and Olambwe seasonal rivers draining it (Calamari *et al.*, 1995).

1.5.3 The Sondu-Miriu Basin

The basin has an area of 3,489 km^2. Some of the Sondu-Miriu tributaries originate from Kericho and the eastern side of Kisii Highlands. Kipsonoi River drains most parts of this area. This extends to the southwestern parts of the main escarpment including some parts of Kericho. The Chemosit River collects water from parts of the main escarpment and joins the other rivers to form River Itare. Itare meets Kipsonoi to form Sondu-Miriu River. Sondu-Miriu River then drains the Nyabondo and Nyakach areas and finally enters Lake Victoria. The river has an annual and monthly average run-off of about 42.2 m^3/s and 43.0m^3/s respectively. It drains the high potential agricultural areas of Kericho and Kisii Highlands with livestock farming. tea and coffee as the major activities. The Sondu-Miriu basin is divided into the Upper Itare. Lower Itare, Kitoi, Kabianga. Sisei. Kapsonoi and Miriu sub-basins (Calamari *et al.*. 1995).

1.5.4 The Nyando Basin

Nyando is the main river. which drains the Nyando basin. It flows through the Kano-Plains and has two main tributaries, small Nyando and Ainamotua. The Ainamotua is composed of streams rising from the Nandi Hills and Tindiret areas in Nandi District while the small Nyando comprises streams rising from the Londiani. Tinderet and the Mau Forest in Kericho District.

Nyando has a total length of 170 km and a catchment area of 3450 km^2. Small Nyando meets Ainamotua about 40 km upstream of Nyakach Bay to form the main Nyando River. It then flows for about 25 km downstream of Nyando-Ainamotua confluence; Awach-Kano is a smaller river that also flows into River Nyando (Figure1.1). The average annual and monthly run off flow is $18.0m^3/s$ and $18.3\ m^3/s$, respectively (Calamari *et al.*, 1995; LVEMP, 2003).

The Nyando drainage basin consists of five main sub-catchment areas namely, Nyando-Nandi, Nyando-Kericho, Awach-Kano, Nyaidho-Kano and Nyando-Kano. More than 50% of the total water discharge of the Nyando comes from the Nyando-Nandi sub-catchment. The Nyando basin traverses Nandi Hills and Londiani, Kipkelion and Sigowet areas of Kericho District as well as Koru, Muhoroni, Chemelil, Lower Nyakach and Kano plains of Nyando District. These areas form the main agricultural and the industrial zones in the Nyando drainage basin. River Nyando serves as a sink for effluents from coffee, tea and sugar factories within the Nyando catchment area. The agricultural activities in this basin which involve the use of fertilizers and pesticides have been identified as one of the major sources of pollution load to the Kenya side of Lake Victoria (Calamari *et al.*, 1995).

1.6 Lake Victoria Water Quality and Pollution Sources

Pollution impact by municipal and industrial discharge and rain run off from agricultural fields are visible in some of the rivers feeding the lake and along shores, such as the shallow Winam Gulf (Kisumu), near Mwanza and Kampala (Kiremire, 1997). Kisumu, a town that celebrated its 100 years of existence in 2002, routinely discharges raw, untreated industrial and sanitation effluents directly into Winam Gulf. High levels of various nutrients and pesticides, as well as low levels of heavy metals have been detected within Lake Victoria sediments (Wandiga, 1981;

Wasswa, 1997) and in the lake water (Sentongo, 1998). Pollution of lake waters by pesticides has also been reported on both the Tanzania and Kenyan parts of the lake in various studies (IUCN, 1992; Cru Ruud, 1995; Henry *et al.*, 2000; Tole *et al.*, 2000). Within the Kenyan lake basin, pesticides (which include insecticides, fungicides, acaricides and herbicides) and fertilizers have increasingly been used to boost agricultural products. Large-scale commercial tea, sugar cane, maize and coffee estates as well as horticultural farms and rice paddies are spread out within the vast catchment.

Increased run-off laden with pesticides and fertilizers from these estates and farms is inevitably finding its way into Lake Victoria through the rivers draining the basin. Pesticides have also been reportedly used for killing bird pests (Aryamanya-Mugisha, 1993) and in fishing (Orgaram, 1992). In May 1999, press reports indicated that fish were allegedly being harvested from the lake by use of endosulfan insecticide. This resulted in the imposition of a fish import ban by the European Union on all fish from Lake Victoria. Commercial fishing activity around the lake and subsequently the economies of the three riparian countries were greatly affected as a result. Total loss of income due to the ban was estimated to be more than US$ 300 million. Despite the ban on the use of Dichlorodiphenyl-1, 1, 1-trichloroethane (DDT), and other organochlorine pesticides in most of the industrialized world, their use in the East Africa region has continued mainly for public health vector control and illegal use. Inevitably the residues are finding their way into the lake waters (Calamari *et al.*, 1995).

1.6.1 Programmes that serve Lake Victoria

All riparian countries have plans to use Lake Victoria water for various purposes. Knowledge and understanding of the water regime in the lake basin is a prerequisite for improving the capacity to sensibly manage the resources. International cooperation around the Lake has a long history because of its significance as a source of the Nile. More recently the countries that share the lake have joined with the international communities in efforts to manage and preserve its water resources. fisheries and environment. This research work was to fill the knowledge gap in the current research efforts going on in the Kenyan side of Lake Victoria. International focus on the health of Lake Victoria gained momentum following the invasion of the lake by the water hyacinth (*Eichhornia crassipes*) and the 1999 fish import ban by the European Union. nternational efforts aimed at understanding the lake's ecosystem have therefore centered on several programmes some of which include: the Lake Victoria Water Resources (LVWR) Project. The Lake Victoria Fisheries Organization (LVFO) and Lake Victoria Environmental Management Project (LVEMP). The LVWR is a regional FAO/Japan project aimed at addressing the most basic infrastructure for water management in the region. This project mainly deals with hydro metrological parameters and has already initiated the establishment of ustainable skeleton network of rain and river gauges for the lake management.

The LVFO comprises the fisheries management and fisheries research institutions in the hree East African countries. The organization is charged with the responsibility of "fostering" a ommon system/resource management approach among the contracting sites in matters regarding ake Victoria, with a goal of restoring and maintaining the health of its ecosystem and assuring ustainable development for the benefit of the present and future generations. With the assistance rom the European Union-funded Lake Victoria Fisheries Research Project (LVFRP), the eparian governments have begun coordinating their responses to managing the fisheries sector. ut have yet to develop a coordinated action plan for managing the lake and its catchment across ll sectors. However the recent formation of East African Community (EAC), and the development of its Protocol for sustainable development of the Lake Victoria Basin, is the beginning of such a response. In spite of these recent positive developments, however, there remains tension between managing the lake to benefit the reparian communities versus managing it to benefit the downstream countries of the Nile River. This issue is currently being addressed within the Nile Basin Initiative (NBI), a forum that brings together all the ten countries in the Nile Basin.

The LVEMP is a comprehensive programme aimed at rehabilitating the lake ecosystem for the benefit of the people and national economies in the catchment areas. The objectives of the project are to: (1) maximize the sustainable benefits to riparian communities by using resources within the basin to generate food, employment and income, supply safe water and sustain a disease free environment; (2) conserve biodiversity and genetic resources for the benefit of the global community, and (3) harmonize national management programs in order to achieve, to the maximum extent possible, the reversal of the increasing environmental degradation. LVEMP Phase I which was funded by the World Bank and Gobal Environment Facility (GEF) became operational in 1997, and was completed in 2004. The Plan for Phase II has just been concluded The Projects components included management and control of water hyacinth, improved fisheries management and research, water quality monitoring, industrial and municipal waste management, conservation of biodiversity, catchment forests and wetlands, sustainable land use practices, and capacity building.

The Governments of the three riparian countries have shown a strong commitment to sustainable utilization of Lake Victoria and this has created a tremendous interest in the lake by both the international and local organizations. In spite of this interest and the amount of work being undertaken in the lake, there is limited work based on chemicals, in particular, pesticides.

For example out of eighty-nine research papers that were presented at the " Lake Victoria 2000" International Conference, which took place in Jinja from 16th May to 19th May 2000, only one research paper (Henry *et al.*, 2000) dwelt on pesticide residues in the lake. And of a total of 122 research papers and posters that were presented, only four papers dealt on the analysis of chemical parameters, the rest dealt on aspects of fisheries. From this information it is clear that there is a gap that needs to be filled.

1.7 Profiles and Environmental concerns of some organochlorine pesticides

Pesticide studies in Kenya have mostly been on organochlorines (Wandiga *et al.*, 1996 (a); Gitahi, 1994; Lalah, 1993; Wandiga *et al.*, 1988 (b)) because of their environmental concerns.

1.7.1 Aldrin

Aldrin, whose chemical name is 1,2,3,4,10-Haxachloro-1,4,4a,5,8,8a-hexahdro-1,4:5,8-dimethanophthalene (Appendix 1.0), is used to control soil insects such as termites, corn rootworms, wireworms, rice water weevils, and grasshoppers. It has been widely used to protect crops such as corn and potatoes, and has been effective in protecting wooden structures from ermites and has been banned in Kenya. Aldrin is rapidly metabolized to dieldrin, by both plants and animals. As a result, aldrin residues are rarely found in foods and animals, but only small amounts. It binds strongly to soil particles and is very resistant to leaching into groundwater. Volatilization is an important mechanism of loss from the soil. Due to its persistent nature and hydrophobicity, aldrin is known to bioconcentrate, mainly as its conversion products. Aldrin is oxic to humans; the lethal dose for an adult man has been estimated to be about 5g, equivalent to 83 mg/kg body weight for a 60 kg person. Signs and symptoms of aldrin intoxication may include headache, dizziness, nausea, general malaise, and vomiting, followed by muscle twitching and convulsion. There is limited information that cyclodienes, such as aldrin, may affect immune responses. The acute oral LD_{50} for aldrin in laboratory animals is in the range of 33mg/kg body weight for guinea pigs to 320 mg/kg body weight for hamsters. The International Authority for Research on Cancer (IARC) has concluded that there is inadequate evidence for the carcinogenicity of aldrin in humans, and there is only limited evidence in experimental animals (ATSDR, 2005). Dairy products, such as milk and butter, and animal meats are the primary sources of exposure to aldrin.

1.7.2 Dieldrin

Its chemical name is 3,4,5,6,9,9-Hexachloro-1,2,2,3,6,6,7,7-octahydro-2,7,3,6-dimethanonapth [2,3-b] oxirene (Appendix 1.0). Dieldrin has been used in agriculture for the control of soil insects and several insect vectors of disease. The latter use has however been banned in a number of countries including Kenya due to environmental and human health concerns. Principal contemporary uses are restricted to control of termites and wood borers and against textile pests (WHO, 1989). Dieldrin binds strongly to soil particles and hence is very resistant to leaching into groundwater. Volatilization is an important mechanism of loss from soil and because of its persistent nature and hydrophobicity, dieldrin is known to bioconcentrate. Action to ban dieldrin has been taken in many countries, while its use is severely restricted in numerous countries. In Laboratory studies, the acute oral LD_{50} value is in the range of 37 mg/kg body weight for rats to 330 mg/kg in hamsters. The No Observed Adverse Effect Level (NOAEL) in rats is 0.5mg/kg diet, equal to 0.025 mg/kg body weight/day. There is limited evidence that cyclodienes such as dieldrin may affect immune response. From several studies IARC has concluded that there is inadequate evidence for the carcinogenicity of dieldrin in humans, but limited evidence exists for experimental animals and it has been classified as a member of group III by IARC.

The acute toxicity of dieldrin is quite variable for aquatic invertebrates; with insects being the most sensitive group (value range from 0.2-40 μg/L). It is highly toxic to most species of fish tested in the laboratory (values range from 1.1-41μg/L). The half life of dieldrin in temperate soils is approximately 5 years. This persistence, combined with high lipid solubility, provides the necessary conditions for dieldrin to bioconcentrate and biomagnify in organisms. Dieldrin's chemical properties (low water solubility, high stability, and semi-volatility) favour its long range transport, as it has been detected in arctic air, water and organisms. Dieldrin residues have been detected in air, water, soil, fish, birds and mammals, including humans and human breast milk. Diet is the main source of exposure to the general public. The average daily intake of aldrin and dieldrin in India was calculated to be 19 μg/person, exceeding the acceptable daily intake of 6.0 μg/60 kg of body weight recommended by the Joint FAO/WHO. Dairy products, such as milk and butter, and animal meats are the primary sources of exposure.

1.7.3 DDT

DDT whose chemical name is 1, 1'-(2, 2, 2-trichloroethylidene) bis (4-chlorobenzene) (Appendix 1.0) was widely used during the Second World War to protect the troops and civilians from the spread of malaria, typhus and other vector borne diseases. After the war, DDT was widely used on variety of agricultural crops and for the control of disease vectors as well. It is still being produced and used for vector control in some countries. Growing concern about adverse environmental effects, especially on wild birds, led to severe restrictions and ban in many developed countries in the early1970s.

The largest agricultural use of DDT has been on cotton, which accounted for more than 80% of use in the USA before its ban in 1972. DDT is restricted for use in indoor spray in the control of malaria vectors in many countries including Kenya. DDT is highly insoluble in water but soluble in most organic solvents. It is semi-volatile and can be expected to partition into the atmosphere as a result. Its presence is ubiquitous in the environment and residues have even been detected in the artic. It is lipophilic and partitions readily into the fat of all living organisms and has been demonstrated to bioconcentrate and biomagnify. The breakdown products of DDT, 1, 1 dichloro-2, 2-bis (4-chlorophenyl) ethane (DDD or TDE) and 1, 1 dichloro-2,2 bis (4-chlorophenyl) ethylene (DDE), are also present virtually everywhere in the environment and are more persistent than the parent compound. The use of DDT has been banned in 34 countries and severely restricted in 34 other countries. DDT that was banned in developed countries long ago was banned for use in Kenya in 1987 and has been replaced by the organophosphate pesticides (PCPB, 1997).

Studies conducted in temperate regions have shown that the organochlorine pesticide p, p'-DDT and its main metabolite p, p'-DDE have high persistence in the environment and are therefore considered environmental contaminants (Bierman and Swain, 1982; De Cock and Rand, 1984). DDT and its metabolites are still reported as major marine contaminants and are some of the main pollution indicators in pollutant monitoring surveys due to their bioaccumulation in sediments and marine organisms (Carvallo *et al.*, 1992; Tanabe *et al.*, 1993; Sericano *et al.*, 1995; Hong *et al.*, 1995). However DDT has been found to dissipate fast and very effective in disease vector control (Cooke and Stringer, 1982; IAEA, 1988; Haken *et al.*, 1992).

1.7.4 Endrin

Endrin whose chemical name is 1,2,3,4,10,10-hexachloro-6,7-epoxy-1,4,4a,5,6,7,8,8a-octahydro-1,4-endo-5,8-dimethanonaphthalene (Appendix 1.0) is a foliar insecticide used mainly on field crops such as cotton and grains. It has also been used as a rodenticide to control mice and moles. It is rapidly metabolized by animals and does not accumulate in fat to the same extent as other compounds with similar structure such as dieldrin. It can enter the atmosphere by volatilization and can contaminate surface water from soil run-off. Endrin is banned in many countries and its use is severely restricted in many others. A study of workers involved in the production of aldrin, dieldrin and endrin did not find endrin in their blood, except in cases of accidental or acute over-exposure. The study found a statistically significant increase in liver and biliary tract cancers in the workers, although the study did have some limitations such as lack of quantitative exposure information. There is limited evidence that a cyclodiene such as endrin may also depress immune response (ATSDR, 2005).

The formation of anti-1,2-hydroxyendrin is considered to be the major route of metabolism of endrin. IARC has concluded that there is inadequate evidence for the carcinogenicity of endrin in humans, and there is only limited evidence in experimental animals. Unlike dieldrin, endrin is therefore not classifiable due to its low carcinogenicity in humans. Endrin is highly toxic to fish, with LC_{50} values below 1.0 μg/L. The Lowest Observed Adverse Effect Levels (LOAEL) for aquatic organisms was 39ng/L over 20 days for reproduction in mysid shrimps. The half life of endrin in soil in temperate regions may be up to 12 years, depending on local conditions. This persistence combined with a high partition coefficient (3.21-5.340), provides the necessary conditions for endrin to bioconcentrate in organisms; although it disappears rapidly. Bluegill sunfish exposed to water containing 14C-labelled endrin took up

91% radiolabeled endrin within 48 hours with half life of loss from the tissues of approximately 4 weeks.

The chemical properties of endrin (low water solubility, high stability in environment, and semi-volatility) favour its long range transport and it has been detected in arctic freshwater. The main source of endrin exposure to the general population is through intake of residues in food. However, contemporary intake is generally below the acceptable daily intake of 0.0002 mg/kg body weight recommended by the joint FAO/WHO. Recent food surveys have generally not included endrin, and hence recent monitoring data are not available (ATSDR, 2005).

1.7.5 Endosulfan

Endosulfan, whose chemical name is 6,7,8,9,10,10-hexachloro-1,5,5a,6,9,9a-hexahydro-6,9-methano-2,4,3-benzodioxathiene-3-oxide (Appendix 1.0) is a neurotoxin organochlorine insecticide of the cyclodiene family of pesticides. It is highly toxic and endocrine disruptor. It has been banned in countries such as Germany, Norway and the Philippines. It is still used extensively in many countries including the US and India. Manufacturers have used several trade names such as Thionex, Thiodan, Phaser and Benzoepin for it. It is used in agriculture around the world to control insect pests including aphids, leafhoppers, Colorado potato beetles, cabbage worms and other pests. It has also been used in tsetse fly control, in wood preservation, and in home gardening. Endosulfan on crops usually breaks down within a few weeks, but sticks to soil particles and may take years to completely breakdown. This compound does not easily dissolve in water. On surface water it is attached to soil particles floating in water or attached to sediments at the bottom.

Endosulfan affects the normal functions of central nervous system (CNS). Hyperactivity, nausea, dizziness, headache, vomiting, diarrhea, or convulsions have been observed in adults exposed to high doses and severe poisoning may result in deaths (ATSDR, 2000). Doses as low as 35 mg/kg body weight have been documented to cause death in humans (IPCS, 2000) and many cases of sub-lethal poisoning have resulted in permanent brain damage (ATSDR, 2000). It is acutely neurotoxic to both insects and mammals including humans. The US EPA classifies it as Category I, "Highly Acutely Toxic" based on a LD_{50} of 30 mg/kg for female rats (USEPA, 2002), while WHO classifies it as Class II "Moderately Hazardous" based on LD_{50} of 80 mg/kg (WHO, 2005). Endosulfan is not listed as known, probable, or possible carcinogen by the EPA, IARC, or other agencies. There are no epidemiological studies linking exposure to endosulfan specifically to cancer in human but *in vitro* assays have shown that it can promote proliferation of human breast cancer cells (Grunfeld *et al.*, 2004). Evidence of carcinogenicity in animals is mixed (ATSDR, 2000).

According to EPA, endosulfan breaks down into endosulfan sulfate and endosulfan diol, both of which have "structures similar to the parent compound and are also of toxicological concerns. The estimated half lives for the combined toxic residues (endosulfan plus endosulfan sulfate) range roughly from 9 months to 6 years. Its recommended level is not more than 74 ppb (parts per billion) in lakes, streams or rivers, and not more than 0.1-2 ppm (parts per million) on surface of agricultural products before consumption. Food and Drug Administration (FDA) allows no more than 24 ppm endosulfan on dried tea.

1.7.6 Heptachlor

Its chemical name is 1,4,5,6,7,8,8-Heptachloro-3,4,4,7,-tetrahyro-4,7-methanol-1*H*-indene. It is a non-systemic stomach and contact insecticide, used primarily against soil insects and termites. It has also been used against cotton insects, grasshoppers, some crop pests and to combat malaria. Heptachlor is highly insoluble in water, and is soluble in organic solvents. It is quite volatile and can be expected to partition into the atmosphere as a result. It binds readily to aquatic sediments and bioconcentrates in fats of living organisms. Heptachlor is metabolized in animals to heptachlor epoxide, whose toxicity is similar to that of heptachlor, and which may also be stored in animal fat. The use of this compound has been banned in several developed and developing countries; Kenya included (NIP, 2006). A study of workers from a plant involved in the manufacturing heptachlor and endrin found a significant increase in the cancer of the bladder. This result was unexpected as no known bladder carcinogens were used at the plant. However, the small number of deaths (NLM, 1992) makes interpretation of these findings difficult. No deaths from liver or biliary tract cancer were observed, although mortality from cerebrovascular diseases was higher than expected. There is limited evidence that cyclodienes such as heptachlor may affect immune response in humans. The acute oral LD_{50} of heptachlor in laboratory animals is in the range of 4mg/kg body weight in rats to 116mg/kg in rabbits. Symptoms in animals include tremors and convulsions.

1.7.7 Lindane

Hexachlorocyclohexane (HCH), formally known as benzene hexachloride (BHC), exists in eight isomers. The different isomers are named according to the position of the hydrogen atoms in the structure of the chemical. Gamma HCH (or γ–HCH, commercially called lindane), is used as an insecticide on fruits, vegetables, and forest crops, and animals and animal premises. It is available for insecticidal use as a dust, powder, liquid concentrate. It is also available as a prescription medicine (lotion, cream or shampoo) to treat and/or control mites and head lice in humans (ATSDR, 2005).

Technical-grade HCH, a mixture of several isomers of HCH typically contains 10-15% of γ–HCH as well as the alpha (α), beta (β), delta (δ), and epsilon (ε) forms of HCH. Virtually all the insecticidal properties are due to the gamma isomer (lindane). Available information about ε isomer is limited. The α-, β-, γ-, and δ-HCH have been found in soil and surface water at hazardous waste sites in United States because they persist in the environment. In air, the different forms can be present as vapour attached to small scale particles such as dust. The particles may be precipitated from the air by rain or degraded by other compounds in the atmosphere. HCH can remain in the air for long periods and travel great distance depending on the environmental conditions. In soil, sediments, and water, HCH is broken down to less toxic substances by algae, fungi, and bacteria, but this process can take a long time (ATSDR, 2005). In general, HCH isomers and the products formed from them in the body can be temporarily stored in body fat. The isomers and the products formed from them in the body are more rapidly excreted in the urine and small amounts in faeces. HCH breaks down in the body to many other substances, including various chlorophenols, some of which have toxic properties.

In humans, breathing toxic amounts of γ -HCH and/or α-, β-, and δ –HCH can result in blood disorders, dizziness, headaches and possible changes in the levels of sex hormones in the blood. These effects have occurred in workers exposed to HCH vapour during pesticide manufacture and application. People who have swallowed large amounts have seizure and some have died. A few people who have used γ-HCH frequently on their skin developed blood disorders or seizures. However, no cause-and-effect relationship between exposure to γ-HCH and blood disorders in humans has been established. Animals that have been fed γ- and α –HCH developed convulsions, while those fed β–HCH have become comatose. All HCH isomers can produce liver and kidney effects (Kashyap *et al.*, 1979: Minur *et al*; 1983). The US Department of Heath and Human Services (DHHS) have determined that all isomers of HCH may reasonably be anticipated to cause cancer in humans. IARC has classified HCH (all isomers) as possible carcinogenic to humans.

The EPA has established suggestive evidence that lindane (γ-HCH) is carcinogenic, but the evidence is not sufficient to assess its human carcinogenic potentials. The EPA has additionally classified technical HCH and α-HCH as probable human carcinogens while β-HCH is a possible human carcinogen. The δ- and ε–HCH have not been linked to human carcinogenicity. EPA has recommended guidelines on how much HCH can be present in drinking water for specific periods without producing health effects. It advises that children should not drink water containing more than 1.2 mg HCH per liter of water (mg/L) for 10days. For life time exposure in adults, EPA recommends that there should not be more than 0.0002mg/L of HCH in drinking water. EPA has classified HCH as a "Hazardous Waste" that must meet certain disposal requirements. According to US Occupational Safety and Health Administration (OSHA) regulations, maximum allowable amount of γ–HCH in workplace air during an 8-hour workday in a 40-hour work week is 0.5 mg per cubic meter of air (ATSDR, 2005)

1.7.8 Methoxychlor

Methoxychlor whose chemical name is 1,1'-(2, 2, 2-trichloro-ethylidene)bis[4-methoxybenzene], is an insecticide applied to protect crops, ornamentals, livestock, and pets against fleas, mosquitoes, cockroaches, and other insects. It has been used to some degree as a replacement for DDT as it is faster metabolized and does not lead to bioaccumulation (Smith, 1991). Methoxychlor has chemical structure and properties similar to those of DDT, but it biodegrades more easily. Aquatic organisms metabolize it and transform it into other less toxic substances and therefore it does not lead to significant bioaccumulation phenomena.

The amount of methoxychlor in the environment is seasonal due to its periodic utilization in farming. Sprayed methoxychlor settles in the ground and degrades more rapidly in aerated soil than in that without oxygen. It is tightly bound to soil and does not dissolve readily in water, so it is not expected to be very mobile in moist soils (Smith 1991). The risk to groundwater should be slight, but may be greater if application rates are very high, or the water table is very high. The movement of pesticides is more likely via adsorption to suspended soil particles in runoffs. In hydrosoils (sediments in an aquatic environment), degradation of methoxychlor to methoxychlor olefin (methoxy dichloro ethane, MDE) occurs only under aerobic conditions (Menzie, 1980). In open water the major products of breakdown in a neutral solution are anisil, and p,p-dimethoxydichloroethene (DMDE). The half-life in distilled water is 37 to 46 days but in some river waters in the US the half-life may be as rapid as 2 to 5 hours (Smith 1991).

Methoxychlor evaporates slowly, but the evaporation may contribute to the cycling of the products in the environment. While methoxychlor is ingested and absorbed by living organisms, it is readily released and does not build up in food chain. It is possible that some metabolites have unwanted side effects. Rats fed on methoxychlor at doses of 500 mg/kg/day for 2 years showed practically no weight gain. but this was attributed to refusal of food rather than any toxic effects of the compound (ATSDR. 2002). Available evidence suggests that high doses of technical methoxyclor (88 to 90% pure) or its metabolites may have estrogenic or reproductive effects (NLM. 1992). EPA has labeled methoxychlor to be in the Toxicity Class IV. It is available as a General Use Pesticide (GUP) and labels for products containing it must bear the signal word CAUTION. For drinking water. EPA established 40ppb as the Maximum Contamination Level (MCL) (NLM. 1992).

1.8 Studies Conducted in Kenya

1.8.1 Pesticide Residues in Water

Various studies conducted in Kenya have shown varying levels of contamination by pesticide residues. Madadi (2005) analysed water. fish. sediments and weeds from Rivers Sio and Nzoia and Lake Victoria (Marenga and Sio Port sites in Kenya) and detected organochlorines and organophosphate pesticides at varying frequencies and concentrations. The disparities were attributed to differences between the sites. sample types. seasons. environmental factors and previous and current use of the compounds. In general. the total residues of DDT. HCH. methoxychlor and endrin were within the WHO limit guidelines for drinking water. whereas aldrin. dieldrin. heptachlor. heptachlor epoxide and endosulfan were above the recommended values. On the other hand. the detected levels of DDT. lindane. heptachlor and endosulfan were above the US EPA and Australian guidelines for drinking water. The total residues of organochlorines detected were higher than those of organophosphorous pesticides.

Getenga *et al.*, (2004) found α-BHC. β-BHC. lindane. endosulfan. heptachlor. aldrin. heptachlor epoxide. dieldrin. endrin and methoxychlor residues in water and soil samples collected from five sampling points along River Nyando. They found residue levels of lindane and α–BHC to be the highest, with α–BHC showing average concentration of 0.219±0.091mg/L for six sampling points, except one point that showed concentrations as high as 0.691mg/L. The same study reported concentration of lindane in water as high as 1.240 mg/L. Wandiga *et al.*, (2002) reported residues of aldrin, α-endosulfan, dieldrin, endrin, DDT, DDE, DDD and lindane in sea-water, sea weeds, sediments and fish from the Coastal region of Kenya. They found levels ranging from 0.503-9.025 ng/l in sea water.

1.8.2 Pesticide Residues in Fish

Wandiga *et al.*, (2002) found concentrations of 1011ng/g and 418ng/g of p, p'-DDT and p, p'-DDD respectively, in fish from the Kenya coastal region. Mugachia *et al.*, (1992), detected the presence of organochlorine pesticide residues in six species of fish from the Athi River estuarine. The concentrations decreased in the order p,p'-DDE, p,p'-DDT, p,p'-DDD, β-HCH, α-HCH, heptachlor and o,p'-DDD. Detected residues showed higher levels in the liver and egg samples than in the fish fillets. The sharks being at the top of the food chain had the widest range of the pesticides residues and significantly higher mean concentrations of DDT compared to shrimps and catfish.

Mitema and Gitau (1990) detected low levels of β-BHC, α-BHC, aldrin, dieldrin, lindane and p'p'-DDT in Nile Perch from Lake Victoria. The p, p'-DDT and its metabolites formed the largest portion of pesticides in the fish samples. The presence of these residues was attributed to various uses of the pesticides in agriculture and aerial control of mosquitoes in the lake region. A study conducted in the Hola irrigation scheme by Munga (1985) demonstrated a strong correlation between DDT and endosulfan tissue residues and the level of fat in fish. Munga examined pesticide residues of DDT and endosulfan in four species, *Clarias gariepinus* Burchell, 1822 (Silviformes: Claridae), Labeo *gregorii* Boulenger, 1903 (Cypriniformes: Cyprinidae), *Oreochromis mossambicus* Peters, 1852 (Perciformes: Cichlidae), and *Tilapia zilli* Gervais, 1848 (Perciformes: Cichlidae) (*C. Mossambicus* is synonymous to *C. gariepinus*).

Pesticide concentrations from lateral muscle and liver tissue and eggs of these species were measured. Liver had the highest concentrations of total (Σ) DDT and endosulfan (based on wet mass), followed by eggs and muscle tissue. The mean concentration of Σ DDT in liver was approximately 7.1 times, and 2.4 times higher than in muscle and eggs, respectively, while the concentration of endosulfan in liver was 12.5 and 5 times higher than in muscle and eggs, respectively. The relative concentrations of Σ DDT and endosulfan in liver egg and muscle tissue (based on wet mass) from *C. gariepinus* showed a pattern different from that of *L. gregorii*. The primary metabolites of *p, p'*-DDT are *p, p'*-DDE and *p, p'*-DDD (Wedemeyr, 1968). The metabolite *p, p'*-DDE is more stable than either *p, p'*-DDD or *p, p'*-DDT and tends to accumulate in adipose tissue (Wedemeyr, 1968; Cherrington *et al*., 1969). Lincer *et al*., (1981) found the bottom feeding fish, *Labeo cylindricus* Peters, 1852 (Cypriniformes: Cyprinidae), from Lake Baringo had a concentration of 0.4 mg/kg wet mass of *p, p'*-DDE in muscle tissue. Apart from the isolated sample of *L. cylindricus* from Lake Baringo, Σ DDT residue levels in fish were higher in samples from the Hola irrigation scheme studied by Munga (1985), than elsewhere in Kenya. Koeman *et al*., (1972) found total DDT (Σ DDT) residue levels in fish of 1.0-7.0 x 10^{-3} mg/kg wet mass, while Lincer *et al*., (1981) found DDE levels in fish of 7.4 x 10^{-2} mg/kg wet mass and DDE levels in biota of 4 x 10^{-2} mg/kg wet mass from Lake Nakuru. These levels are much lower than concentrations found more recently in marine species (Everaarts *et al*., 1996; Barasa, 1998). The differences may be attributed to the drainage areas covered by rivers emptying into the lakes and the agricultural activities upstream. The Sabaki River drains a larger area with varied agricultural and industrial activities into Indian Ocean. They found very low levels of Σ DDT (<0.001-0.064 mg/kg) in Lake Nakuru birds and fish (Lincer *et al.*, (1981).

1.8.3 Pesticide Residues in Sediments

Recent research has reported presence of pesticides residues in sediment samples from the Coastal region of Kenya. Wandiga *et al.*, (2002) reported presence of residues of lindane, aldrin, p,p,-DDT and p,p'-DDE. Endosulfan, dieldrin, p,p'-DDD and endrin were either present in low concentrations or absent in most of the samples, with concentrations range of 0.584-59.00 ng/g in sediments. Everaats *et al.*, (1996), showed presence of pesticides residues in sediments and macroinvertebrates organisms along the Kenyan Coast. Samples collected from the shallow coastal stations at the mouth of Sabaki River were contaminated with PCB congeners 28, 52, 101,138 and 153 in the concentration range of 7.1 to 62.2ng/g of organic carbon. p,p-DDE was also detected at levels ranging from 32.1 to 508.8ng/g of organic carbon. Contamination by α-HCH was detected in increasing amount across the continental shelf at both shallow and deep-water stations along the Kenyan Coast, whereas γ–HCH was detected in samples from six stations at concentrations ranging from 7.3 to 53.2ng/g of organic carbon. The shallow sediments of Sabaki River contained high levels of dieldrin and p,p'-DDE at concentrations of 37 ng/g and 510 ng/g organic carbon, respectively.

According to Harkey (1994; Wilcock *et al.*, (1993) and Phipps *et al.*, (1993), different organisms living in identical media tend to accumulate different levels of pollutants. Carvalho *et al.*, (1992) suggested that tropical fauna living in sediments accumulate a substantial fraction of pesticides and other pollutants absorbed directly from the sediments. Also Pollution of streams and rivers by agricultural wastes and chemicals has led to habitat destruction and exposure to pollution for fish and species of other organisms which live in brackish water on the island of Mauritius in the Indian Ocean (UNEP, 1984). These findings were a cognitive tool to our study on River Nyando. Our study aimed at establishing what the case for the Nyando drainage basin holds.

1.8.4 Pesticide Residues in Soil

Getenga *et al.*, (2004) found α-BHC, β-BHC, lindane, endosulfan, heptachlor, aldrin, heptachlor epoxide, dieldrin, endrin and methoxychlor in soil from the sugar belt zone of Lake Victoria. They reported higher levels of α–BHC, β-BHC and lindane compared to the other pesticides. A number of laboratory studies have been carried out on DDT, DDE and lindane to establish the behaviour of their residues in soil (Sleischer and Hopcraft, 1984: Wandiga and Natwaluma, 1984: Wandiga and Mughenyi, 1988: Lalah *et al.*, 1994: Ng'ang'a, 1994). The half-lives of the pesticides studied showed faster dissipation rates under Kenyan tropical climate compared to the temperate climates (Wandiga, 1996).

1.8.5 Pesticide Residues in Animals and humans

The persistence of pesticides at the top of the food chain has been exhibited by detection of various pesticides in cows'milk, birds' eggs and human breast milk. Maitho (1978) detected low levels of p.p,-DDT, p.p,-DDE, lindane, aldrin and dieldrin in cattle fat. Kituyi *et al.*, (1997) found contamination of cow milk by chlorofeniphos residues at levels ranging between 0.52 and

3.90 mg/kg of milk fat in dry seasons and 1.58 to 10.69 mg/kg during wet seasons. The same study showed that milk collected from plunge dipped cows had higher concentrations of the pesticide than milk obtained from hand sprayed cows.

Kahunyo *et al.*, (1986) detected high levels of p, p'-DDT and dieldrin residues in chicken eggs from Embu district. The contamination was attributed to free range system of rearing poultry, which allowed free forage for food exposing them to pesticide residues around the farm. Wandiga and Mutere (1988) detected γ–HCH in human milk sampled from patients at a Nairobi hospital. The residue levels of the γ–HCH ranged from $9X10^{-6}$ to 1.0mg/kg. Kanja (1988) had earlier on detected thirteen organochlorine pesticides in human milk collected from eight different areas in Kenya. The pesticide frequencies were noted to vary with the pesticide type: p,p'-DDT (100%), p,p'-DDE (100%), HCB (60%), aldrin (35%), lindane (30%), β-HCH (27%), dieldrin (20%), α-HCH (8%), heptachlor (4%), endrin (4%) and heptachlor epoxide (0.4%). In another study, higher levels of DDT and HCH isomers were reported in human serum samples in India (Bhatnager *et al.*, 2004), who found the concentrations of Σ DDT at 32.61±2.32µg/L while that of Σ HCH at 41.23±3.77µg/L and BHC 0.20±0.002µg/L. Studies conducted in Canada reported medium and maximum whole blood levels of BHC as 0.11 and 0.34 ppb (Mes, 1992).

1.8.6 Pesticide Residues in Macro-invertebrates

Everaarts *et al.*, (1996) detected presence of polychlorinated biphenyls (PCB) and cyclic pesticides in benthic organisms from the Kenyan Coast. They reported higher concentrations of PCB congeners and cyclic pesticides at the mouth of River Sabaki than at the mouth of River Tana. The bivalve molluscs from the mouth of River Sabaki and Kiwaya Bay had the highest levels of PCBs. Residues of p,p'-DDE were detected in all the samples at levels ranging from 15 to 48 ng/g of lipid in both bivalves and gastropod molluscs. The contamination was attributed to washout effects from the river flow, as evidenced from the gradient (increasing) across the continental slopes towards deep water. All the animal groups analyzed showed the presence of PCBs and p, p'-DDE. The gastropod molluscs and edible peracid prawns had the highest levels of the compounds.

1.9 Extraction methods for organochlorine pesticides from various matrices

For sediment, soil and weed samples classical soxhlet extraction method has been widely used. For water samples classical extraction techniques liquid/liquid extraction or solid-phase extractions (SPE) have commonly been employed. The extract is transferred to suitable solvents and a three-stage open-column clean-up using silica, alumina or carbon is followed by gas chromatography-electron capture detection.

1.9.1 Soxhlet extraction of soil and sediments

The analysis of organochlorine pesticide residue in soil, sediments and weeds use classical soxhlet extraction. The procedures are documented in detail in sections 2.4.1.1, 2.5.1.2 and 2.5.3.1 respectively

1.9.2 Solid Phase Extraction (SPE) for water samples

A measured volume of sample is adjusted to a specific pH and then extracted using a Solid-phase Extraction (SPE) device. Target analytes are eluted from the solid-phase media using methylene chloride (dichloromethane) or other appropriate solvents (Tomkins *et al*., 1992). The resulting solvent extract is dried using sodium sulphate and concentrated. The concentrated extract may be exchanged into solvent compatible with subsequent cleanup procedures or determinative procedures employed for the measurement of the target analytes.

The decomposition of some analytes has been demonstrated under basic extraction conditions. Organochlorine pesticides may dechlorinate. The rates of dechlorination reaction increases with increasing pH and reaction times. Bonded phase silica (C_{18}) will hydrolyse on prolonged exposure to aqueous samples with pH less than 2 or greater than 9. Hydrolysis will increase at the extremes of this pH range and with longer contact times. Hydrolysis may reduce extraction efficiency or cause baseline irregularities. Styrene divinylbenzene (SDB) extraction disks should be considered when hydrolysis is a problem.

Sample particulate may also clog the solid-phase media and results in extremely slow sample extractions. Use of an appropriate filter aid results in shorter extraction time without loss of method performance if clogging is a problem. Even when a filter aid is employed, this method may not be appropriate for aqueous samples with high levels of suspended solids (> 1%), as the extraction efficiency may not be sufficient, given the small volumes of solvents employed and the short contact time.

1.9.3 Liquid-Liquid Extraction for Water Samples

The problems of dechlorination of organochlorine pesticides, hydrolysis of bonded phase silica (C_{18}) and clogging of solid-phase media makes liquid-liquid extraction a method of choice for organochlorine pesticide analyses in turbid river water over solid phase extraction (SPE). The procedure for liquid-liquid extraction has been documented in detail in sections 2.5.1.1.

1.10 Separation and detection methods for oragnochlorine pesticides

1.10.1 Gas Chromatography

1.10.1.1 General Principle

Gas chromatography (GC) has become the most commonly used method for the separation and quantification of pesticides in various matrices. Gas chromatography accomplishes separation by partitioning solutes between a mobile gas phase and stationary phase which may be a liquid held on a soild adsorbent support. Sample containing the solutes is injected into a heating block where it is immediately vapourised and swept as vapour by carrier gas stream into the column. Each solute travels at its own rate, influenced by differences in partition coefficients between the liquid stationary phase and the mobile gas phase. The separated components emerge from the far end of the column at different times and pass through a detector which measures the concentration. Out-put from the detector is feed into a recorder and each chemical is registered as a peak. Time spent in the column between injection and detection is known as the retention time and is characteristic for each compont under a specific set of operating conditions. Peak area is proportional to the amount of compound that has passed through the detector. Gas chromatography thus provides both quantitative and qualitative measurements. Gas chromatography is an important technique for determination of pesticide residues in different matrices.

1.10.1.2 Detection

A good GC detector should have high sensitivity (high signal to noise ratio). low limit of detection. It should have good linearity and a wide linear working concentration range so that it is not easily overloaded. High selectivity in detectors is important so that there is only response from the compound of interest in sample being analysed. Detectors commonly used for GC analyses include Flame Ionozation (FID), Thermal conductivity (TCD), Electron capture (ECD), Flame photometric (FPD) and Nitrogen phosphorous (NPD). The FID, TCD and ECD are the most commonly used detectors for routine work.

1.10.1.2.1 Flame Ionization Detector

The Flame ionization detection is based on the principle that organic compounds when combusted in a hydrogen/air flame produce ions

$$\text{Compound} + H_2 + O_2 \rightarrow CO_2 + H_2O + (\text{ions})^{+} + (\text{ions})^{-}$$

Combination of the negatively charged species and electrons create a current flow. The ions are collected by a pair of polarized electrodes inside the FID to generate current which is amplified into a measurable signal. The larger the amount of compound in a sample the higher the current and therefore the larger the signal. FID have a linear working range of 10^{-9} to 10^{-2} g , and detection limit to the order of 10^{-9} g (1 ng).

1.10.1.2.2 Thermal conductivity detector

Thermal conductivity detectors are based on the fact that the temperature and thus the resistence of a wire through which a current is flowing is dependent upon the thermal conductivity of the gas in which it is immersed. The thermal conductivity of a gas is a function of its composition. The detector has two sides (known as the reference and sample sides) in which identical wires are used. These wires are connected to Wheatstone bridge and heated by passage of a current.

The carrier gas flow through the reference side before the sample is injected in the bridge and thus reference side always contains gas the same composition. The gas flows through the sample side as it exits from the column and thus contains the separated components as well as the carrier gas. When there is no component exiting from the column, the gas in the two sides is identical, and the Wheatson Bridge remains in balance since the wires have the same temperature. As soon as a sample component enters the sample side, the composition of the sample side differs from the reference side. This causes a change in temperature of the wire and an imbalance is a function of the concentration of the component in the carrier gas, the recorder draws the elution curve for the chromatographic process. The limit of detection for TCD is of the order 10^{-7} g. The TCD is universal, accommodates large sample sizes, is non-destructive and is used in the analysis of water and inorganic compounds.

1.10.1.2.3 Electron capture detector

An ECD has a beta-emitting source (eg Ni^{63} or tritium) in its house chamber. Bombardment of the carrier gas with the beta radiation causes ionization of the gas to occur in which electrons are produced.

N_2+β-particles → N_2^+ + thermal electrons or low energy electrons

When a potential between the source and anode is applied, a current is produced by aggregation of the electrons in the chamber. If an electrophilic compound is present in the chamber, a reaction can occur in which the collected electrons are captured. The capture of the electrons is the basis of ECD detection. The net process is the replacement of fast moving electrons with slow moving negative ions in the chamber. The process results in a change in standing current of the detector as the compound elutes. This change is measured and displayed on the chromatogram after appropriate amplification.

The ECD is selective towards molecules containing the electronegative atoms, nitrogen. oxygen, sulphur and particularly halogens. hence pesticides give excellent response. It requires a clean laboratory environment to avoid contamination of the radioactive ionization source. It has a detection limit of 10-12 g. Due to its high sensitivity, an ECD unless carefully handled is easily contaminated and is difficult to use and maintain. Quantification of a sample component can easily be made by comparing it with known amounts of oure analytical standard under the same GC conditions.

1.11 Information Gaps

Use of pesticides is one of the major components of chemical revolution, which altered agricultural methods (Hassall, 1990). A component that creates alternative agricultural methods such as the use of pesticides should be lauded. But the weaknesses and threats associated with it cannot be over looked. By extensive use of pesticides many countries have become self-sufficient in total food needs. However, pesticides being toxic compounds to the target material may have a detrimental effect to non-target organisms. Lake Victoria was in the news on March 30th, 1999, not because its waters had claimed lives in a boating accident, but because it was reportedly awash with toxic chemicals from agricultural farmland that threaten marine and human life (Daily Nation, 1999). Fishermen around the lake were accused of using chemicals to harvest fish resulting in a ban on all the fish export to European Union (EU) markets. The EU demanded that the three East African countries submit a list of all chemicals sold in the region, their toxicity to humans and their persistence in fish and water before any negotiations begun (Daily Nation, 2000). There is no evidence that a comprehensive analysis of pesticide use, distribution and fate has been done in water, soil, sediments and fish in Lake Victoria or any of its tributaries to date.

Agricultural sector in Kenya heavily depends on pesticides (PCPB, 2007). Although there are scarce data available on the residue levels of pesticides in soil, water, fish and sediments from other rivers and lakes (Koeman, 1972: Lincer *et al.*, 1981: Munga, 1985: Everaats *et al.*, 1996) there is very little information on Lake Victoria and its waterways (Getenga *et al.*, 2004: Madadi, 2005). Lack of this information has resulted in the absence of surveillance programs for pesticide residue levels in the agricultural and fisheries products from the Lake Victoria basin. Lake Victoria fishing earns the country between KSh 4 billion and KSh. 6 billion (USD 85 million) annually from fish exports. However, experts warn that all this might be lost if laxity is allowed to continue in this industry (Daily Nation, 1999). Monitoring of pesticide residue levels in soil, fish, water and agricultural products in Lake Victoria basin and its drainage system has recently attracted a lot of interest for research.

Pesticide residues and their break down products have been found in increasing amounts in water, fish, weeds, soil and sediments from Lake Victoria basin in Kenya (Getenga *et al*., 2004; Madadi, 2005). These studies are in agreement with those from study by Otieno and Okidi (1992) and raise great concern, since total load could easily reach levels that are irreversibly damaging to the lake water. Other studies aimed at providing baseline information on the current levels of organochlorine pesticide residues in aquatic system of Lake Victoria showed ratios of DDE to DDT suggesting previous use of the pesticides and significant use of lindane and endosulfan within the Lake Victoria basin in Uganda (Mbabazi, 1998; Kasozi, 2001). Most of these compounds are introduced every year, often without a full understanding of the risks they pose to the environment in general, human health and aquatic life in particular. They have two effects on humans, immediate short-term toxicity and reactions from long-term exposure. Both effects can result in chronic symptoms and death. Even as the impassioned debate about the quality of Lake Victoria's water ecosystem rages in media and the various researches done on the lake's water, there is no evidence that a well targeted comprehensive analysis has been done on the lake or any of its drainage basins.

The levels of pesticide residues in each waterway and that of the lake remain unknown to date. Data from the study of pesticide residue levels in the drainage to the lake and that of the lake itself is therefore needed. Bad agricultural practices like cultivating on slopes adjacent to rivers and on river bank have caused massive soil erosion. As a result of this, the rivers in Lake

Victoria catchments are carriers of both sediments and nutrient loads that chocke the lake (ICRAF, 2000). It is evident that rivers such as River Nyando and Kagera are more prominent in their share of sediments and nutrients deposition into the lake. Sediments are the main carriers of pesticide residues and other organic and inorganic pollutants. Studying River Nyando which is the major Kenyan river source of sedimentation into the lake is important for restoration and management of the lake. The findings above contribute a springboard for our study on the drainage to the Lake Victoria as part of a long-term strategy to conserve ecology in the lake basin. If done for one drainage system, for example, the result will form the basis for the study of the other waterways and that of the lake itself.

1.12 Overall Objective

The objective was to investigate the use of and monitor the residual levels of some selected organochlorine pesticides that have either been banned or restricted with special focus on the River Nyando drainage basin.

1.12.1 Specific Objectives of the Study

Investigation to monitor levels of a few selected banned and restricted organochlorine pesticide residues along the River Nyando drainage basin has been undertaken in an effort to conserve ecology in Kenya's Lake Victoria. The specific objectives were to:

1. Identify the agrochemicals that are in use in the agriculture and their environmental impacts on the ecology of the River Nyando Catchments.

2. Quantify the residue levels of a few selected banned or restricted organochlorine pesticides in soil from different farms along the Nyando drainage basin where coffee, tea, sugarcane, rice, maize and vegetables have been grown over the years.
3. Quantify the residue levels of organochlorine pesticides in water, sediments and aquatic weeds along the Nyando drainage basin.
4. Determine the occurrence, abundance and distribution of benthic macroinvertebrates along the Nyando drainage basin.
5. Link the occurrence, abundance and distribution of benthic macroinvertebrates to effects of some measured physico-chemical parameters and organochlorine pesticide residue levels along the Nyando drainage basin.

1.13 Justification

The River Nyando drainage system traverses three districts (Kericho, Nandi and Nyando) which are major agricultural and industrial zones in Western Kenya region. It serves as a sink for factory effluents from tea, coffee and sugar factories as well as numerous agricultural activities in the basin. The basin has the highest slope and rates of sedimentation compared with all the rivers draining into Lake Victoria. This coupled with the fact that Nyando watershed has been identified as a major source of sedimentation and nutrient flow into Lake Victoria (ICRAF, 2000) justifies its selection for this case study. In Kenya most pesticide pollution cases go undetected, unreported and unanalyzed. It has been argued that poor land-use management practices, use of agrochemicals and the free flow of nutrients and sediments have negative impacts on River Nyando and Lake Victoria (Peters and Meyback, 2000) ecosystem. It was therefore important to monitor agro-chemical pollution problems in Nyando River basin.

CHAPTER TWO

2.0 Materials and Methods

2.1 The Study Area

2.1.1 Climate of River Nyando Catchment

The River Nyando drainage basin covers Kericho, Nyando and Nandi districts in Kenya. It has a catchment area of 3450 km^2 and a total length of 170 km. The drainage basin lies between latitude 0° 25'S to 0°10'N and longitude 34° 50'W to 35°50'E. The climate of Nyando is sub-humid with a mean annual temperature of 23°C. The mean annual rainfall varies from 1000 mm near Lake Victoria to over 1600 mm in the highlands (Njogu, 2000; National Environmental Secretariat, 2002; LVEMP, 1999). The annual rainfall pattern shows no distinct dry seasons and has a bi-model rainfall distribution subsidized by convectional rainfall from Lake Victoria with peaks during long rains (March-May) and short rains (October-December). The rainfall is controlled by north and southward movement of the Inter-Tropical Convergence Zone (ITCZ). However, altitude, proximity to highlands and nearness to lakeshore causes considerable spatial and temporal variation in rainfall (Njogu, 2000).

2.1.2 Population and Land Use in River Nyando Catchment

In general, the study area is dominated by a patchwork of forested and agricultural land, with some tracts of wetlands along the lake. Some portions of the basin area contain developed land and dense network of roads and footpaths. Land use and land cover, population distribution and farming methods have significant influences on the catchments. The population of Nyando catchment is estimated to be about 746,000 inhabitants with an average population density of

214 persons per square kilometer although in some areas the density exceeds 1,200 persons per square kilometer (Hansen, 2000). Rapid population growth of about 3.2% per year (Kenya CBS, 2000) over the last 50 years has led to cultivation of marginal lands on steep slopes, and high livestock densities are common throughout the basin (LVEMP, 1999).

The forests and the wetlands are under threat from population pressures and consequent fragmentation of land. Generally, apparent effects of these threats include loss of biodiversity, rapid deterioration in land cover and depletion of water availability through destruction of catchments and aquifers. Following altitude gradient and subsequent variation in climate, the Nyando watershed can be divided into different land use/cover zones. Small-scale subsistence maize, sorghum and rice farming characterize the lower part of the watershed and the lake plains. At higher altitudes, there are large and small-scale sugar plantations, coffee, tea estates and relatively large-scale maize and horticulture (potatoes, kales, cabbages etc) farms.

Study by LVEMP (1999) showed that the most dominant land use types within the Nyando drainage basin vary with topography and agro-climatic conditions. In upland areas like Londiani, Kipkelion and Tinderet the land is used for fallow/grazing, cultivation, forest, maize and sugarcane farming, marshes and a considerable portion (10 %) is bare ground. Overstocking of livestock within Nyando district is a problem and has resulted in overgrazing and serious gully erosion. The majority of the watershed is more or less continuously cropped. The few exceptions are two remaining forest areas, Tinderet and Mau forests, that are currently being heavily deforested and steep sloping escarpments originally Government trust land are quickly being devegetated through charcoal burning and illegal farming. At the base of the escarpment, numerous streams cut deeply through poor sorted beds of coarse gravel sands and sandy clay in to Kano plain. The area around the lake is characterized predominantly by poor drained, fine textured, deep and fertile black cotton soil. The condition of the soils together with the multitudes of rivulets and low-lying lands that characterizes the area brings about water stagnation. Flooding is therefore a common occurrence and the area is known to suffer from periodic inundation, particularly after heavy rains in the adjacent escarpments and hills.

There is a severe widespread land degradation problem throughout the Nyando River basin that currently affects an estimated 1444-1932 km^2 (39.5-52.9%) of the area (ICRAF, 2000). These include accelerated run-off and sheet erosion over much of the catchments leading to severe rill, gully and stream bank erosion in the lower parts of the river basin as well as landslides in the upper parts in proximity to Tinderet and Londiani areas. The principle cause of erosion in the basin include deforestation of the headwaters and overuse of extensive areas of fragile lands on both hill slopes and plains, coupled with loss of watershed filtering functions through encroachment on the wetlands and loss of riverine vegetation. The sub-surface soils found in Kano plains are virtually impermeable during the dry seasons.

The main livelihood strategy in Nyando basin is farming with many households directly depending on agriculture. The farming depends entirely on the quality of rainy season (Inter-governmental Panel on Climate Change, IPCC, 1997). This is further compounded by the fact that the majority of soils in Nyando River basin are deficient in plant available phosphorous (ICRAF, 2001); low levels constrain the production of crops that people depend upon for their livelihoods.

2.1.3 Ecosystem Services

Ecosystem Services are defined as the "conditions and processes through which natural ecosystems, and the species, sustain and fulfill human life" (Daily G.C. 1997). Ecosystems services are valued for their supporting, regulation, provision and cultural roles (Millennium Ecosystem Assessment, 2003). The use and excessive use of agro-chemicals especially pesticides can adversely affect the generation of ecosystem services through contamination of soil, plants and water and it can also be severe threat to wildlife.

2.2 Identification of agrochemicals in use in River Nyando Basin

2.2.1 Methodology

2.2.1.2 Ecological Risk Assessment

Ecological Risk Assessments (ERA) is defined as a "Process of estimating and characterizing the likelihood that adverse effects of human actions on the environment will occur or have occurred". ERAs generally adopt anthropocentric views rather than ecocentric ones this was done in this study. In this ERA the focus was on ecological and health aspects valued most by the communities along the River Nyando drainage basin.

2.2.1.3 Characterization of exposure and effects

In order to characterize exposure and effects of pesticide use, information from interviews, observations, quantity measurements, literature studies and analyses of pesticide residue levels in samples were used.

2.2.1.4 Focus Group discussions

To get the overview of agrochemicals use especially pesticides, pest problems and pesticide problems connected to the environment and health, interviews were first conducted with six District Agriculture and District Livestock Officers in Nandi, Kericho and Nyando districts. This allowed different opinions to be discussed with the groups and provided the research team with an overview of what was important or not important in the communities regarding the issues at hand. The involvements of the interviewers were kept to minimum, thus promoting much discussion from the Agriculture and Livestock Officers in a focused manner.

2.2.1.5 Participatory Rural Appraisal methods

Participatory Rural Appraisal (PRA) methods were developed primarily to enable effective communication with local communities and as a response to criticism to earlier top-down regulated development work (Bernard, 1994). The overall aim was to collect data through establishing a dialogue with the people of the local communities, thus enabling the informant to discuss and analyze their own situation rather than answering a fixed set of questions developed without any knowledge about the communities to be investigated, meaning that perspective of the local people became the guidelines for this research (Mikkelsen, 1995; Bernard, 1994; Scoones *et al.*, 1994). Using PRA is a way to acquire knowledge about attitudes, local knowledge and values and is therefore important when investigating socio-ecological systems; however, it can not be measured in quantitative terms (Kapoor, 2000). There are potential risks of biasness when interpreting qualitative information. To get as accurate results as possible it is portant for the interviewer to be aware of these risks when conducting field studies as well as en analyzing the results. During the field study and data collection for this research work, the earch team visited farmers and the farms in February, May, September and December 2004 to her information on pesticide use and demarcate the sampling sites (Figure 1.1). This gave the earcher a better understanding of the culture and farming system in different areas along the er Nyando drainage basin. Focus group discussions were held with farmers whose farms were ch closer to the identified sampling points.

total of 115 farmers were interviewed in the whole catchment area as shown in brackets: ndiani (15), Kedowa (20), Lambel farm (8), Kipkelion (13), Muhoroni (6), Songhor (11), bigori (8), Ahero (19), Tinderet (10) and Savani (13) to get information on agrochemicals ed, pest problems and pesticides use in different areas along the Nyando drainage basin. uctured interviews with the farmers in those areas (see questionnaire in Appendix 2.1) and antity measurements of sizes of some farms were done. Finally semi-structured interviews th key informants from government authorities were conducted. In the structured interviews l informants were asked the same specific questions. A semi-structured interview differs from is, here the informants were asked to talk more freely on certain topics.

2.1.6 Structured Interviews

A presentation of the study was held for some Provincial Administration Officers (Chiefs and Assistant Chiefs in some cases). This gave the local communities opportunities to pose questions the research team and the process facilitated further contacts in the villages. In some areas the terviews were done through translation by a local farmer. Structured interviews (appendix 2.1) important for the interviewer to be aware of these risks when conducting field studies as well as when analyzing the results. During the field study and data collection for this research work, the research team visited farmers and the farms in February, May, September and December 2004 to gather information on pesticide use and demarcate the sampling sites (Figure 1.1). This gave the researcher a better understanding of the culture and farming system in different areas along the River Nyando drainage basin. Focus group discussions were held with farmers whose farms were much closer to the identified sampling points.

A total of 115 farmers were interviewed in the whole catchment area as shown in brackets: Londiani (15), Kedowa (20), Lambel farm (8), Kipkelion (13), Muhoroni (6), Songhor (11), Kibigori (8), Ahero (19), Tinderet (10) and Savani (13) to get information on agrochemicals used, pest problems and pesticides use in different areas along the Nyando drainage basin. Structured interviews with the farmers in those areas (see questionnaire in Appendix 2.1) and quantity measurements of sizes of some farms were done. Finally semi-structured interviews with key informants from government authorities were conducted. In the structured interviews all informants were asked the same specific questions. A semi-structured interview differs from this, here the informants were asked to talk more freely on certain topics.

2.2.1.6 Structured Interviews

A presentation of the study was held for some Provincial Administration Officers (Chiefs and Assistant Chiefs in some cases). This gave the local communities opportunities to pose questions to the research team and the process facilitated further contacts in the villages. In some areas the interviews were done through translation by a local farmer. Structured interviews (appendix 2.1) without fixed answers were used: this has in other studies in developing countries (Jones. 1996) proven to be most successful since imposition of exogenous criteria is avoided.

The interviews provided the following information

- Sizes of farms
- Type of farming
- Types of crops grown and farm animals reared
- When are the planting seasons
- Pest and other problems
- Types and quantities of farm chemicals used on farms and on animals
- Farmers knowledge and attitude towards agro-chemicals
- Where the farmers procure the agro-chemicals from
- Farmers' perception on environmental and health problems connected to use of agro-chemicals.
- Disease associated with use of pesticides or any other chemicals

2.2.1.7 Semi-structured Interviews with Key Informants

To supplement the information obtained from the farmers. interviews were also conducted for the government officers. thereby including another perspective of the agro-ecosystem. This group of people provided the researchers with available background data within their specific areas of interest. Scientists from LVEMP and KARI and officers from administration were interviewed to gather relevant literature for this report as well as questions regarding their institution and its role to get a broad picture of the handling of pesticides in the Lake Victoria region. District Agricultural and District Livestock Officers in the three districts were also interviewed about their experience on agro-chemicals use in their districts. Pesticide retailers in Londiani, Kedowa, Kipkelion, Muhoroni, Ahero, Nandi Hills and Savani areas were also interviewed about the agrochemicals that they sell and also about knowledge and attitude towards pesticides in the area.

2.2.1.8 Measuring Quantities

It was difficult to get an understanding of the quantities of pesticides used and the sizes of some farms through interviews. Measurements of sizes of some twelve farms (six from each sub-catchment area) were taken. The farmers/workers responsible for application of agrochemicals were asked on specific doses they used in these particular farms. These were mainly farms on which same chemicals was applied in order to be able to compare these measurements. This information could be used as basis for a "back of the envelope" calculation in order to illustrate the usage in the region and the results can also be compared to the usage of pesticides in other areas and/or other types of production.

2.3 Sampling Sites

For water sediment, aquatic flora and benthic macroinvertebrate samples were collected from 26 sampling sites along River Nyando catchment areas as had been marked by Lake Victoria Environmental Management Project (LVEMP), Pollution Loading Component in Kenya (Figure 1.1). Soil samples were collected from tomato, cabbage/maize, sugar cane, coffee, tea and rice farms adjacent to sampling sites (1, 4, 22, 23, 26 and 33 respectively).

Figure 1.1: Map of River Nyando Drainage Basin Showing Sampling Sites

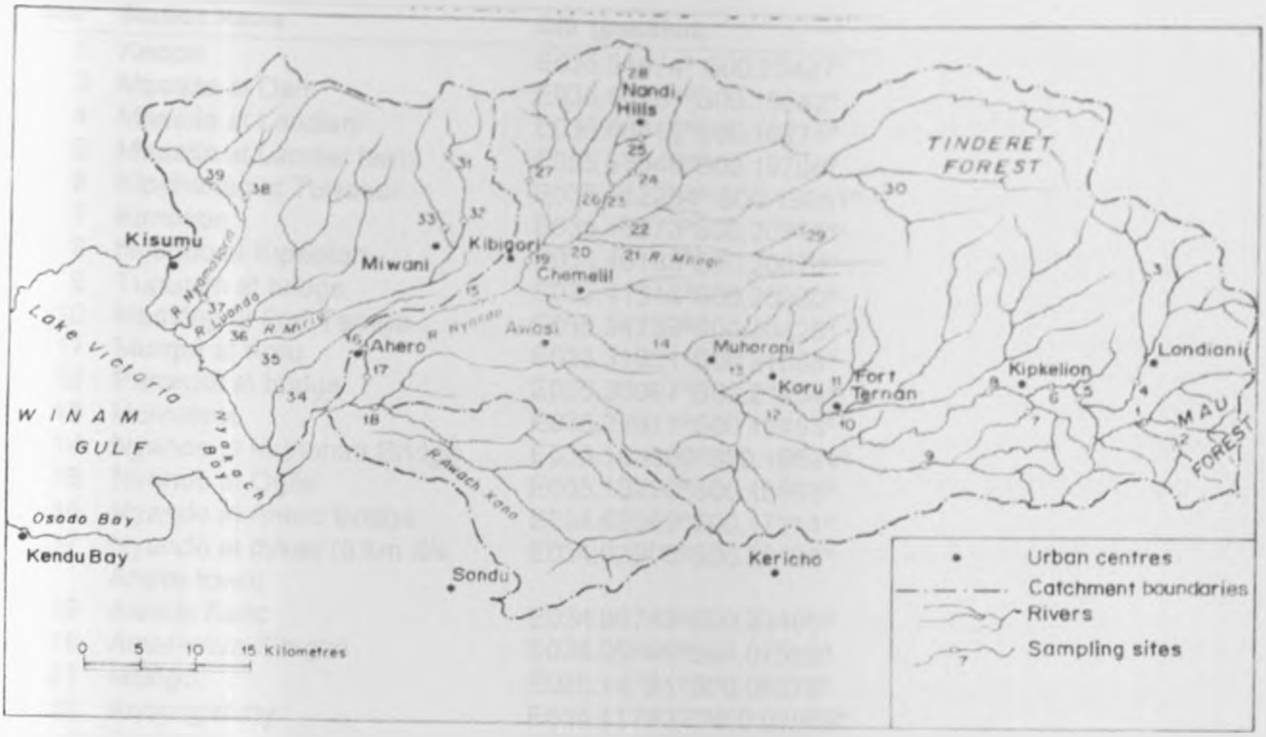

Table 1.11: Names and Locations of the Sampling Sites

Site	Station Name	GIS (position)
1	Kedow	E035 54474° S00 23427°
3	Masaita at Dam	E035 60181°S00 13542°
4	Masaita at Londiani	E035 58415°S00 16274°
5	Masaita at Lambel farm	E035 53546°S00 19706°
6	Kipchorian at Tuiyobei	E035 512254° S00 19051°
7	Kimoson	E035 46373°S00 20716°
8	Nyando at Kipkelion	E035 46185°S00 20679°
9	Tugunon at bridge	E035 41516°S00 25000°
10	Namting at Fort Ternna	E035 34739°S00 20428°
11	Murgut at Koru	E035 31921°S00 21388°
12	Pararget at bridge	E035 30097°S00 21254°
13	Homalime	E035 29911°S00 18453°
14	Nyando at Muhoroni Bridge	E035 183600°S00 16594°
15	Nyando at Ogilo	E035 16220°S00 16563°
16	Nyando at Ahero Bridge	E034 92069°S00 17211°
17	Nyando at dykes (5 km d/s Ahero town)	E034 92906°S00 20108°
18	Awach Kano	E034 95745°S00 23405°
19	Ainamutua-Kibigori	E035 05595°S00 07583°
21	Mbogo	E035.14791°S00 06076°
22	Anopngetuny	E035 117937°N00 02969°
23	Anopsiwa	E035.117467°S00.02825°
25	Chemwanabei	E035.18810°N00 06519°
26	Kapngorium	E035.0997°N00.05356°
27	Kundos	E035.06172°N00 05110°
30	Chebirirkut at Tinderet Dam	E035 34793OS00 03673^0
33	Ahero Irrigation Channel	E034 90789°S00.17173°

The above network comprised of three basic types of sampling sites:

(i) Reference site (site 30), which was selected in the upper catchments of the river and designed to provide baseline data on natural water quality.

(ii) Polluted sites: Sampling sites chosen near to known point sources of pollution and were specifically for pollution control purpose.

(iii) Self cleaning sites: Sampling sites (16 and 17) selected further down stream to assess the self-cleaning capacity of the river.

(iv) Sites 2, 20, 24, 28 and 29 were not chosen as part of sites to be monitored since they are flumes/seasonal streams and do not have major agricultural activities.

2.3.1 Sampling Plan

Sampling was done four times in a year in February, May, September and December in 2005 and 2006. This coincided with the scenario due different periods and farming activities on residue levels of the pesticides in use. Samples collected in February were mainly to capture the scenario due dry period (January-February) when farmers plough the fields; some pesticides are applied to soil between February and March to kill soil dwelling pests in preparation for the planting season between March and April. Samples collected in May were therefore to capture the scenario due to long rain (wet) period on pesticides applied in the fields during ploughing and planting. Samples collected in September (short dry season) were to capture the scenario due to pesticides applied to the fields after the long rains. Samples collected in December were to reflect the scenario due to short wet period when most food crops except vegetables and fruits have been harvested. During this period most pesticides are usually applied to cash crops, fruits and vegetables.

2.3.2 Materials and Methods for data and environmental samples collection

2.3.2.1 Materials

Chemicals used were of analytical grade or equivalent and were obtained from international suppliers, including Fisher Scientific (USA) and Aldrich Chemical (United Kingdom). The analytical grade acetone, hexane and dichloromethane, were bought from Kobian Ltd and triply distilled before use, however, diethyl either and HPLC grade hexane were not distilled as these were bought at 99% purity. The purity of the HPLC grade hexane was checked by running its Gas Chromatogram to see if there were any peaks other than that of the solvent. Florisil and anhydrous sodium sulphate were activated at 350 °C and 200 °C respectively before use for the clean up process (UNESCO, 1993), while sodium chloride and activated charcoal were baked at 120°C for at least two hours and cooled in desiccators before use. The detergents were bought from the supermarkets. Glasswares and crucibles were soaked in chromic acid for at two hours, washed with tap water, rinsed in distilled water and finally with triply distilled methanol. The apparatus were then dried in a Gallenkamp oven for four hours at 105°C. Containers for nutrients and total suspended solids (TSS) were washed in tap water and then soaked over night in 10% hydrochloric acid (HCl) and washed in tap water then thoroughly rinsed using distilled de-ionized water.

2.3.2.2 Methods for soil sampling and analysis

Soil samples were collected from randamly selected sites within the farms adjacent to sites 1, 4, 22, 23, 26 and 33 along the river (Figure 1.1). Site 1 was a tomato farm at Kedowa while site 4 was a cabbage/maize farm at Londiani Township. Site 22 represented two sugar cane farms on opposite sides at Ainopngetuny close the Chemilil. Site 23 was a coffee farm at Ainopsiwa in Soghor area while site 26 was a tea farm at Savanni Tea Estate in Nandi Hills. Finally site 33 was rice farm close to Ahero Town in Nyando District. All the pesticides were assumed to have been applied to the fields at rates recommended by the manufacture.

Sampling sites were randomly selected within each farm. A soil core was dug using hoe and scooped using a spade down to the depth of 15-30 cm from five different locations within the farm and approximately 200 g of the core scopped. The cores were thoroughly mixed to give a composite sample. Four replicate samples of approximately 200 g were taken from the composite sample. Two of the replicate samples (Batch A) were each wrapped in aluminum foil labeled, and placed in black plastic bag before transferring to a lebeled self sealing polythene bag. They were stored temporarily in polyurethene cool-boxes prior to transportation to the laboratory for analysis and further storage. The other two replicates (Batch B) were treated as field recovery samples. They were placed in aluminium foil and spiked with 4 ml of 100 mg/kg of pesticide mixture containing aldrin, dieldrin, endrin, lindane, p,p'-DDT, o,p'-DDE, p,p'-DDD, endosulfan sulfate, α-endosulfan, β-endosulfan, heptachlor, heptachlor epoxide and methoxychlor and treated as for Batch A. In the laboratory portions of unspiked samples were taken for characterization while the rest were stored at ≤ -19°C to await extraction and analysis of pesticide residues which was done within 14 days.

2.3.2.2.1 Soil characterization and determination of total organic carbon

This was done at the National Agricultural Laboratory (NAL), Kenya Agricultural Research Institute (KARI) in Nairobi. Soil sample for the assessment of soil texture was taken only once during the time of site selection. The soil samples were dried and sieved to 1 mm coarse size and stored in 750 ml sealed containers and taken to NAL for characterization. At the NAL, the soils were characterized for particle sizes using sedimentation characteristics of soil (Avery and Bascob, 1982) and total organic carbon using a LOCO SC-444 Analyzer. The results are as given in Table 4.11.

2.3.2.2.2 Determination of soil pH

The pH for each soil sample was determined by taking 10 g of the homogenized sieved samples in a 50 mL beaker and adding 25 mL of distilled water to form a 2:5 soil/water suspension. The mixture was then stirred manually for 15 minutes with sterilized glass stirring rod before the electrode was immersed into the suspension to determine the pH. All the readings were taken at room temperature. Buffer solutions of pH 4.00, 7.00 and 10.00 were used to calibrate the pH meter prior to taking sample measurements.

2.3.2.2.3 Determination of soil moisture and organic matter

A 30 g portion sample was taken, homogenized and sieved through 2 mm mesh-size sieve. Duplicate 5 g portions each was placed in pre-weighed (W_1) dry clean crucibles (W_2) and dried in an oven overnight at 105°C, then cooled to room temperature in a desiccators and re-weighed (W_3) to obtain the mosture contents. The re-weighed samples were then transferred into muffle furnace and heated to 600 °C for 2 hours. The samples were then cooled in the desiccator and re-weighed (W_4) to obtain organic matter and volatile matter. Analysis of organic matter by loss of weight on ignition (LOWI) has some disadvantages in that it can lead to volatilization of materials other than organic matter but is still used in analysis (Simmons *et al*., 1999).

2.3.2.2.4 Determination of water holding capacity of soil

Three weighed filter papers were folded and each placed in a funnel. 25 g of soil was placed in each filter paper and the soil saturated with 50 ml of water. The funnel was covered with aluminium foil and water was allowed to drain by gravity for 1 hour into 100 ml beaker. The wet soils were weighed, dried overnight in an oven at 105°C, cooled and re-weighed to obtain percent (%) water at field capacity.

2.4 Recovery tests

2.4.1 Qualitative Charecteristics

Reference standards of the organochlorine pesticides obtained from Iolc (Warsaw: Puder, Poland) were used in various steps in the analysis. Working reference standard solutions in the range 0.01-1.0 ppm were prepared individually. Each standard solution (1.0 µL) was then injected into the Varian Chrompack CP-3800 Gas Chromatograph (GC) under the following conditions: Column (non polar): CP-SIL 8CB-15 m, 0.25 mm internal diameter (id), 0.25µm film: sample size:1.0 µL split ratio 1:20; detector: Ni^{63} Electron Capture Detector (ECD) at 300°C; column temperature at 150°C held for 1 minute then programmed to 200°C at 4°C/min and finally to 300°C at 4.5 °C/min; nitrogen carrier gas flow pressure inlet was 30 Psi, and injector temperature was held at 250 °C. Data processing was done using Star Version 5.4. The individual pesticide's retention time (for identification) and peak area (for quantification) were recorded.The procedure was repeated for the mixed standard solutions. The retention times and peak areas obtained were used for the calibration of GC.

2.4.1.1 Sample and field recovery tests extraction

Soil samples and field recovery test samples were removed from the deep freezer and left to thaw over night and air dried. Pebbles, stones and plant materials were removed from the air dried samples crushed and homogenized in mortar and pestle and sieved through 250 µm mesh size sieves. Triplicate 30g portions were each thoroughly mixed with equivalent amounts of anhydrous sodium sulphate (previously activated at 110 °C) to dry the samples before transferring each sample to a pre-extracted Whatman (9.0 cm) filter paper. The stapled samples were soxhlet-extracted for 24 hours in 150 ml of triply distilled acetone: hexane (1:1) mixture. The extracts were each concentrated to about 10 ml using rotary evaporator.

2.4.1.2 Sample clean up procedures

The 10-ml extract were cleaned up by passing through a 60 cm long x 2 cm (id) fabricated glass columns packed with 15 g of activated florisil (magnesium silicate, 60-100 mesh size) and topped up with 4 g of activated anhydrous sodium sulfate (dry agent) and 1.5 g of activated charcoal as a decolourizer. The extracts were eluted through the columns at a flow rate of 3 ml/min using 200 ml of 6%, 15% and 50% of diethyl ether HPLC grades in hexane. The three eluents were combined and concentrated to near dryness in rotary evaporator at 40°C and transferred to graduated tubes. The samples were then reconstituted in 5 ml HPLC grade n-hexane and further reduced to 5 ml using a stream of nitrogen gas and preserved for GC analysis using the conditions set in section 2.4.1

2.4.1.3 Blanks and laboratory recovery tests

The matrix blanks and laboratory recovery samples were extracted at the same time with the actual samples. For matrix blank, 30 g of activated anhydrous sodium sulphate was taken into a pre-extracted filter paper and procedures followed as in sections 2.4.1.1, 2.4.1.2 and 2.4.1 respectively. While for the recovery tests, triplicate 5 g portions of soil samples thought to be free from pesticide residues (from Chiromo Campus) were spiked with 0.1 ml, 0.2 ml, 0.4 ml and 0.6 ml of 100 mg/kg of a mixture of the pesticide standards. Each spiked sample was homogenized for even distribution of pesticide residues and stored in deep freezer overnight to attain equilibrium. Recovery samples were removed from the deep freezer, left to thaw for 6 hour, air dried and procedures followed as in, 2.4.1.1, 2.4.1.2 and 2.4.1 respectively.

2.4.2 Identification, Confirmatory tests, Limits of Detection and Quantification

2.4. 2.1 Identification and confirmatory tests

Where, many compounds, including co-extracts had identical retention times, their identities were confirmed by running the samples on two different (non polar and polar) columns with different stationary phases. Non polar column CP-SIL 8CB-15 m, 0.25 mm internal diameter (id), 0.25µm film (section 2.4.1) and polar column DB-1701-15 m, 0.53 mm internal diameter (id), 0.5µm film were used. Whenever retention times of the substances and standards agreed on both the columns, and the calculated concentrations were about the same, the compound's identity was ascertained. The resolution and identification were also confirmed using relative retention times obtained by measuring the retention time of each test analyte relative to that of parathion and comparing the result with published literature values. For the soil samples concentrations were expressed in µg/kg dry weight (µg/kg, dw).

2.4.2.2 Limits of detection

The limit of detection is defined as the lowest concentration of the analyte that the analytical process can reliably detect. The estimation of LOD as given by equation **3.1** is based on the relationship between the lowest detectable analyte signal S_d, the field blank S_b, and the variability in the field blank (σ_b). LOD can be defined as the analyte concentration which gives a gross signal exceeding S_b by Kd units of σ_b

At LOD, $S_d = S_b .\ Kd\,\sigma_b$ **(3.1)**

Where a value of three is assumed for *Kd* (Kd=3)

2.4.2.3 Limits of quantification

For the estimation of limits of quantification (LOQ) as given by equation **3.2**, the quantification (Numerical estimations of the amount) of the concentration of the analyte is considered reliable if the corresponding gross signal (S_q) is:

$$S_q = S_b + Kt\,\sigma_b \qquad \textbf{(3.2)}$$

Where a value of 10 is assumed for *Kt* so that at least one figure of the results is significant

2.5. Methods for water, sediment and weed sampling and Analysis:

2.5.1 Water samples collection

Triplicate water samples for the determination of pesticide residues were collected from each sampling site by grab sampling method into labeled 2.5 litre amber glass bottles.One of the triplicate samples was spiked with 10 ml of 100 mg/L of the pesticide standard mixture. Sodium chloride (100g) was added to all samples for preservation while the samples for dissolved inorganic nutrients and TSS analyses were collected in 1.0 L plastic bottles. The samples were then temporarily stored in polyurethane cool boxes containing dry ice in the field vehicle for transportation to the laboratory for analyses.

2.5.1.1 Extraction of water and field samples for organochlorine pesticides residues analysis

In the laboratory, 2-litres of water sample was transferred into 3 L beaker and pH adjusted to neutral using few drops of 1N HCl or 0.1 N sodium hydroxide (NaOH). The neutral solution was

Where a value of three is assumed for *Kd* (Kd=3)

2.4.2.3 Limits of quantification

For the estimation of limits of quantification (LOQ) as given by equation **3.2**. the quantification (Numerical estimations of the amount) of the concentration of the analyte is considered reliable if the corresponding gross signal (S_q) is:

$S_q = S_b + Kt\,\sigma_b$ **(3.2)**

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In the laboratory, 2-litres of water sample was transferred into 3 L beaker and pH adjusted to neutral using few drops of 1N HCl or 0.1 N sodium hydroxide (NaOH). The neutral solution was then transferred into 2.5-litre separatory funnel. 50 g of oven dried NaCl (to salt out pesticide residues from aqueous to organic phase) was added and separatory funnel plus content vigorously shaken until NaCl completely dissolved. The pesticide residues were extracted thrice from aqueous phase using 60-ml of triplly distilled dichloromethane and the organic phase collected in 250 ml Erlemeyer flask. The clean up was done by passing the organic phase through glass column fixed with a tap and packed with 15g of activated florisil followed by 4 g sodium sulphate (drying agent) and 0.5 g activated charcoal (decolourizer). The pesticide residues were eluted from the column using 100 ml portions of 6%, 15% and 50% of diethyl ether in triple distilled hexane in that order at a flow rate of 5 ml/min. The eluents were collected in a 500 ml round-bottom flask and reduced to just about dryness using rotary evaporator and then reconstituted with 5 ml HPLC grade hexane before 1 μL of sample injected and analysed by the Gas Chromatography (GC) using the conditions set in section 2.4.1.

2.5.2 Sediment and field samples collection

Sediment samples were scooped with spade below the water surface. Six cores were scooped within a length of 50 m from left bank, midstream and right bank using a spade and thoroughly mixed for composite sample and four replicate samples of approximately 200 g were taken from the bulk. Treatment and storage was done as in the case of soil samples (section 2.3.2.2)

2.5.2.1 Extraction of sediment and field samples for pesticides residues analysis

In the laboratory, pH, moisture contents and pH for the sediment samples determined. Pesticides extraction procedures foe sediment and field samples were followed as in the case of the soil samples (sections 2.3.2.2.3, 2.4.1.1, 2.4.1.2, 2.4.1.3, 2.4.2.1, 2.4.1) respectively.

2.5.3 Weed and field samples collection

The aquatic weeds samples were harvested using a stainless steel knife, wrapped in pre-extracted aluminium foil and transferred to labeled self sealing polythene bags and tranported to the laboratoy for identification and analysis.

2.5.3.1 Extraction of weed and field samples for pesticides residues analysis

In the laboratory, portions of the weed samples were taken to the University of Nairobi's Haberium for identification while the remaining were thoroughly washed with methanol to remove soil particles and then dried in an oven at 50°C. The dried sample (10 g) was weighed in triplicate into 150 ml teflon vial and extracted for 12 hours using 50 ml triply distilled acetone on orbital shaker. Extracts were decanted in Erlemeyer flask and temporarily stored under refrigeration at -4°C. Extraction was repeated twice using 25 ml portions of acetone and the final filtrate collected by Buchner funnel filtration. The extracts were combined and rotary evaporated to 10 ml. The 10-ml extract was passed through the column and procedure followed as in the case of soil samples using the procedures of sections 2.4.1.2 and 2.4.1 respectively.

2.6 Benthic macro invertebrate samples

2.6.1 Benthic macro invertebrate sample collection

Benthic macro invertebrate samples were collected at 26 sampling sites (Figure 1.1) using the kick and sweep sampling method with 1m by 1m ($1m^2$) standard pond net for the small rocks and shallow sampling sites with ripples. In muddy and deeper sampling sites, an eckman grab sampler was used. Large debris were removed from the samples after carefully washing off the attached organisms into appropriately labeled 750-mL amber bottles. Triplicate samples were taken randomly over a river length of 50 m at each site; sieves of 500 µm mesh size were used to separate organisms from sediments. Debris were washed in a bucket and water was filtered through 250 µm mesh size sieves to separate the organisms from debris. The retained mesh material was then preserved in 10 % formalin, temporarly stored in polyurethane cool boxes for transportation to the laboratory.

2.6.2 Processing and analysis of benthic macro invertebrates samples

The macro invertebrates samples were taken to the zoology laboratory at the University of Nairobi for identification. In the laboratory, samples were filtered through 250 µm-mesh size sieves, rinsed with distilled water into Petri dishes and sorted out under stereomicroscope to the lowest taxonomic groupings, counted and then preserved in 70% alcohol. Identification was based on keys, figures and plates (Mandah-Barth, 1954, Crowley et al. 1964; Mellanby, 1971, Mac Cafterty, 1981).

2.7 Measurements of water quality parameters

2.7.1 Measurements of water temperature, pH, conductivity and dissolved oxygen.

Temperatures of water, pH, conductivity and dissolved oxygen (DO) were measured in the field using Hydro lab YSI 610 instrument at the time of sampling benthic macro invertebrates. Calibration of all the probes was done before the use of the equipment. The parameters were measured at a depth of about 5 to 10 cm below the water surface. The probes were then rinsed with deionized water after each measurement to avoid corrosion and contamination in accordance with the manufacture's instructions.

2.7.2 Determination of total phosphorus, nitrogen and suspended solids

From each sampling site. Triplicate 1 litre of water samples were collected in labeled plastic containers and taken to the laboratory for the determination of total nitrogen and phosphorus (TN and TP) and total suspended solids (TSS). the analysis was done at the LVEMP laboratory in Kisumu.

2.7.2.1 Determination of total nitrogen

For the determination of total nitrogen (TN), the method of Mackereth *et al.* (1989) was used. 0.30 g of potassium persulphate was weighed in triplicate and each transferred to a dry pressure bottle. 4.20 ml of sodium hydroxide solution (0.5 M) and 25 ml of water sample were added to each bottle. The stoppers were inserted (fitted with silicon rubber gasket) and secured by means of toggle action clips.

The bottles were placed in autoclave, steamed out and closed to digest at about 100 kN m^{-2} (15 lb in^{-2}) pressure for 45 min. After cooling the bottles were removed from the autoclave and the pH of contents measured using a pH meter. The pH were adjusted to between 8 and 9 using 0.5 M NaOH drop by drop while stirring using magnetic stirrer. A high pH was reduced using 0.1 M sulphuric acid. The solutions were diluted to 50 ml, mixed and 10.0 ml of aliquot transferred to 30-ml polystyere bottles. 3.0 ml of 2.6 % w/v (aqueous solution) of ammonium chloride solution and 10.0 ml of 2.1 % w/v (aqueous solution) of borax solution added followed by 0.5 to 0.6 g of spongy cadmium. The bottles were corked and shaken on a mechanical shaker. for 20 min. 7.0 ml from each aliquot was transferred to 50-ml volumetric flask and 1.0 ml (1% w/v solution in 10% v/v dilution from conc HCl) of sulphanilamide reagent. The solution was mixed by swirling; after 4-6 min., 1.0 ml (0.1% w/v aqueous solution) of N-1-naphthylenediamine dihydrochloride was added and mixed. The solution was topped to the mark with distilled water, mixed and absorbance readings taken after 10-20 min using Analogue Spectrophotometer (model S104) at 543 nm in 1-or 4-cm cell against blank prepared by using distilled water in place of sample.

Calibration curve was prepared using a dilution series from stock solution (7.22 g/L, 1.0 ml contain 1 mg NO_3-N) of anhydrous potassium nitrate (KNO_3). The mean factor relating concentration to absorbance was determined in each analytical occasion for the concentration of interest. For samples with low concentration, the volume of sample plus reagent was made to 10 or 25 ml rather than 50 ml

2.7.2.2 Determination of total phosphorus

Total phosphorus present in water sample may be operationally divided, by filtration, into particulate phosphorus and total dissolved phosphorus. Both these quantities can be estimated after a sutable digestion. The latter may be further divided into solution reactive phosphorus and insoluble organic phosphorus (Mackereth *et al.*, 1989). These forms of phosphorus can be determined using two procedures (a) persulphate digestion and (b) vanadomolybdophosphoric acid colorimetric method.

2.7.2.2.1 Determination of total phosphorus by persulphate digestion method

Triplicate 50.0 ml water samples were taken into 250 Elmeryer flask and 1 drop of phenolphthalein indicator added. if red colour developed. sulphuric acid solution (75 ml acid in 150 ml distilled water and made to 250 mark) was added drop wise until the red colour is just discharged. 1.0 ml of H_2SO_4 and 0.5 g solid potassium persulphate ($K_2S_2O_8$). The solutions were boiled gently for 30-40 min until the volume is reduced to 10 ml. cooled and diluted to 30 ml with distilled water. One drop of phenolphthalein was added and titrated with 0.1 N NaOH to a faint pink colour. The resultant solution was diluted to 100m with distilled water. The absorbance of each solution was taken at 470 nm using the Analogue Spectrophotometer (model S 104) in 1-or 4-cm cell against blank prepared by using distilled water in place of sample.

The calibration curve for 0 ppm. 0.5. 1.0. 1.5. 3.0. 5.0. 7.0 and 10.0 ppm were prepared from phosphorus stock solution (4.390 g of KH_2PO_4 in 1 L distilled water).

2.7.2.2.2 Total phosphorus by vanadomolybdophosphoric acid calorimetric method

10.0 ml of 0.25% NH_4VO_3 was mixed with 10.0 ml of 5% $(NH_4)_2MoO_4$ (in aqueous solution) to form the vanado-molybdate reagent in Elmeryer flask.1 ml of phosphate standard solution (1000 ppm) was added to 9 ml of dionised water to form a 10 ppm solution. Appropirate portions of standard phosphorus solutions were transferred into flasks to obtain solutions of concentrations 1ppm. 3 ppm. 5 ppm. 7ppm. 9 ppm. 11 ppm. 13 ppm. 5.0 ml of water samples were take in Elmeryer flasks and two drops of $HClO_4$. followed by 1 ml of vanado-molybdate solution. The solutions were thoroughly mixed and diluted to 10 ml using deionized water and the absorbance reading taken for each solution.

2.7.2.3 Determination of total suspended solids

100 ml water samples were taken in triplicate and filtered through dried and pre-weighed filter papers (glass-fibre filter, Whatman GF/C grade) using Buchner funnel fitted to vacuum pumps. The filter papers were then dried in an oven for 5 hours at 105°C, cooled in disiccators and reweighed. The process of drying, cooling and reweighing was repeated until a constant weight was obtained (Mackereth *et al.*, 1989).

2.8 River Gauging

River flow measurements were taken at the time of sampling macroinvertebrates. Discharge measurements or river gauging was done by measuring cross-sectional area of the stream and then by using a current-meter, the average velocity in the cross-section was determined. Whenever cross-sectional area measurements were not possible due to too much water, a rough estimate of velocity was made by measuring the time required for a weighted float to travel a fixed distance along the river (float method).

2.9. Data Analysis

The data obtained was analyzed using Statitical Programme for Social Scientists (SPSS) version 10.0, Microsoft Excel and CANOCO version 4.5 to establish relationship between pesticide residue levels in the samples from different sampling sites, the sampling seasons and effects of pesticides and physico-chemical parameters on benthic macro invertebrates. Bivariate correlation coefficients were established using Pearson product moment correlation coefficient, "r", a dimensionless index, whose value is in the range of $-1.0 \leq r \leq 1.0$ for the soil, water, sediments and aquatic weeds. For the benthic macro invertebrates, the multivariate analysis i.e Redundancy

Analysis (RDA) and Canonical Correspondence Analysis (CCA) were performed on the data on benthic macro invertebrates, pesticide concentrations and physico-chemical parameters to determine the statistical significance of the relationships by Monte Carlo permutation test.

CHAPTER THREE

3.0. Pesticides Use and their Environmental Impact in the River Nyando Catchments

3.1 Results and Discussion

3.1.1 Scope

This chapter gives the results of the study undertaken to identify the agro-chemicals used in different agricultural areas along the Nyando drainage basin in both the large and small-scale agro-ecosystem since there are risks that use of agro-chemicals especially pesticides can:

1. Lead to loss of important ecosystem services that contribute to human welfare both in direct and indirect ways.
2. Cause toxicity to aquatic fauna and impairment of water quality for drinking purposes.

In the study a frame work of Ecological Risk Assessments (ERA) was used (Newman and Ungar 2003).

3.1.2 Problem formulation in Nyando Catchment Area

The first step in ERA, was problem formulation, here we define what we want to protect. The benefits from pesticides and other agro-chemicals used were balanced against possible negative effects on the agro-ecosystem. The next step was the exposure and effect assessment; here the contact between contaminants and the ecosystem weree described together with effects caused by the contaminants. To gain this information interviews with local informants were conducted together with observations and analyses of pesticide residues in environmental samples as documented in the preceeding chapters. In the problem formulation endpoints for the ERA were established to define important ecological concerns, in this case loss of "ecosystem services".

When working within the ERA concept endpoints are essential, they are issues or organisms that are at risk and that needs to be protected or remediated.

For the assessment endpoint for this ERA, loss of pollinating insects and birds and biological control of tick parasites were chosen. These endpoints were chosen since from the interview results, they were valued by the communities and are ecologically relevant for the agro-ecosystem assessed: many of vegetables, grains and fruits production in Nyando catchment area are pollinated by bees and birds. Some birds in the area eat ticks and insect pests that can be problematic in the agro-ecosystem. These endpoints are also susceptible to pesticides used in the area and they are valued as important ecosystem services by the communities along the Nyando basin.

3.1.3 Characterization of Exposure and Effects

This was made from information from interviews with farmers (see Appendix 2.0: Questionaires for the farmers in River Nyando catchment area), officers from government authorities, quantity measurements and literature review.

3.1.4 The Farming System in Nyando Catchment

3.1.4.1 The types of crops grown in Nyando catchments area

Majority of house holds (82%) said that agriculture is the only or most important source of income while 18% said that they were also employed elsewhere. The production is heavily constrained by rain especially in the lower Nyando basin. Only 51% of the farmers produce enough if there is penury of rain. From Figure 3.11 farms (% Hectares) have been set aside for cash crops such as tea (6%), Sugar cane (4%), pyrethrum (3%) and coffee (2%). Maize which is the staple food is grown for house consumption and also for sale (17%). The most common foods grown are, beans (15%), Kales (14%), cabbage *Brassila sp* (12%), Tomatoes *Lycopersicon sp* (11%), sweet potatoes *Solanum Sp* (8 %), peas *Fabeceae sp* (5%), Onions *Allium sp* (3%) and cassava *manihot sp* (2%). From pilot studies (Maturwe and Opango, 2002) and from the focus group discussions with the Administration, Agriculture and Livestock officers, it was clear that horticulture and maize farming concentrated most in Nyando catchment area and especially around Londiani, Kedowa, Kipkelion, Muhoroni, Nandi Hill and Savani areas. More pesticides are used in horticulture than in maize farming. Diversity in gender, age of farmer and scale of crops production were deliberately searched for (as far as possible) when selecting informants.

Pollination is important for the vegetables, both for seed production and increased harvest. Most of the farmers sell more than 80% of the vegetable they produce, which makes vegetables their most important cash income source. The vegetables are sold at local markets, transport and connections in some areas are rear. If the harvest is destroyed for some reason there is less money for medical care, school fees, agricultural inputs and other costly investments. Average income per house hold is US $ 300-1000 per year; if there is draught, annual income can be less than US$ 300. The majority of farmers are literate, 56% of them stated that they could read and write both English and Swahili languages, 32% could read and write Swahili only, while 18% could not read or write both languages.

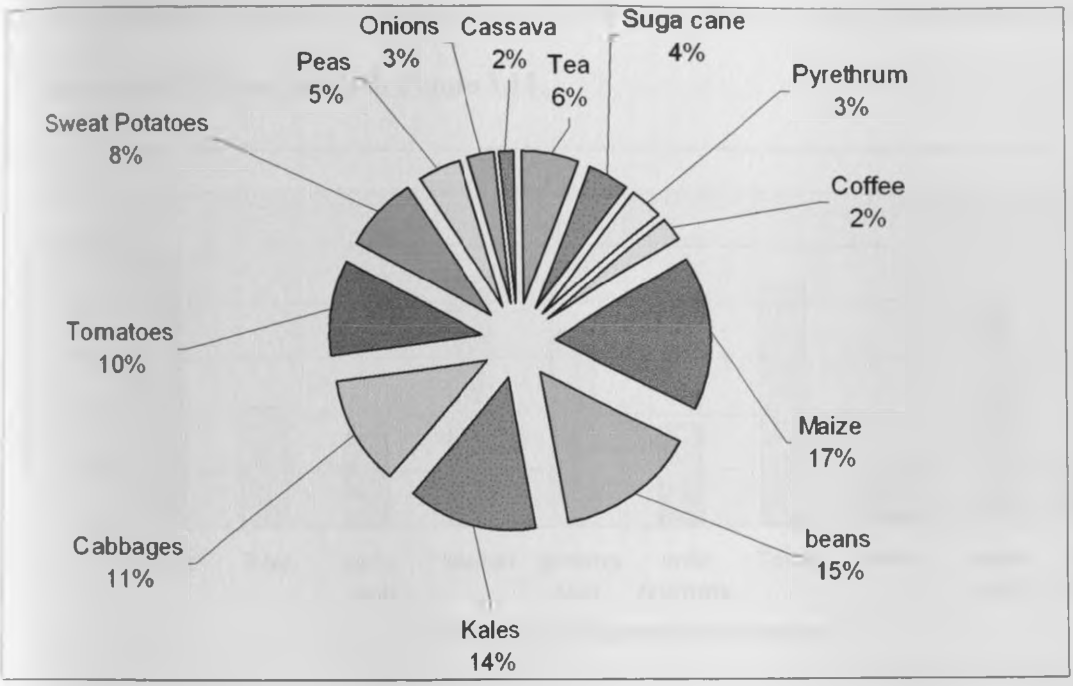

Figure 3.11: Types of Crops (% Hectares) grown by small scale farmers in Nyando Catchment

3.1.4.2 Problems Encountered by the Farmers in Nyando Catchment

From the interviews 96% farmers stated that crop pests were one of the major problems in their farming activities as shown in Figure 3.12. Other common problems were lack of rain (43%) and poor agricultural soils (33%) especially in lower Nyando sub catchment area. Other problems they mentioned were market (89%), lack of field for grazing their livestock (70%), crops raiding by wildlife in lower Nyando (36%), lack of farm tools (87%), lack of labour (25%) and lack of ferlizers and pesticides (77%). Some of the farmers mentioned that pest problems have gotten worse due to climate changes (18%). 43% of the farmers were of the opinion that some areas are more arid now compared to the 1980's. Major pest problem in the area are maize stalk borer (*Buseola spp. Lepidoptera*) (86%), onion thrips (*thrips tabaci, thysanoptera*) (13%), aphids (*Aphidae spp. Homoptera*) (38%), Fungi, cutworm (*Agrotis spp. Lepidoptera*) (48%), Diamond ack moth (*Plutella xylostella, Lepidoptera*) (36%) and tobacco mosaic virus (9%), termites (20%) and weeds (8%) as shown in Figure 3.13.

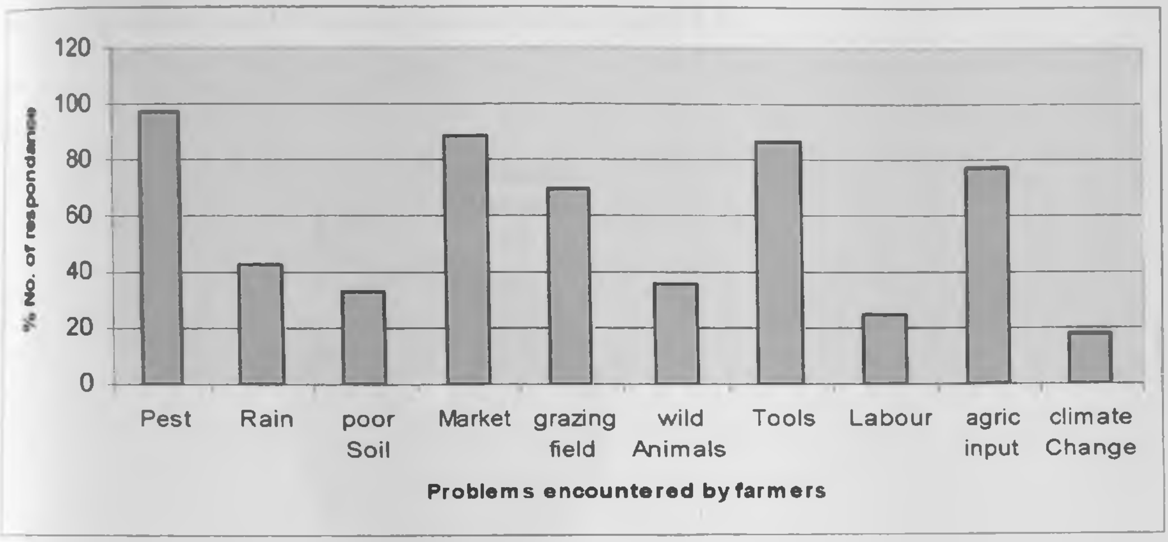

Figure 3.12: Problems encountered by the farmers

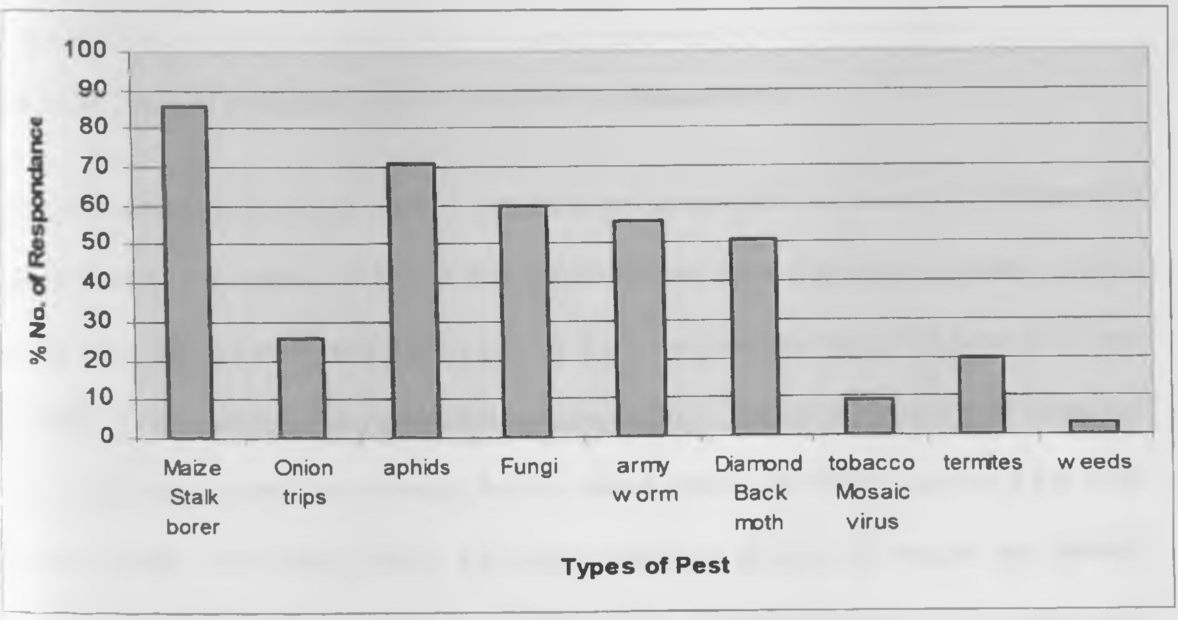

Figure 3.13: Major pest in Nyando catchments area

1.4.3 *Pesticides used in Nyando catchment area*

Seven percent (7%) of the farmers only use traditional pesticides in their farming systems, 77% se synthetic pesticides and 16% use both as shown in Figure 3.14.

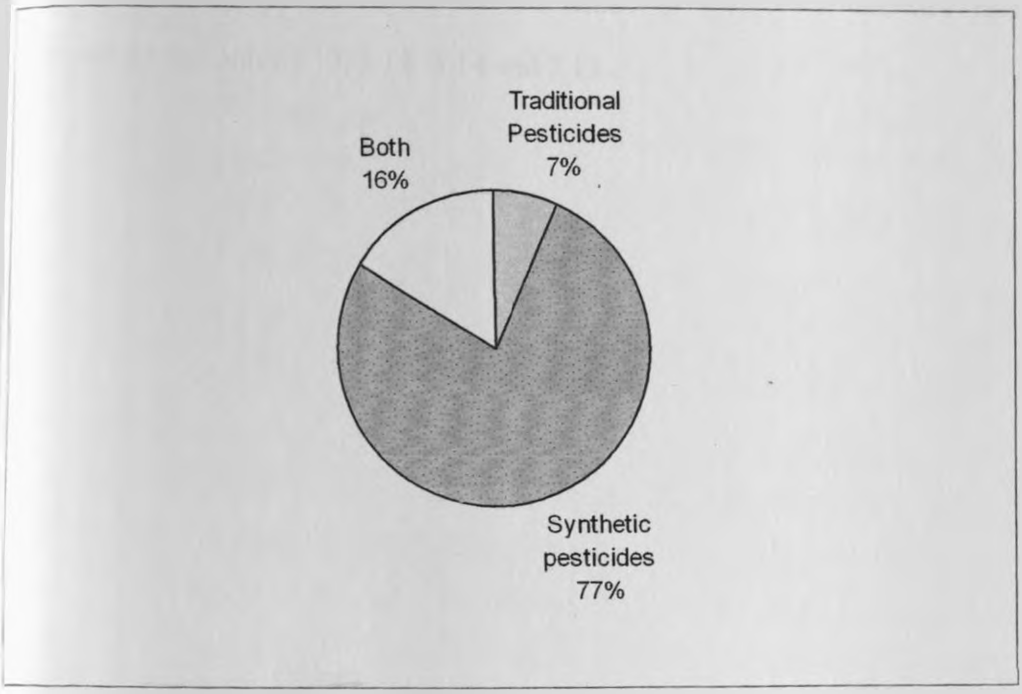

Figure 3.14: Types of pesticides used in Nyando Catchments area

Most farmers use pesticides more often in vegetable production than in maize (91% compared to 9% respectively). The reason for this is that vegetables are more difficult to produce without pesticides since they are easily attacked by pests and also because vegetables are house hold cash crops. About 42% house holds use pesticides in grain storage. The use of pesticides in storage of grains is declining because new storage facility called drum (100-1000 l capacity) has been introduced. Drum, are closed systems for storing grains in absence of oxygen and thereby creating an unfriendly environment for pests. Herbicides are used on coffee, tea and sugar cane farms. In maize and vegetable production, no herbicides are used since the households practice weeding instead of using pesticides, however herbicides are used in large scale farming of tea, coffee, maize and sugar cane . Insecticides are often used more than fungicides. The farmers use between 3-9 different pesticides in their farms. The most commonly used pesticides are presented in Appendix 3.0, Table 3.11 together with a description of each. Specific information on agrochemicals used in the catchment area and their recommended rates is as shown in Appendix 3.0, Tables 3.12, 3.13, 3.14 and 3.15.

Table 3.11: Major pesticides used in Nyando catchment and their classification

roduct name	Active ingredient	Types of pesticides	Toxic classification (WHO, EPA)	Use by percent (%) Household
ursban	Chlorpyrifos	Insecticide	WHO:II, EPA:II	56
ithane/Sancozab	Mancozeb	Fungicide	WHO:III, EPA:IV	60
mithin	Fenitrothion	Insecticide		78
eocidal	Diazinon	Insecticide	WHO:II	47
ntracol	Propinab	Fungicide	WHO:III, EPA:IV	12
aradan	Carbofuran	Insecticide		36
prado 50 WP	Copper Oxychloride	Fungicide	WHO:III, EPA:III	9
rate	Lambacyhalothrin	Fungicide	WHO:II, EPA:II	9
und Up	Glyphosate	Herbicides	WHO:II	48
amoxone	Paraquat	Herbicides	WHO:II	33
nbush CY	Cypermethrin	Insecticide	WHO:III	49
iodan EC	Endosulfan	Insecticide	WHO: II, EPA: I	13
lladone	Chlorfenviphos	Insecticide	WHO: I, EPA: I	64
ctic/Tixfix	Amitraz	Acaricide	WHO:III, EPA:III	40

WHO: World Health Organization. EPA: Environmental Protection Agency (US).
WHO classification from I to III and EPA classification from I to IV with I being the most hazardous

Most Pesticides are used during the short rain season (October-December) when most farmers grow vegetables to a large extent. Vegetables are grown throughout the year with the highest peak between October and December. The dose of the most commonly used pesticide according to the households range between 0.75-1.5litres to 3-5litres per hectare in some areas. This range probably could have a large margin of error since area estimation could be difficult if not done properly and on regular basis. But this still gives an overview of how the use differs. Pesticides are sprayed between twice and ten times in the year depending on the pest's outbreaks and the farmer's purchasing power. The spraying and the spraying intervals seldom correlate with the recommended dose from the manufacturer, though much of the time there are recommendation of dose on the containers.

Aerial spraying is only done in large tea estates in Kericho and Tinderet areas. Knapsack sprays are the most commonly used spraying method in coffee, sugarcane, vegetables and crops grown on small scale. Most small scale farmers use knapsack spray method. Glyphosate, with application rate of 3-5litres per hectare and Linulon (5kg per hectare) are the most common herbicides used in the plantations as shown in appendix 3.0, Table 3.12. Most farmers (65%) claim to decide on the dose on the basis of the recommendation on the container/bottles. Many of them (89%) purchase whole container of the pesticides in milliliters (ml) or in grams and therefore have an access to the safety information and recommendations from manufacturer. 11% of the farmers may be buying their chemicals from other farmers hence may therefore miss the safety information and recommendations from the manufacture. Nearly all the house holds that keep livestock and were interviewed, use pesticides on their livestock against ticks (spreading east coast fever, anaplasimosi, babesiosi and heart water), tse tse flies (spreading typanasomiasis).

Chlorfenviphos is the most commonly used pesticides (64%) on livestocks followed by amitraz (40%) by households as shown in Table 3.11. Livestock spraying occurs at least once every month all year round for most of the farmers. 80% of the livestock keepers spray their animals 2-4 times a month. To be sure to keep the livestock healthy one must spray the animals every week since the life cycle for tick is one week said 70% of the farmers. The spraying of pesticides is usually done by male adults and in very rare occasions by women. The reason farmers gave for this is because of different biological features in male and female.

3.1.4.4 Major Agricultural Enterprises in Nyando Catchment Area

From Figures 3.15, 3.16 and 3.17, the main food crops in the three districts are maize, beans, rice and sorghum. The food crops occupy 58%, 28% and 49% of the arable land in Kericho, Nandi and Nyando districts respectively. The main cash crops are tea, coffee, and sugar cane which occupy 27%, 11% and 34% of the land in the three districts respectively. Much land (54%) in Nandi district is devoted for livestock while only 7% and 10% respectively are for the same purpose in Kericho and Nyando. Information on major agricultural enterprises and agrochemicals used in the three districts are shown in Appendix 3.0, Tables 3.16, 3.17 and 3.18.

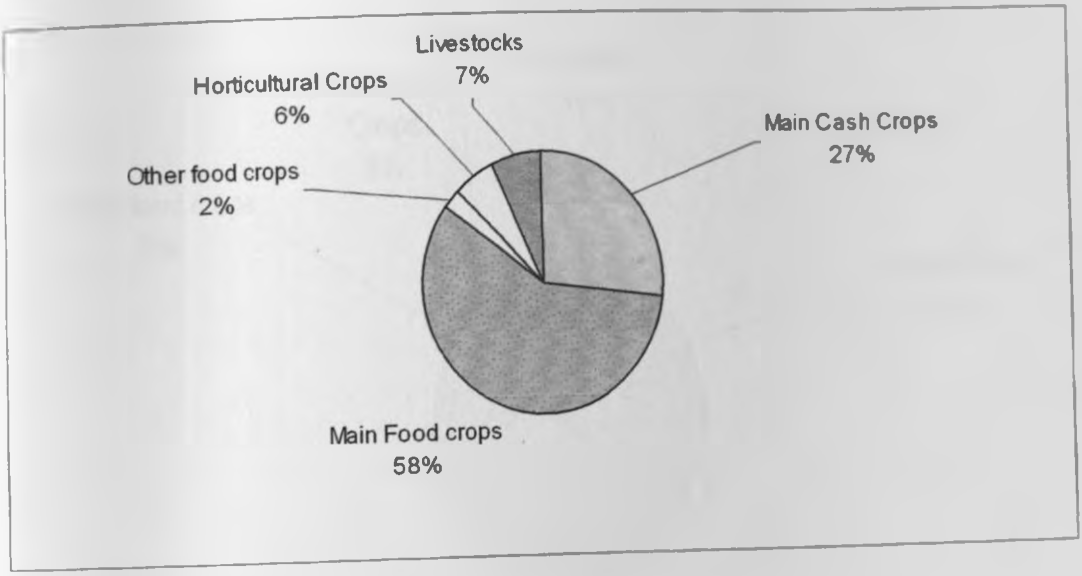

Figure 3.15: Major agricultural enterprises in Kericho District

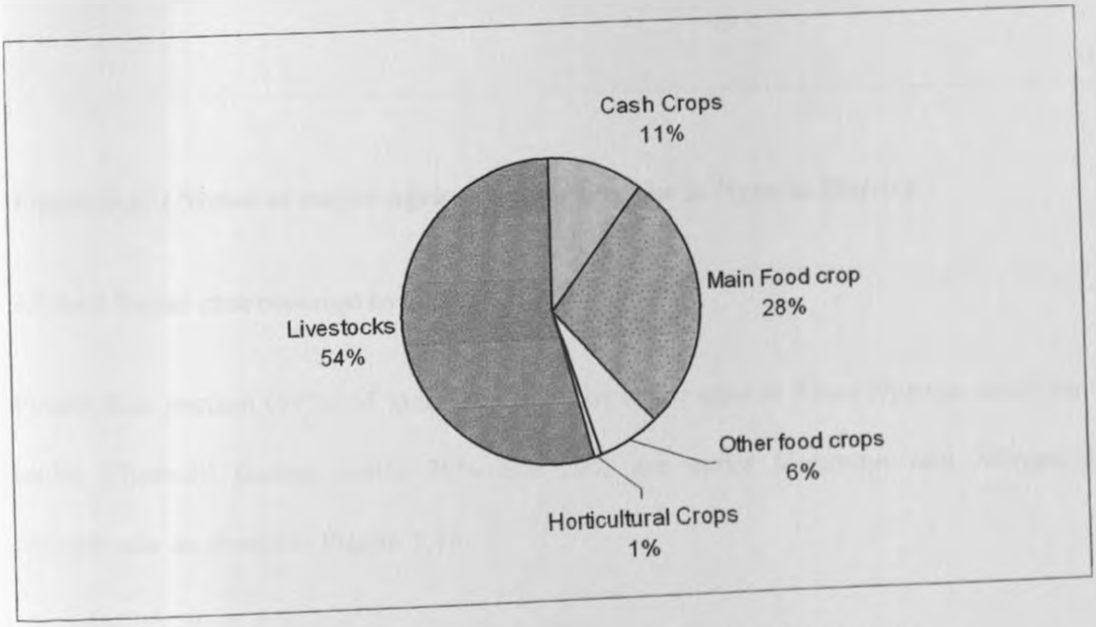

Figure 3.16: Status of major agricultural enterprises in Nandi District

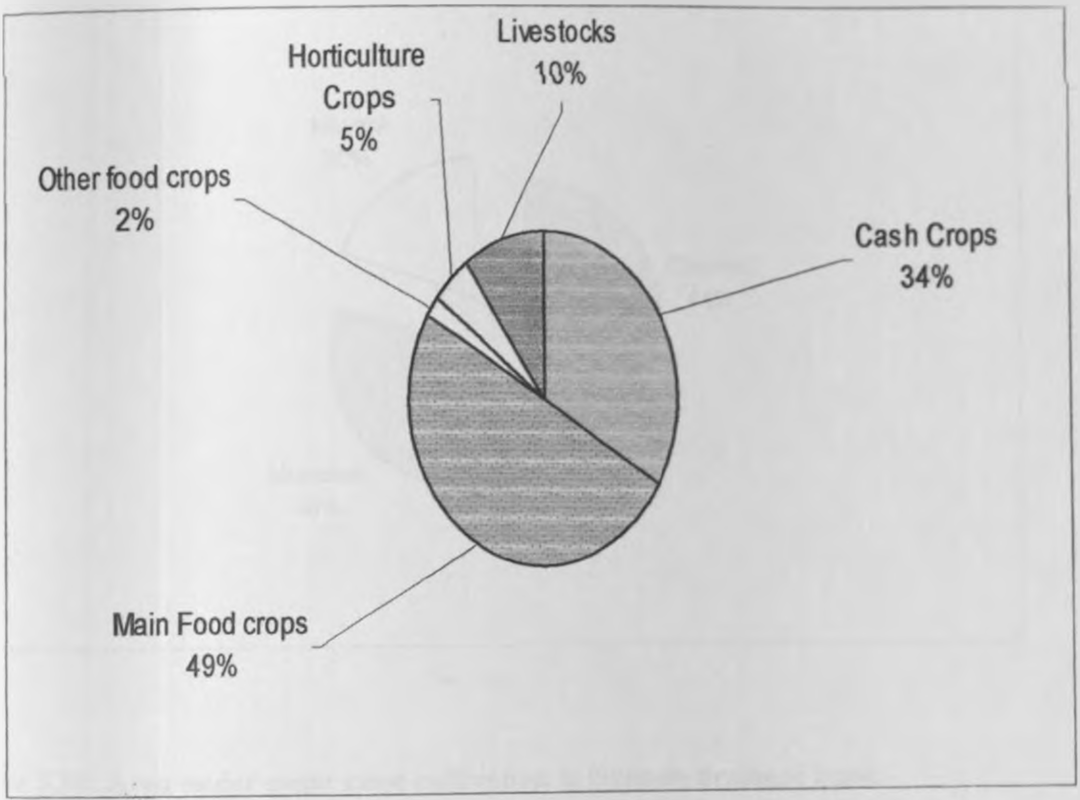

Figure 3.17: Status of major agricultural enterprise in Nyando District

3.1.4.4.1 Sugar cane coverage by factory zone

Fourty four percent (44%) of total area cover by sugar cane in River Nyando catchment area is under Chemelil factory while 36% and 20% are under Muhoroni and Miwani factories respectively as shown in Figure 3.18.

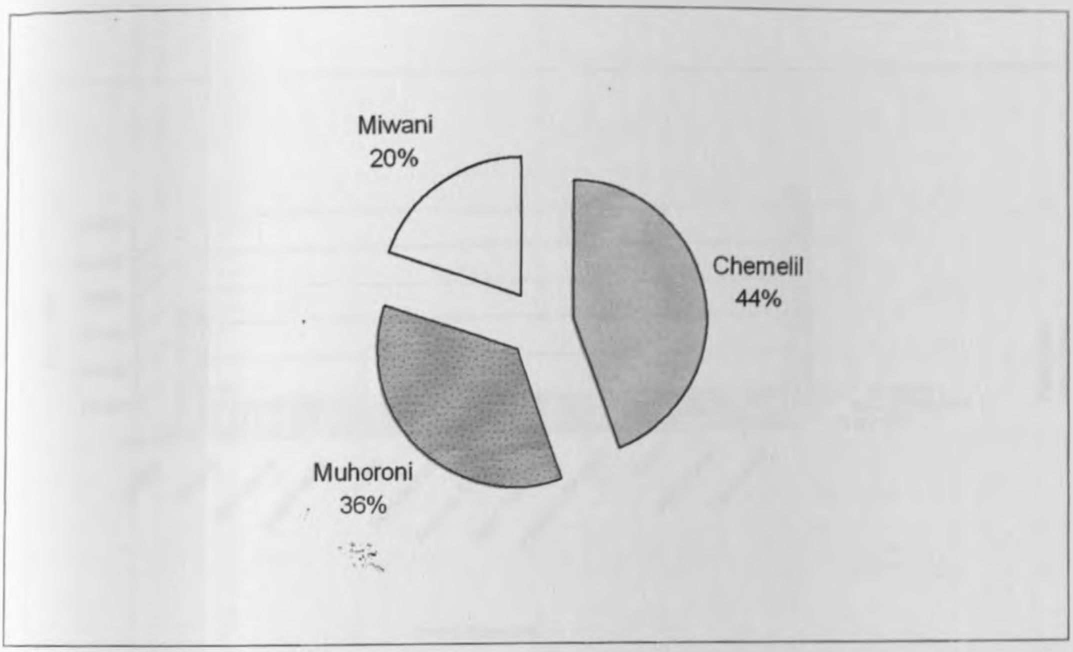

Figure 3.18: Area under sugar cane cultivation in Nyando drainage basin

3.1.4.4.2 Current general levels of pesticides usage in Nandi District

In Nandi District maize is grown in large scale and insecticides are widely used in this area as shown in Figure 3.19. Since livestock rearing has a lot of traditional values in this district, the levels of acaricide application are high in Nandi as shown in Figure 3.19. Another significant use of pesticide in this region is on sugar cane plantation where much herbicide is used. The other agricultural activities in this district use minimal pesticides as compared to livestock, maize and sugar cane.

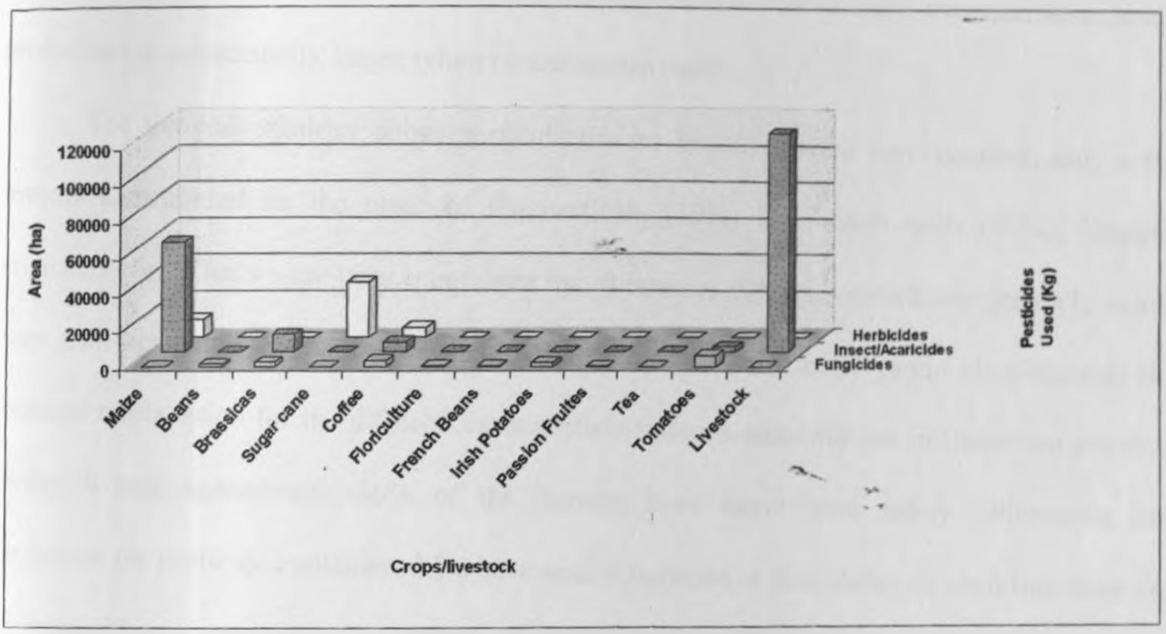

Figure 3.19: Current General Levels of Pesticides usage in Nandi District

3.2. Environmental impacts of pesticides used in Nyando catchments

3.2.1 Farmer's Knowledge and Attitude towards Pesticide Usage

Most of the farmers (97%) were of general opinion that the pesticides used in agriculture were effective. However many of them (86%) were also concerned about the health risks and wanted to find an alternative. Other concerns were escalating prices of pesticides and fertilizers and lack of user knowledge among the framers. When asked about future use of pesticides, 94 of the Households think that it will increase or stay the same, since new products are coming into the market. A decrease in pesticide usage than currently is only possible if a well functioning and cheaper alternative will be available they said.

Reasons for not using more pesticides than currently needed are low purchasing power (60%) and health risks (30%). Reason for not using the exact dose as recommended by the manufactures was lack of purchasing power and poverty (48%). 10% of farmers in Londiani and Kedowa have used ecological farming but still think that use of pesticide is better if they can afford it. This is, according to both the farmers and agricultural officers, because the vegetable production is substantially larger when pesticides are used.

The general opinions about pesticide use on livestock were very positive, only a few farmers commented on the price of the pesticide (30%) and health risks (36%). Negative environmental effects were only mentioned by 10 farmers (9%). Livestock are generally valued more than agricultural products in Nandi compared to Kericho and Nyando Districts; this is a potential explanation for the differences in altitude towards pesticide use in these two practices (livestock and agriculture). 86% of the farmers have never used safety information and instruction on pesticide container. 32% have read it between at least thrice or each time they use the pesticide in question. A typical answer when asked to reproduce the text on the container/bottle was "Drink milk after spraying, keep away from children, and do not spray against wind". These answers, according to the research team, reflected a common sense more than the text on the container. Simple safety equipment like wearing of protective clothing and gloves, or cloth around the mouth is used when available. 20% of the farmers have equipment recommended by the chemical companies. The main information source for the farmers is through the local agriculture and livestock officers from divisional and location levels and radios. The information services are provided free of charge from the government. All the farmers felt a need for more information to avoid health effects. Chemical companies only have direct contacts with the farmers growing typical cash crops such as coffee, tea and sugarcane.

3.2.1.1 The link between pesticide use and environmental problems and health

On answering a direct question, majority of the farmers (77%) responded that they have not experienced or heard of any environmental effects due to pesticide use. Only 23% said that they have experienced some environmental effects. The farmers who have noticed environmental effects of pesticides mentioned a decline in number of pollinating bees (40%) and butterflies (18%), the disappearance of Haria bird (red billed oxpocker, *Buphagus erythrorthynchus*) (20%) and non target insects dying after spraying (12%). Other mentioned effects were death of wild animals when/after spraying (10%). Local agricultural officers in each area confirmed that the bees' population has decreased in the area but have increased in forest areas. Honey has to a larger extent been imported from other areas.

The birds disappeared when the government subsidized a common place for dipping the livestock with insecticides in the 1980's. Since then the birds have only been observed in game reserves. Only 3% of the farmers had seen signs of poisoned birds so the alternative that the birds moved to another habitat for other reasons cannot be excluded. However, it seemed likely that the pesticides are responsible for the disappearance since it coincided in time when the places for dipping livestock were introduced. In agro-ecosystems where organic farming is practiced more arthropods were found in soil compared to areas where pesticides were being used. Also other beneficial insects such as predatory insects were affected by pesticides, both insecticides and fungicides can have this effect, killing the predatory insects and fungi. Fungal Pathogens are naturally parasitic on pest insects and when the fungi are eliminated there is an increased survival of pest insects according to one District Agricultural Officer.

Many birds are excellent indicators species of pesticide pollution. They are sensitive to pesticides, relatively easy to spot and more vulnerable to environmental pollution than other vertebrates. Birds living in cultivated areas have decreased substantially since the 1980's. A major cause for this decline was believed to be the depletion of food (the insects and weeds) they fed on due to pesticides used. Birds can also be affected directly by the pesticide poisonings, which can lead to chronic toxicity, such as endocrine disruption and impaired reproduction or even to acute toxicity (White *et al.*, 1982, Stone and Gradoni 1985. Pimental *et al.*, 1992).

When asked about the connection between the sizes of their harvest and the healthy environment (e.g. bees for pollination of their crops and predators birds and insects feeding on pests), 58% of the farmers mentioned pollination and bacteria in the soil being important ecosystem services in their farming system. On a direct question about insects' positive role in the farming system. 87% of the farmers answered "pollination", indicating local ecological knowledge. 19% said that it was natural to see the bees visiting plants while, 10% of the farmers did not know the roles of these insects. These results illustrate the importance of asking questions in a way that include all the interviewed persons', irrespective of social background and its relevancy in the local context. Majority of the household were positive about changing to less harmful pesticides as long as they work effectively well. This applied to both pesticides harmful to the environment and humans.

When asked about the banned or restricted pesticides in the country, 56% answered, DDT, endrin, dieldrin and lindane. 39% of them did not know that these are restricted or banned while 5% had never heard about these pesticides. 10% of farmers in Londiani and Kedowa areas, admitted to have used unlabelled pesticides obtained from relatives from the neighbouring Nakuru District. None of the farmers was aware of any obsolete or stockpiles of the banned or restricted pesticides in the region. From this information it is clear that 44% of the farmers in Nyando catchment area are not aware of the ban or restriction imposed on some pesticides in

Kenya and that these pesticides can easily find their ways into the region from other districts. From the results of this study and other studies conducted within Lake Victoria catchments area it was therefore important to monitor residue levels of banned and restricted organochlorine pesticide along Nyando catchment area.

3.2.1.2 Quantification of pesticides usage

Measurements of the doses used on specific areas proved to be in the same order of magnitude as the farmers had stated during the interviews (between 0.25 and 5.0 kg per hectare). Doses ranging from 0.75 to 1.5 liters of pesticides per hectare were also mentioned. The total amount of the pesticides used on the 12 fields measured with a total area of 28 hectares was 20 kg (0.71 kg of pesticide per hectare). According to United States Environmental Protection Agency (US EPA) the doses should be 0.25 kg per hectare. three of the twelve farmers were using this dose; nine farmers were therefore not using the correct doses as recommended by US EPA.

3.2.1.3 Conclusion of characterization of exposure and effects

Insect pests are the major problem in Nyando catchment area. from the interview results. maize stalk borer being the major pest followed by aphids. Vegetables grown without pesticides were severely impacted by pests. An active pest management is necessary to secure the harvest. For a start pesticides could be a part of the treatment but hopefully the dependence can decrease with new knowledge about the alternative pest management such as the use of organic farming. The communities along River Nyando basins are highly dependent on what they can produce. both for food and for income. Large-scale tea. coffee and sugarcane employ most people. Not many people among the communities have jobs that can replace farming; crop failures therefore have large impact on their everyday life.

The farmers are aware of environmental problems connected to their pesticide use; many of them also see links between ecosystem services and their farming system. But very few have means and knowledge on how to change the way they produce food. A change to other pest management techniques can be restrained by the "economic barrier" created by dependency on pesticides. The farmers are dependant on harvest and lack the risk capital that is needed to try new techniques. Many of them mentioned organic farming as alternative and so did the District Agriculture Officers and staff from Ministries of Water (LVEMP) and Agriculture (KARI). This type of production is still very small in this part of the world but there are signs of an increased demand for organic products from customers.

The farmers lack important knowledge regarding pesticides and their effects and also regarding alternative ways of pest management. Even though many of them consider health risks and environmental problems it seems clear from the interviews that the majority of these small-scale farmers would use more pesticides if they had more money to purchase it. It is apparent that the use of pesticide will increase in future. People who work in agricultural sector supported this opinion. The difference in attitude towards pesticides use in livestock and agriculture in Nandi district reflects the effects of how information is given. Both the District Agricultural Officer and local Non Governmental Organizations (NGOs) inform the farmers about health risks and environmental problems connected to pesticide use in agriculture and this has influenced their opinion. The companies selling pesticides in Kenya should only focus on farmers growing cash crops in order to encourage other techniques which do not involve use of pesticides for vegetable production.

3.3. Risk Characterisation

A risk evaluation based on pesticide residue analyses in soil, water, sediment and weeds would give information on toxicity risks of these pesticides in the environment as outlined in the proceeding chapters. In this study, however, larger perspective was adapted through interviews, thus allowing the combination of information on sources of pesticides used with observed biological effects related to pesticide use, which in turn gives a more realistic risk characterization.

In spite of relatively low pesticides dosages used, detrimental effects on ecosystem services in the Nyando catchments areas can be seen. A declining bee population was mentioned as one of the negative effects. Out of the fourteen commonly used pesticides in Nyando Catchment area four are toxic to bees (Table 3.21, Appendix 3.0). This can seriously affect the harvest and production of seeds. An expansion of cultivated land, and thereby a loss of native habitat is another possible reason for the decline of bees population. Ricketts (2004) indicated that forests surrounding agricultural fields enhance pollinator activity. In Nyando, surrounding bush land and forests are increasingly being cleared due to population increase (growth rate 3.2% per year, Kenya CBS, 2000) resulting in expansion of agricultural land. Since bees produce honey, the population decline can easily be measured in the amount of honey produced. Other beneficial insects, such as predatory insects, are not easy to quantify. It is reasonable to assume that a similar effect has occurred or is expected to occur. The use of pesticide on livestock is also a likely explanation for the decline of the Red Billed Oxpecker, either directly by being toxic to the bird or indirectly by reducing the birds' prey (Tomil, 1997). Out of the fourteen commonly used pesticides in Nyando catchment area five are toxic to birds (Table 3.22, Appendix 3.0). If the farmers in Nyando adopt biological control as an alternative pest management, birds have to be reintroduced to the area.

The Red Billed Oxpecker is a bird that can easily be spotted. If people without a specific interest in birds have noticed that the bird is gone, it is likely that other less conspicuous birds have also been affected by pesticides. Approximately 85-90% of the pesticides used in agriculture never reach the target most are carried away by rain run-off (advection) from agricultural fields and wind (drifting) (Moses *et al.*, 1993). Effects from the pesticides on non-target organisms can be direct or indirect, long term or short term. An estimation of risks connected to pesticide use is difficult to do; many factors are complicating the process of determining the actual risk. As in this example, there are a number of pesticides interacting with each other. In several studies they have all been tested separately, however, there is still little knowledge regarding the toxicity of the pesticide mixture. For several insecticides the actual effects has proven to be up to a 100 times stronger in the presence of other substances. Chlorpyrifos increased toxicity in the presence of the herbicide Atrazin. Lambacyhalothrin increased toxicity in the presence of fungicide Prokloraz (Wivstad, 2005).

Reliance on single species standardized toxicity tests only lead to underestimations of risk since different species have different responses to chemicals. "No risk" for one species does not mean that all species are safe. Many of the pesticides used have the same mode of action; they affect the nerve system, low doses of several pesticides can act together and become a high dose. Repetitive exposure to pesticide can also cause adverse effects even though the dose of each application is low. Risk of resistance can become a serious problem if the farmers continue to use lower doses than recommended. Agricultural Officer from one of the districts said that onion trips show signs of resistance and that farmers often are using underdose pesticides because of low purchase power in some areas. Resistance among insects in Africa has become an increasing problem that will continue to grow, if the only way to control pests is through the use of chemicals. Globally 504 arthropods are already resistance to pesticide (Georghiou 1990). To combat the growing resistance doses may have to be greatly increased compared to the recommended rates and this in turn may result in a larger impact on the environment. From financial point of view this reduces the economic return for every dollar spent on pesticides to levels where it is no longer profitable to use pesticides. The quantities of pesticides imported into Kenya from 1986-2008 are shown inAppendix 3.0, Table 3.23.

3.3.1 Future Management

Farmers need cheap, simple and sustainable means of controlling pests. The use of pesticides in agro-ecosystem is an important question with an unclear answer. By valuing ecosystem services a potential for conservation of ecosystems is created. When using pesticides a cost-benefit analysis has to be included in an overall picture. Pest Management demands an understanding of the biology and ecology of the pests. Pesticides use should not be the only pest management practiced; other important preventive strategies are release of pheromones, crop rotation, resistant host-plants, biological control and use of Genetic Modified Organisms/Crops (GMO/GMC). Integrated Pest Management (IPM) strategies apply a combination of these control tools and are designed for local pest problems. It has been successfully practiced in both perennial and annual crops in temperate and tropical conditions for control of all pests, especially insects and fungi (Oerke and Dehne, 2004). IPM advocates the minimal use of pesticide. Results from rice farming shows that IPM farmers use much less pesticides, one third of the amount that non-IPM farmers use. IPM practices are therefore providing an economic as well as ecological sustainable alternative to conservational pest management (Berg. 2001). When it comes to insecticides, environmental impacts often decrease with the adoption of IPM (Fernadez-Cornejo. 1998). Considerable basic research and support are required in order to realize the full potential of integrated control. When the Government cuts off the general subsidies on importation of agrochemicals, the farmers are forced to stop using pesticides or use only the much they can afford. This however is not a permanent solution as the economy of the farmer is improving and the government is inviting investors who can invest in agriculture.

Pesticide application should be confinement to area and time of outbreak and weeding instead of using herbicides. The largest amounts of pesticides used in Nyando catchment area by small scale farmers is used in tea, sugar cane and coffee farms and rice paddies. Farmers should be encouraged to weed instead of using herbicides. Since many of the crops are introduced to the African Continent no co-evolution with pests has occurred, biological control can be a valuable solution. The benefits of biological programmes are numerous; one example in Africa being control of the cassava mealy bug (*Phenacoccus manihoti*) with the parasitoid *Epidinocarsis lopizi*, which saves US$ 250 million annually. The environmental losses from the pesticide usage are not included in this figure (Yarro, 1999). A Survey of agrochemicals commonly used in the Nyando catchment area reveals that insecticides (fenitrothion, chlopyrifos and cypermethrin), acaricide (chlorfenviphos and amitraz), herbicides (glyphosate and paraquat) and fungicides (mancozeb and propinab) in that order are commonly used. Farmers mainly use these chemicals in the maize in Nandi, tea in Kericho and sugar cane and rice paddies in Nyando Districts. Table 2.13 and 2.14 show a list of fertilizers and pesticides used along Nyando drainage basin. Most of the pesticides used are organophosphate and a few organochlorine compounds. Since 44 % of the farmer in Nyando catchment area are ignorant of the ban or restrictions imposed on organochlorine pesticides in Kenya. the pesticides could still be in use and could find their way into the water system of River Nyando and finally into the Lake Victoria. It has also been observed that most farmers (80 %) are ignorant of the safe use and handling of the agro-chemicals being used in the catchment. which results in some injuries and illness.

CHAPTER FOUR

4.0 ORGANOCHLORINE PESTICIDES RESIDUES IN SOIL

4.1 Results and Discussion

All soil samples from the randomly selected sites within the farms adjacent to sites 1, 4, 22, 23, 26 and 33 along the River Nyando basin were characterised as sand and clay in terms of total organic carbon (TOC), pH, sand, silt, Mn, Fe, Cu and Zn as shown in Appendix 4.1, Table 4.11. All the pesticides analysed for this study were banned in Kenya in 1986 except for aldrin, dieldrin, lindane and DDT whose uses were at the time restricted to the control of termites in the building industry and in public health for vector control (PCPB, 1992). The organochlorine pesticides have ubiquitous distribution in the atmosphere and are resistant to biological and chemical degradation. The compounds are known to be highly toxic to animals and human because of the potential to bioaccumulate/biomagnify and significant impact on the health of human and animals. Some are suspected to be carcinogenic, mutagenic, endocrine disruptors and have effects on reproduction in humans. It is therefore important to determine the residue levels of the selected organochlorine pesticides in soil and water, as well as sediments and weeds from aquatic environment in order to understand their fate and potential effects on both terrestrial and aquatic organisms.

Table 4.12 gives percentage recoveries and limits of detection for the pesticides in soils. The pesticide residue levels detected in the soil samples were not corrected since all recovery values (Table 4.12) were within the acceptable range of 70-120% (Hill, 2000).

Table 4.12: Percent Recoveries from soils and Limits of Detection (LOD)

Compound	% Recovery	LOD (µg/L)	Compound	%Recovery	LOD (µg/L)
Aldrin	76.10±1.35	0.0040	lindane	85.77±3.58	0.0016
dieldrin	96.42±2.91	0.0035	methoxychlor	92.16±0.41	0.0016
endosulfan S	86.40±2.36	0.0024	o.p-DDT	90.13±1.23	0.0016
α-endosulfan	92.03±0.99	0.0012	p.p-DDT	90.88±0.49	0.0015
β-endosulfan	84.81±0.88	0.0022	p.p-DDD	77.02±1.39	0.0017
Endrin	87.37±1.31	0.0024	o.p-DDE	86.09±2.22	0.0017
heptachlor	82.67±1.64	0.0012			
heptachlor-epoxide	86.95±0.83	0.0012			

n=4 mean ± standard deviation

The residue levels of the pesticides detected in the soil samples in February, May, September and December 2005 and 2006 were as given in Tables 4.21, 4.23, 4.31, 4.33, 4.41 and 4.43 respectively.

4.1.1 Pesticides residues in soil samples at various sites in February

February is a dry period with average monthly rainfall of 44 mm as shown in Figure 4.5. Out of the sixteen organochlorine pesticides monitored in February, sites 33 (Rice farm at Ahero) and 26 (Savanni Tea farm in Nandi District) had the highest number (6) of residues detected followed by sites 1 (tomato farm at Kedowa) and 4 (cabbages/maize farm at Londiani Township) which showed four pesticide residues each while sites 22 (sugar cane farm at Ainopngetuny) and 23 (coffee farm at Ainopsiwa in Songhor) showed three pesticides in 2005 (Table 4.21). These values are also presented in Figure 4.21.

Table 4.21: Pesticide residue levels (µg/kg, dw) in soil at various sites in February 2005

Pesticides/sites	1	4	22	23	26	33
Aldrin	BDL	BDL	BDL	BDL	BDL	BDL
Dieldrin	10.717±0.095	BDL	BDL	BDL	14.073±0.440	10.644±0.372
endosulfan S	0.997±0.127	1.299±0.028	1.625±0.034	0.925±0.065	1.369±0.033	1.808±0.044
α-endosulfan	BDL	BDL	BDL	BDL	BDL	BDL
β-endosulfan	BDL	BDL	BDL	BDL	17.956±0.096	1.503±0.452
Endrin	BDL	BDL	BDL	BDL	BDL	BDL
heptachlor	BDL	BDL	BDL	BDL	BDL	BDL
heptachlor-epoxide	BDL	BDL	BDL	BDL	BDL	BDL
Lindane	BDL	BDL	BDL	BDL	BDL	BDL
methoxychlor	BDL	10.826±0.699	BDL	BDL	1.959±0.158	7.031±0.675
o,p-DDT	BDL	BDL	BDL	BDL	BDL	BDL
p,p-DDT	6.406±0.270	4.616±0.652	4.167±0.177	3.234±0.764	6.020±0.784	7.139±0.777
o,p-DDD	BDL	BDL	BDL	BDL	BDL	BDL
p,p-DDD	1.602±0.183	1.454±0.033	0.392±0.088	0.432±0.0123	BDL	6.206±0.182
o,p-DDE	BDL	BDL	BDL	BDL	22.190±0.508	BDL
p,p-DDE	BDL	BDL	BDL	BDL	BDL	BDL

BDL = below detection limits n = 6, mean ± sd dw = dry weight

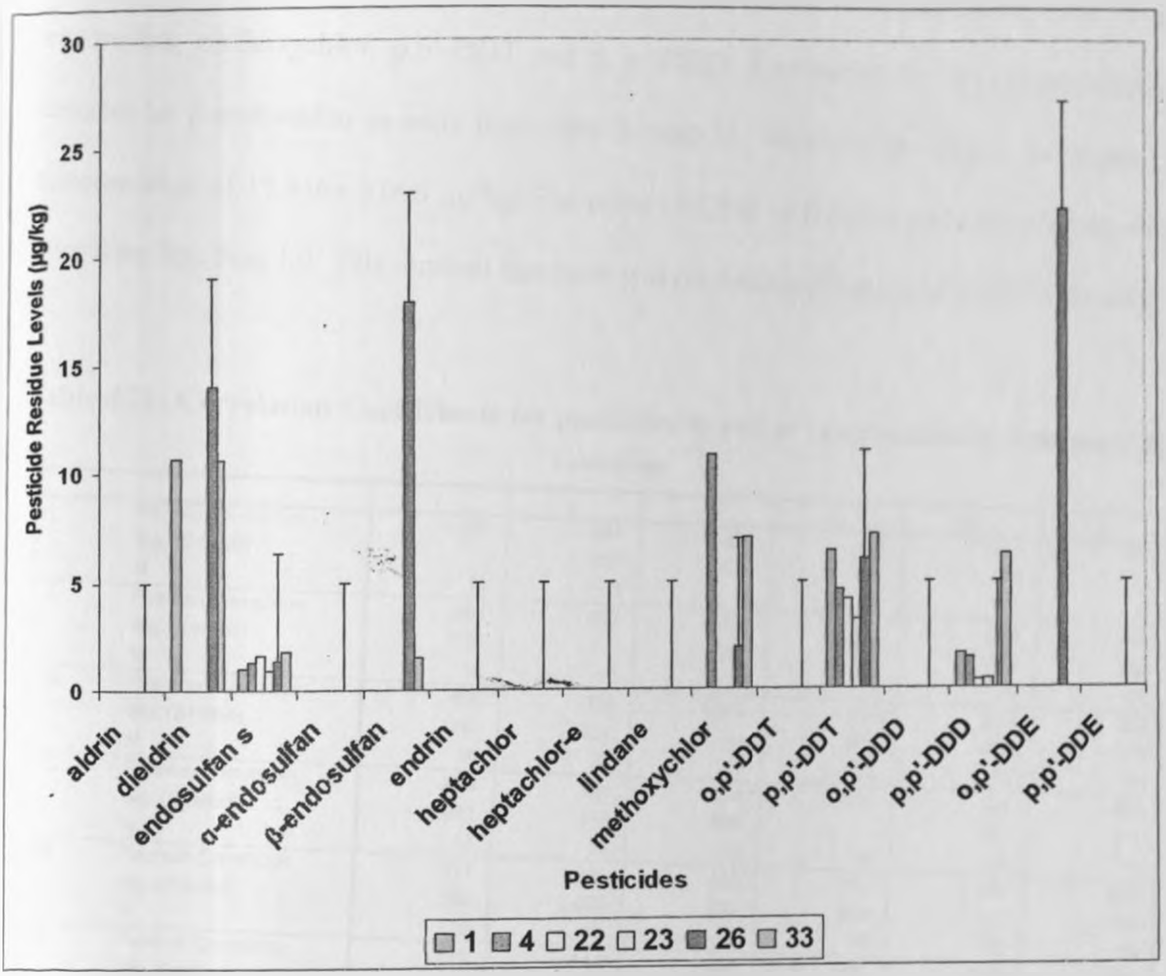

Figure 4.21: Pesticide residue levels (µg/kg, dw) in soil at various sites in February 2005

The pesticide residues in the soil showed strong positive Pearson correlation coefficients (P<0.01) in the range of 0.544 - 0.994 (Table 4.22). The correletion value of 0.994 was highest (sites 22 and 23) followed by 0.819 (sites 1 and 33) and 0.544 (sites 4 and 33). For two sites showing strong positive Pearson correlation coefficient, same pesticides were detected.

Endosulfan sulfate and p, p'-DDT were detected in all the soils sampled in 2005. The highest endosulfan sulfate (1.808±0.044 µg/kg) and p,p'-DDT (7.139±0.777 µg/kg) concentrations was detected in soil from site 33. Soils from sites 22 and 23 which had the highest Pearson correlation coefficient (0.994) showed endosulfan sulfate, p,p'-DDT and p,p'-DDD while sites 1 and 33 showed dieldrin, endosulfan sulfate, p,p'-DDT and p,p'-DDD and sites 4 and 33 showed endosulfan, methoxychlor, p,p'-DDT and p, p'-DDD. Endosulfan (α- and β-endosulfan) was detected as β-endosulfan in soils from sites 26 and 33, with site 26 having the highest mean concentration of 17.956± 0.096 μg/kg. The ratios of DDE to DDD in soils from all the sampled sites were less than 1.0. This implied that there was no fresh application of DDT in the soil.

Table 4.22: Correlation Coefficients for pesticides in soil at various sites in February 2005

Correlations

		1	4	22	23	26	30
1	Pearson Correlation	1 000	084	435	449	341	819**
	Sig (2-tailed)		757	092	081	196	000
	N	16	16	16	16	16	16
4	Pearson Correlation	084	1.000	.320	328	- 069	544*
	Sig (2-tailed)	.757		227	215	800	029
	N	16	16	16	16	16	16
22	Pearson Correlation	435	320	1 000	994**	023	382
	Sig. (2-tailed)	092	.227		000	933	144
	N	16	16	16	16	16	16
23	Pearson Correlation	449	328	994**	1 000	028	406
	Sig. (2-tailed)	081	215	000		919	118
	N	16	16	16	16	16	16
26	Pearson Correlation	.341	-.069	.023	.028	1 000	259
	Sig. (2-tailed)	.196	.800	.933	919		332
	N	16	16	16	16	16	16
30	Pearson Correlation	819**	544*	382	406	259	1 000
	Sig. (2-tailed)	000	029	144	118	332	
	N	16	16	16	16	16	16

**. Correlation is significant at the 0 01 level (2-tailed)

*. Correlation is significant at the 0 05 level (2-tailed)

Out of the sixteen organochlorine pesticides monitored in February 2006, soils from site 33 showed the highest frequency (10) for the pesticides followed by sites 1 and 26 which showed eight pesticides and sites 4 (cabbages/maize farm at Londiani Township) and 23 (coffee farm at Songhor area) which showed six pesticide residues each while sites 22 (sugar cane farm Ainopngetuny) showed five pesticides in 2006 (Table 4.23). These values are also presented in

Figure 4.22.

Table 4.23: Pesticide residue levels (µg/kg, dw) in soil at various sites in February 2006

Pesticides/sites	1	4	22	23	26	33
Aldrin	BDL	BDL	BDL	BDL	BDL	BDL
Dieldrin	9.69±0.512	BDL	BDL	BDL	9.931±0.905	12.371±0.531
endosulfan S	1.029±0.062	0.961±0.055	1.310±0.061	1.059±0.072	0.884±0.038	1.505±0.041
α-endosulfan	BDL	BDL	BDL	BDL	BDL	BDL
β-endosulfan	0.322±0.034	0.119±0.037	0.839±0.056	0.691±0.019	11.577±0.019	1.324±0.080
Endrin	1.179±0.053	BDL	BDL	BDL	BDL	1.778±0.248
heptachlor	BDL	BDL	BDL	BDL	BDL	BDL
heptachlor-epoxide	BDL	BDL	BDL	BDL	0.139±0.013	1.361±0.101
Lindane	7.555±0.595	BDL	BDL	BDL	7.765±0.698	6.821±0.560
methoxychlor	BDL	12.980±0.098	BDL	17.983±0.996	23.894±0.152	35.666±0.453
O'P-DDT	BDL	BDL	BDL	BDL	BDL	BDL
P'P-DDT	5.781±0.308	3.831±0.318	3.314±0.309	2.715±0.322	5.156±0.138	5.523±0.387
O'P-DDD	BDL	BDL	BDL	BDL	BDL	BDL
P'P-DDD	1.234±0.111	0.934±0.046	0.187±0.009	0.262±0.028	BDL	5.50±0.178
O'P-DDE	BDL	BDL	BDL	BDL	BDL	BDL
P'P-DDE	1.929±0.042	0.739±0.035	0.461±0.028	1.039±0.038	0.837±0.038	6.711±0.089

BDL = below detection limits   n = 6, mean ± Sd, dw = dry weight

The pesticide residues in the soils showed strong positive Pearson correlation coefficients ($P<0.01$) in the range of 0.790 - 0.988 (Table 4.24). The correletion value of 0.988 was highest (sites 4 and 23) followed by 0.920 (sites 23 and 33) and the lowest value was 0.790 (sites 4 and 26). Endosulfan sulfate, β-endosulfan, p,p'-DDT and p, p'-DDE were detected from all the sites sampled in 2006. The highest concentration of endosulfan sulfate was detected at site 33 (1.505±0.041 µg/kg) while β-endosulfan was highest at site 26 (11.577±0.019 µg/kg) and p,p'-DDT at site 1 (5.781±0.308 µg/kg). The ratio of DDE to DDT concentration was < 1.0. implying no fresh application of DDT and significant use of β-endosulfan in tea farms in the Nyando catchment area.

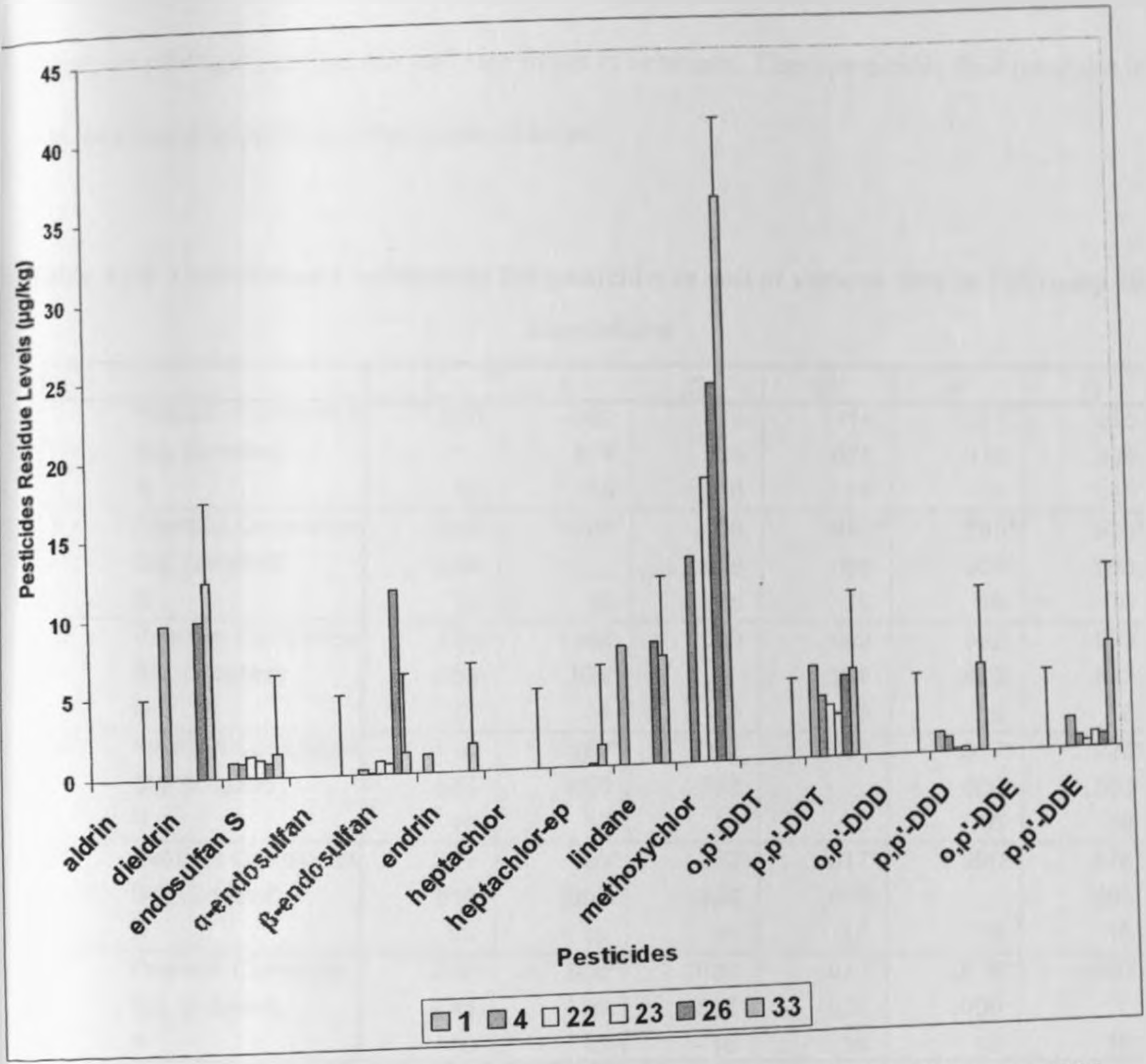

Figure 4.22: Pesticide residue levels (µg/kg, dw) in soil at various sites in February 2006

Dieldrin and methoxychlore were each detected at three sites; 1, 26, 33 and 4, 26 and 33 respectively (Table 4.23). The highest dieldrin concentration was at site 26 (14.073 ± 0.440 µg/kg) while the highest methoxychlor was at site 33 (7.031±0.675 µg/kg). Lindane was detected at increasing concentrations in soils collected at sites 33 (6.821±0.560 µg/kg), 1 (7.55±0.595 µg/kg) and 26 (7.765±0.698 µg/kg) in 2006 respectively. There was no lidane detected from soil samples collected in 2005. Soils collected in 2006 showed higher pesticide concentrations than in

2005. This would imply continued use of β-endosulfan in tea and rice farms, dieldrin in totato, tea and rice farms while lindane finds use in tomato, tea and rice farms and methoxychlor is used mainly in cabbages, coffee, tea and rice farms in February. These pesticides find most use in rice and tea crops compared to other types of crops.

Table 4.24: Correlation Coefficients for pesticides in soil at various sites in February 2006

Correlations

		1	4	22	23	26	33
1	Pearson Correlation	1.000	- 062	.274	-.114	271	210
	Sig. (2-tailed)	.	.819	.305	675	.310	436
	N	16	16	16	16	16	16
4	Pearson Correlation	-.062	1.000	.166	.988**	.790**	.908*
	Sig. (2-tailed)	.819	.	.539	.000	.000	.000
	N	16	16	16	16	16	16
22	Pearson Correlation	.274	.166	1.000	.042	062	-.039
	Sig. (2-tailed)	.305	.539		878	820	887
	N	16	16	16	16	16	16
23	Pearson Correlation	-.114	.988**	.042	1.000	817**	.920*
	Sig. (2-tailed)	.675	.000	.878	.	.000	.000
	N	16	16	16	16	16	16
26	Pearson Correlation	.271	.790**	.062	817**	1.000	876*
	Sig. (2-tailed)	.310	.000	820	.000		000
	N	16	16	16	16	16	16
33	Pearson Correlation	.210	908**	-.039	920**	876**	1.000
	Sig. (2-tailed)	436	.000	887	.000	.000	
	N	16	16	16	16	16	16

**. Correlation is significant at the 0.01 level (2-tailed).

4.1.2 Pesticides residues in soil samples at various sites in September

September is dry period with average monthly rainfall of 31.35 mm (Appendix 4.0, Figure 4.5). The value obtained for the pesticides residue levels in soils collected in September 2005 is given in Table 4.31. These values are also presented in Figure 4.23.

Table 4.31: Pesticide residue levels (μg/kg, dw) in soil at various sites in September 2005

Pesticides/sites	1	4	22	23	26	33
Aldrin	BDL	BDL	BDL	BDL	BDL	BDL
Dieldrin	12.609±0.654	BDL	BDL	BDL	10.297±0.392	11.502±0.378
endosulfan S	11.120±0.038	2.329±0.052	2.878±0.118	1.978±0.107	2.158±0.006	1.451±0.012
α-endosulfan	BDL	BDL	BDL	BDL	BDL	BDL
β-endosulfan	BDL	BDL	BDL	BDL	27.253±0.360	BDL
Endrin	1.345±0.123	BDL	BDL	BDL	BDL	3.198±0.794
heptachlor	BDL	BDL	BDL	BDL	BDL	BDL
heptachlor-epoxide	BDL	BDL	BDL	BDL	0.982±0.023	2.895±
Lindane	BDL	BDL	BDL	BDL	BDL	BDL
methoxychlor	BDL	10.738±0.122	BDL	BDL	20.302±0.440	5.503±0.169
o,p-DDT	BDL	BDL	BDL	BDL	BDL	BDL
p,p-DDT	7.232±0.109	5.499±0.236	4.109±0.052	3.876±0.214	5.149±0.018	6.183±0.099
o,p-DDD	BDL	BDL	BDL	BDL	BDL	BDL
p,p-DDD	1.669±0.139	1.549±0.071	0.426±0.025	0.543±0.012	BDL	5.076±0.090
o,p-DDE	BDL	BDL	BDL	BDL	24.7±0.090	BDL
p,p-DDE	BDL	BDL	BDL	BDL	BDL	BDL

BDL = below detection limits n = 6, mean ± sd dw = dry weight

Strong positive Pearson correlation corfficient (Table 4.32) was obtained for residue concentrations at various sites in September 2005. Site 1 and 23 showed the lowest value (r = 0.559), followed by sites 1 and 22 (r = 0.610). sites 1 and 33 (r = 0.675) and sites 22 and 23 (r = 0.988). Endosulfan sulfate and p.p'-DDT were detected from all sampling sites. The concentration of endosulfan sulfate was in the range 1.451±0.012 μg/kg -11.120±0.038 μg/kg with the highest concentration detected at site 1 and lowest at site 33. The concentration of p.p'-DDT was in the range 3.876±0.214 μg/kg -7.322±0.109 μg/kg. The highest concentration of p,p'-DDT was detected at site 1 and the lowest at site 23. The ratios of concentrations of DDE to DDT in soils at various sites show that there is no fresh application of DDT in the soils. The low levels of DDT and its metabolites p,p'-DDE and p.p'-DDD is due to its restricted use only in public health sector.

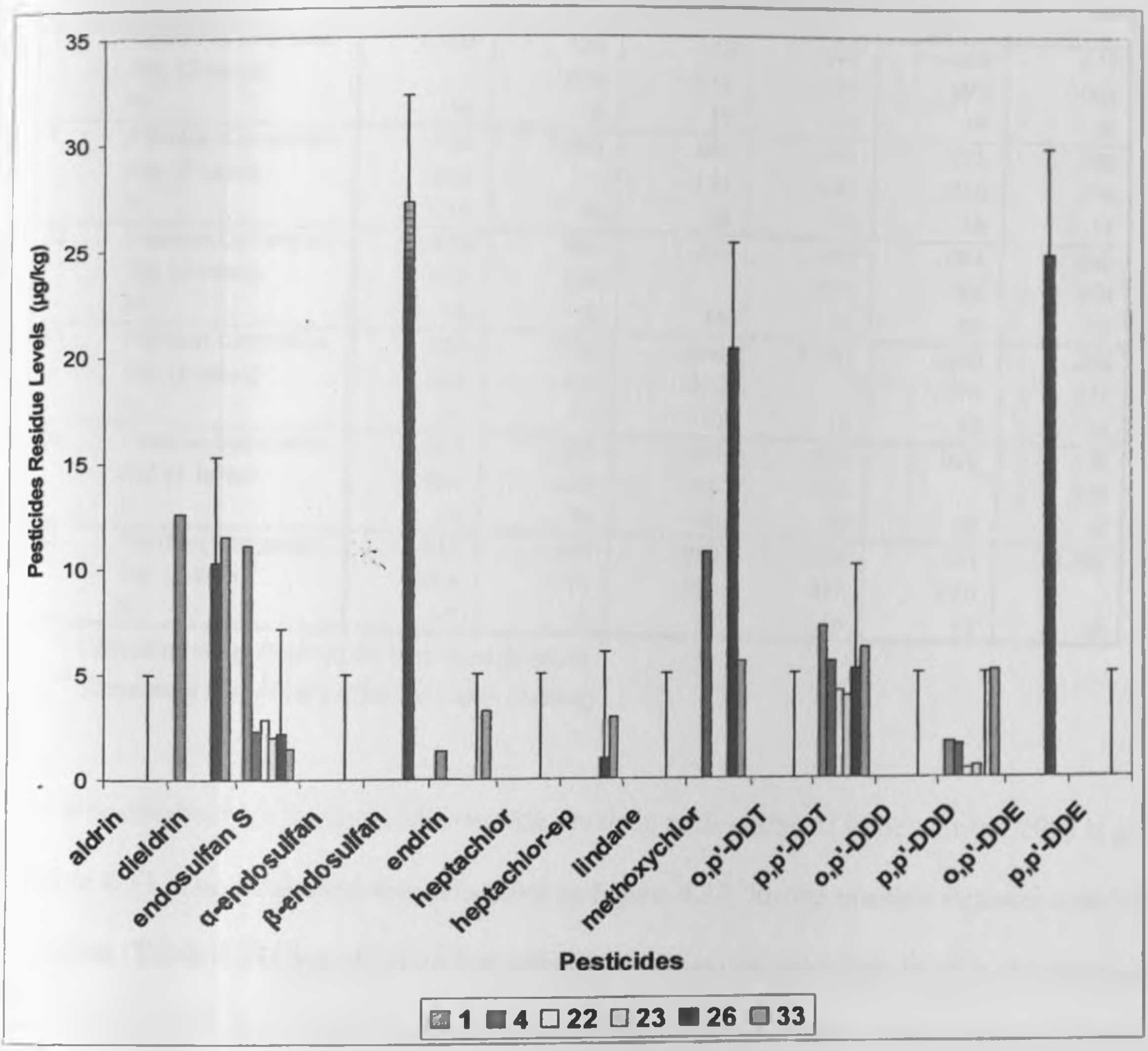

Figure 4.23: Pesticide residue levels (µg/kg, dw) in soil at various sites in September 2005

β-endosulfan was only detected at site 26 with a value of 27.253±0.360 µg/kg. These results show that endosulfan was in use in the Nyando drainage basin as β-endosulfan and endosulfan sulfate in tomato and tea farms in 2005. Dieldrin was detected at three sites (1, 26 and 33). Site 1(12.609±0.654 µg/kg) showed the highest concentration followed by site 33 (11.502±0.378 µg/kg) and site 26 (10.297±0.392 µg/kg) respectively. This shows that dieldrin was in use in tomato, rice and tea farms in September 2005.

Table 4.32: Correlation Coefficients for pesticides in soil at various sites in September 2005

Correlations

		1	4	22	23	26	33
1	Pearson Correlation	1.000	.138	.610*	.559*	- 003	675**
	Sig. (2-tailed)		.610	012	024	991	004
	N	16	16	16	16	16	16
4	Pearson Correlation	.138	1.000	390	405	325	405
	Sig. (2-tailed)	.610		.136	.120	219	119
	N	16	16	16	16	16	16
22	Pearson Correlation	.610*	.390	1.000	.988**	- 084	250
	Sig. (2-tailed)	012	.136		000	756	350
	N	16	16	16	16	16	16
23	Pearson Correlation	.559*	.405	.988**	1.000	- 080	289
	Sig. (2-tailed)	.024	.120	000		770	.277
	N	16	16	16	16	16	16
26	Pearson Correlation	-.003	.325	- 084	- 080	1 000	134
	Sig. (2-tailed)	991	.219	.756	.770		620
	N	16	16	16	16	16	16
33	Pearson Correlation	.675**	.405	.250	.289	.134	1.000
	Sig. (2-tailed)	.004	.119	.350	.277	620	
	N	16	16	16	16	16	16

*. Correlation is significant at the 0.05 level (2-tailed)

**. Correlation is significant at the 0.01 level (2-tailed).

The value obtained for the pesticides residue levels in soils collected in September 2006 is given in Table 4.33. The values are also presented in Figure 4.32. Strong positive Pearson correlation corfficient (Table 4.34) was obtained for pesticides residue concentrations in soils at various sites in September 2006. Site 1 and 23 showed the highest value (r = 0.994), followed by sites 26 and 33 (r = 0.989), sites 1 and 26 (r = 0.985) and sites 1 and 4 (r = 0.885) and site 1 and 23 (r = 0.885).

Table 4.33: Pesticide residue levels (μg/kg, dw) in soil at various sites in September 2006

Pesticides/sites	1	4	22	23	26	33
Aldrin	BDL	BDL	BDL	BDL	BDL	BDL
Dieldrin	BDL	BDL	BDL	BDL	BDL	BDL
endosulfan S	14.369±1.273	1.977±1.286	BDL	6.983±1.342	9.890±0.865	12.841±0.927
α-endosulfan	BDL	BDL	BDL	BDL	BDL	BDL
β-endosulfan	BDL	BDL	BDL	BDL	BDL	BDL
Endrin	BDL	BDL	BDL	BDL	BDL	BDL
heptachlor	BDL	BDL	BDL	BDL	BDL	BDL
heptachlor-epoxide	BDL	BDL	BDL	BDL	BDL	BDL
Lindane	6.259±0.222	BDL	BDL	BDL	6.017±0.480	5.478±0.349
methoxychlor	BDL	BDL	BDL	BDL	BDL	BDL
O'P-DDT	BDL	BDL	BDL	BDL	BDL	BDL
P'P-DDT	4.082±0.133	BDL	BDL	BDL	4.233±0.430	5.187±0.283
O'P-DDD	BDL	BDL	BDL	BDL	BDL	BDL
P'P-DDD	BDL	BDL	BDL	BDL	BDL	BDL
O'P-DDE	BDL	BDL	BDL	BDL	BDL	BDL
P'P-DDE	BDL	BDL	BDL	BDL	BDL	BDL

BDL = below detection limits n = 6, mean ± Sd , dw = dry weight

Table 4.34: Correlation Coefficients for pesticides in soil at various sites in September 2006

Correlations

		1	4	22	23	26	33
1	Pearson Correlation	1.000	.885**	.[a]	.885**	.985**	.994**
	Sig. (2-tailed)		.000	.	.000	.000	.000
	N	16	16	16	16	16	16
4	Pearson Correlation	.885**	1.000	.[a]	1.000**	.792**	.858**
	Sig. (2-tailed)	.000		.	.000	.000	.000
	N	16	16	16	16	16	16
22	Pearson Correlation	.[a]	.[a]	.[a]	.[a]	.[a]	.[a]
	Sig. (2-tailed)	.	.	.	.	.	.
	N	16	16	16	16	16	16
23	Pearson Correlation	.885**	1.000**	.[a]	1.000	.792**	.858**
	Sig. (2-tailed)	.000	.000	.		.000	.000
	N	16	16	16	16	16	16
26	Pearson Correlation	.985**	.792**	.[a]	.792**	1.000	.989**
	Sig. (2-tailed)	.000	.000	.	.000		.000
	N	16	16	16	16	16	16
33	Pearson Correlation	.994**	.858**	.[a]	.858**	.989**	1.000
	Sig. (2-tailed)	.000	.000	.	.000	.000	
	N	16	16	16	16	16	16

**. Correlation is significant at the 0.01 level (2-tailed).

a. Cannot be computed because at least one of the variables is constant

Endosulfan sulfate was detected at all sites except site 22 in September 2006. Site 1 showed the highest concentration of endosulfan sulfate (14.369±1.273 μg/kg) and site 4 (1.977±0.1286 μg/kg) showed the lowest concentration. Lindane and p,p'-DDT were detected at sites 1, 26, and 33. Most pesticides residues were detected in soils collected in September 2005 compared to 2006.

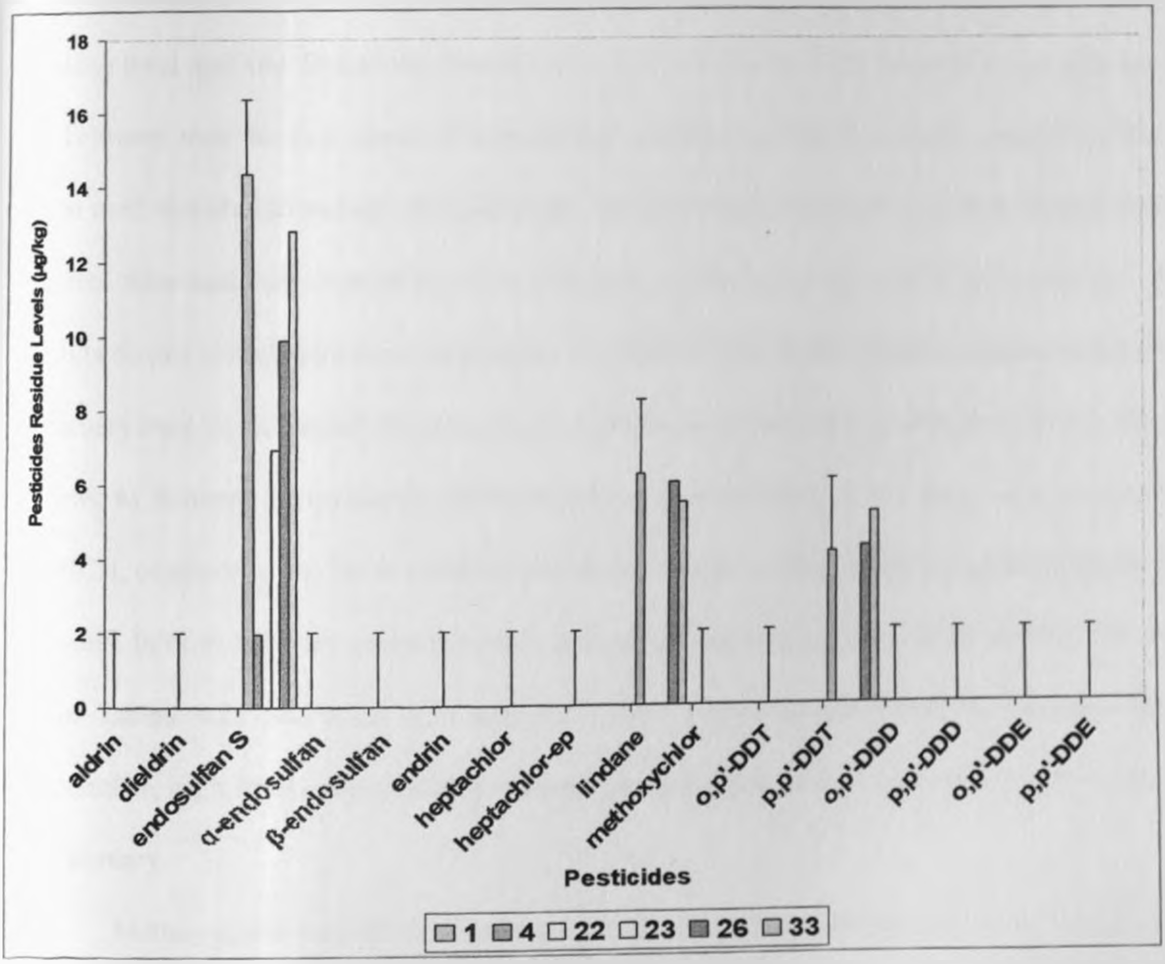

Figure 4.24: Pesticide residue levels (μg/kg, dw) in soil at various sites in September 2006

The levels of β-endosulfan were higher in February while those of endosulfan sulfate were higher in September this could be due to accumulation of endosulfan sulfate. There was no aldrin and heptachlor detected in the soil samples in February and September from any of the sampling sites and were therefore reported as below the detection limit (BDL). This implied that there were no application of aldrin and heptachlor on soils at the various farms. However dieldrin, a metabolite of aldrin was detected at sites 1, 26 and 33 in February and September 2005, indicating the use of dieldrin in tomato, tea and rice farms respectively. Heptachlor epoxide, a degradation product of heptachlor was detected at sites 26 and 33 in February and there were no residues detected in any of the soils from various sites in September. Station 33 had the highest residue level and site 26 had the lowest levels this would imply that heptachlor epoxide detected in February may be as a result of atmospheric deposition. Endrin, a foliar insecticide that has been used worldwide mainly on field crops such as cotton and grains and also as rodenticide to control mice and voles was detected in February and not from any site in in September. These results do not reveal any recent application of endrin in the fields; therefore amounts detected in February may be as a result of atmospheric deposition. Hexachlorocyclohexane (HCH), formally known as Benzene Hexachloride (BHC) exists in eight isomers. In this study only gamma HCH (γ-HCH, commonly known as lindane) was monitored due to lack of pure standards for the other isomers. In both February and September lindane was detected at sites: 1, 26 and 33. The results from Tables 4.21 and 4.23, 4.31 and 4.33 show higher residue levels in February than in September, high levels may possibly indicate continued use of the compound in the three farms in February.

Methoxychlor was detected at sites 4, 23, 26 and 33 in February and sites 4, 26 and 33 in September. The levels detected in February were higher than those detected in September. This implies that methoxychlor is mostly used during the dry periods in cabbages, tea and rice farms respectively. The results for February also show higher levels in 2006 than 2005 implying that the compound was used more during the dry periods in 2006. p,p`-DDT and p,p`-DDD were detected at frequencies of 60 % each in February. There were no o,p-DDT and o,p-DDD detected in February and September whereas only p,p-DDE was not detected in September. The concentration of p,p-DDT was highest at site 1 and lowest at site 23 in February while in September the highest concentration was detected at site 33 and lowest at site 23. p,p-DDD was detected in all the sites except site 26 while o,p-DDE was only detected in site 26. Ratios of DDE/DDT, α-HCH/lindane, dieldrin/aldrin and heptachlor epoxide/heptachlor in soil are often used as indicators of recent DDT, lindane (γ-HCH), aldrin and heptachlor inputs into the environment, with low ratios, particularly <1, indicating recent input (Gonzalez et al. 2003). The values calculated in this study, for DDE/DDT ratio from site 1, 0.963/6.094 = 0.158 and in site 4 the ratio was 0.370/4.224 = 0.088. All the other sites also showed ratios <1. This indicates recent application, of DDT; however DDT was banned in Kenya in 1986 and has been restricted to disease vector control only. The number of pesticide residues detected in September was lower than those in February. Endosulfan sulfate, β-endosulfan, dieldrin, methoxychlor, p,p`-DDT, p,p`-DDD and p,p`-DDE were the most frequently detected residues in the dry periods in soil from rice, tea and tomato farms respectively.

4.1.3 Pesticides residues in soil samples at various sites in May

The average monthly rainfall value for May (wet period) was 213.70 mm as shown in Appindix 4.0 (Figure 4.5). Out of the sixteen organochlorine pesticides monitored in May, sites 33 and 26 had the highest number (5) of residues detected followed by site 1 which showed four pesticide residues while sites 4, 22 and 23 showed three pesticide residues each in 2005 (Table 4.41).

Figure 4.25 show the monthly residue levels in 2005. Four sampling sites showed strong positive Pearson correlation (P<0.01) to each other with the coefficients in the range of 0.870 - 0.998 (Table 4.42).

Table 4.41: Pesticide residue levels (μg/kg, dw) in soil at various sites in May 2005

Pesticides/sites	1	4	22	23	26	33
Aldrin	BDL	BDL	BDL	BDL	BDL	BDL
Dieldrin	12.508±0.243	BDL	BDL	BDL	9.799±0.373	12.311±0.405
endosulfan S	1.213±0.142	2.297±0.079	1.677±0.088	1.137±0.342	2.085±0.039	2.584±0.290
α-endosulfan	BDL	BDL	BDL	BDL	BDL	BDL
β-endosulfan	BDL	BDL	BDL	BDL	25.827±0.496	BDL
Endrin	BDL	BDL	BDL	BDL	BDL	BDL
heptachlor	BDL	BDL	BDL	BDL	BDL	BDL
heptachlor-epoxide	BDL	BDL	BDL	BDL	BDL	BDL
Lindane	BDL	BDL	BDL	BDL	BDL	BDL
methoxychlor	BDL	10.499±0.119	BDL	BDL	1.853±0.103	5.828±0.087
O'P-DDT	BDL	BDL	BDL	BDL	BDL	BDL
P'P-DDT	7.358±0.111	5.377±0.231	3.736±0.173	2.967±0.121	4.708±0.331	5.369±0.202
O'P-DDD	BDL	BDL	BDL	BDL	BDL	BDL
P'P-DDD	1.632±0.043	BDL	1.501±0.089	1.134±0.321	BDL	5.238±0.180
O'P-DDE	BDL	BDL	BDL	BDL	23.317±0.355	BDL
P'P-DDE	BDL	BDL	BDL	BDL	BDL	BDL

BDL = below detection limits n = 6, mean ± Sd, dw = dry weight

The correletion value of 0.998 was highest for sites 22 and 23 and the lowest for sites 1 and 33. At site 22 and 23, β-endosulfan (1.677±0.088 μg/kg and 1.137±0.342 μg/kg), p,p'-DDT (3.736±0.173 μg/kg and 2.967±0.121 μg/kg) and p,p'-DDD (1.501±0.089 μg/kg and 1.134±0.32 μg/kg) respectively were detected. Aldrin, α-endosulfan, endrin, heptachlor, hepterchlor epoxide and lindane were below the detection limits, this implies that these pesticides were not in use in May 2005. Dieldrin was detected at sites 1(12.508±0.243 μg/kg), 26 (9.799±0.373 μg/kg) and 33 (12.311±0.405 μg/kg). This indicates that dieldrin was applied to tomatoe, tea and rice farms in 2005 respectively. Endosulfan and p,p'-DDT were both dectected in soils sampled in May 2005.

ghest endosulfan sulfate was detected at sites 33 (2.584±0.290 µg/kg) followed by site 26 5 ± 0.039 µg/kg). The highest p,p'-DDT was detected at site 1 (7.358 ±0.111 µg/kg) and st at site 23 (2.967±0.121 µg/kg). The levels detected do not reveal fresh application of ulfan sulfate and DDT in May 2005. Methoxychlor was highest at site 4 (10.499±0.119 g) followed by site 33 (5.828 ±0.087 µg/kg) and 26 (1.853±0.103 µg/kg), implying that oxychlor was applied to cabbage far in May 2005.

le 4.42: Correlation Coefficients for pesticides in soil at various sites in May 2005

Correlations

		1	4	22	23	26	33
	Pearson Correlation	1 000	110	410	420	146	870**
	Sig (2-tailed)		685	115	106	590	000
	N	16	16	16	16	16	16
	Pearson Correlation	110	1 000	361	365	-075	397
	Sig (2-tailed)	685		169	165	781	128
	N	16	16	16	16	16	16
	Pearson Correlation	410	361	1 000	998**	-063	342
	Sig (2-tailed)	.115	169		000	818	195
	N	16	16	16	16	16	16
	Pearson Correlation	420	365	998**	1 000	-067	342
	Sig (2-tailed)	.106	.165	000		833	195
	N	16	16	16	16	16	16
	Pearson Correlation	.146	-075	-063	-067	1 000	067
	Sig (2-tailed)	590	781	818	833		806
	N	16	16	16	16	16	16
	Pearson Correlation	870**	397	342	342	067	1 000
	Sig (2-tailed)	000	.128	.195	195	806	
	N	16	16	16	16	16	16

**. Correlation is significant at the 0 01 level (2-tailed)

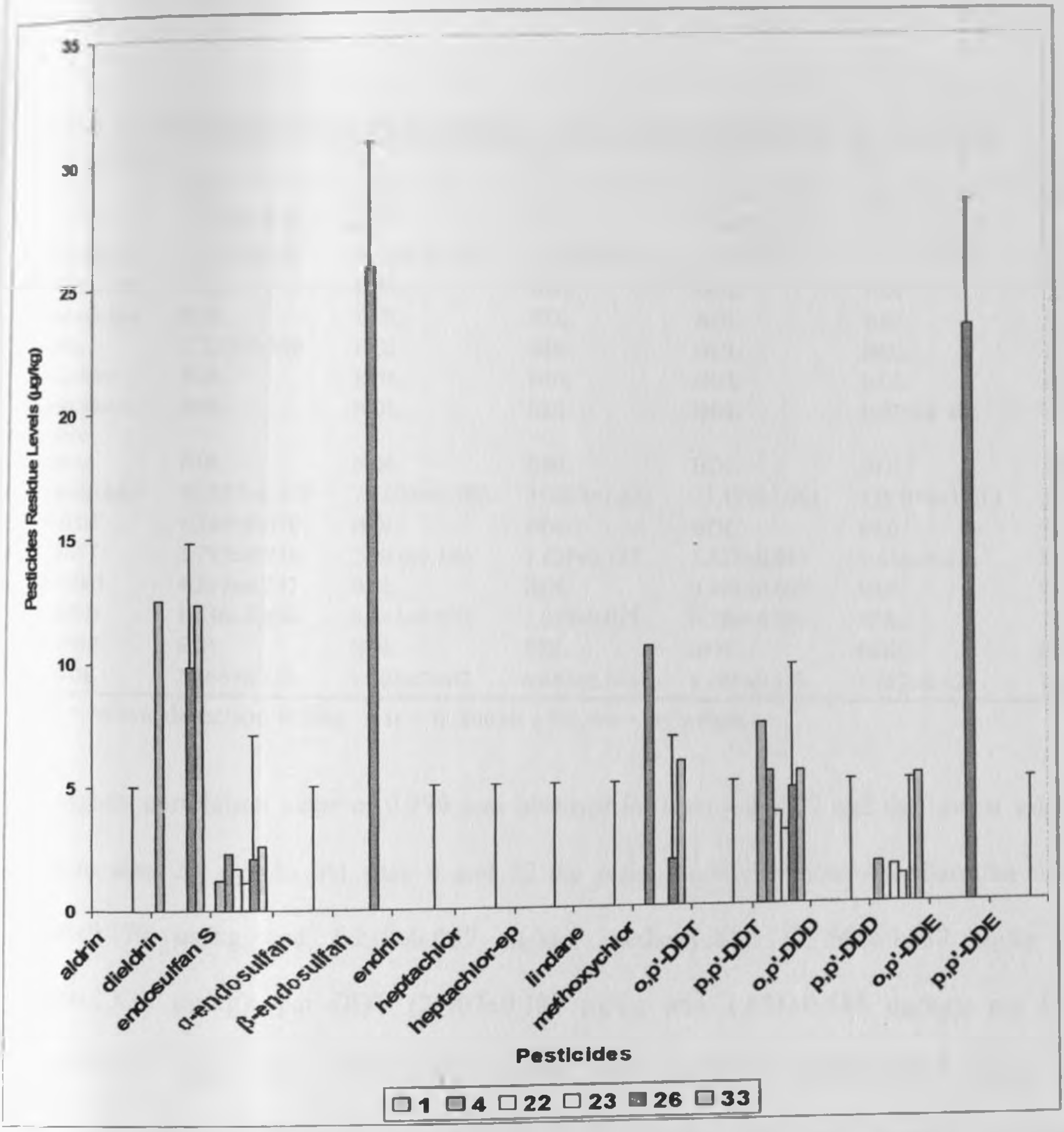

Figure 4.25: Pesticide residue levels (µg/kg, dw) in soil at various sites in May 2005

Out of the sixteen organochlorine pesticides monitored in May 2006, sites 1 and 33 had the highest number (9) of residues detected followed by site 23 which showed eight pesticide residues while site 26 showed six pesticides and 4 and 22 showed five pesticide residues each in 2006 (Table 4.43). Figure 4.26 show the residue concentrations detected in May 2006. All the sampling sites showed strong positive Pearson correlation ($P<0.01$) to each other with the coefficients in the range of 0.865 - 0.999 (Table 4.44).

Table 4.43: Pesticide residue levels (µg/kg, dw) in soil at various sites in May 2006

Pesticides/sites	1	4	22	23	26	33
Aldrin	BDL	BDL	BDL	4.444±0.051	BDL	BDL
Dieldrin	9.2888±0.401	BDL	BDL	7.688±0.439	4.302±1.234	12.742±0.
endosulfan S	1.073±0.102	1.166±0.170	1.238±0.057	1.784±0.112	0.637±0.040	1.521±0.03
α-endosulfan	BDL	BDL	BDL	BDL	BDL	1.312±0.34
β-endosulfan	BDL	BDL	BDL	BDL	BDL	BDL
Endrin	1.720±0.309	BDL	BDL	BDL	BDL	2.117±0.16
heptachlor	BDL	BDL	BDL	BDL	BDL	BDL
heptachlor-epoxide	BDL	BDL	BDL	BDL	0.675±0.086	2.387±0.06
Lindane	BDL	BDL	BDL	BDL	BDL	BDL
methoxychlor	51.587±2.918	72.600±0.387	35.609±1.823	23.179±1.904	138.970±1.517	26.336±2.2
O'P-DDT	1.389±0.270	BDL	BDL	BDL	BDL	BDL
P'P-DDT	2.792±0.778	2.907±0.181	1.621±0.145	1.628±0.085	1.630±0.076	4.438±0.3
O'P-DDD	4.319±0.532	BDL	BDL	0.401±0.002	BDL	BDL
P'P-DDD	1.436±0.034	0.642±0.081	2.039±0.025	0.289±0.006	BDL	3.023±0.90
O'P-DDE	BDL	BDL	BDL	BDL	BDL	BDL
P'P-DDE	2.666±0.150	1.002±0.002	0.652±0.043	1.866±0.153	1.162±0.124	7.507±0.63

BDL = below detection limits n = 6, mean ± Sd , dw = dry weight

The highest correletion value of 0.999 was obtained for sites 4 and 22 and the lowest value of 0.865 at sites 22 and 33. At sites 4 and 22 the residue concentration of endosulfan sulfate (1.166±0.170 µg/kg and 1.238±0.057 µg/kg), methoxychlor (72.600±0.387 µg/kg and 35.609±1.823 µg/kg), p,p`-DDT (2.907±0.181 µg/kg and 1.621±0.145 µg/kg), p,p`-DDD (0.642±0.081 µg/kg and 2.039±0.025 µg/kg) and p,p`-DDE (1.002±0.002 µg/kg and 0.652±0.043 µg/kg) respectively were detected in soil samples. The result shows significant use of methoxychlor in cabbage and sugar cane farms in May 2006. β -endosulfan, lindane and o,p`-DDE were below the detection limits, this implies that these pesticides were not in use in May 2006. Dieldrin was detected at sites 1 (9.288±0.401 µg/kg), 23 (7.688±0.439 µg/kg), 26 (4.302±1.234 µg/kg) and 33 (12.742±0.563 µg/kg). This implies that dieldrin was applied to tomato, coffee, tea and rice farms in 2006 respectively. Endosulfan, p,p'-DDT and p,p'-DDE were dectected in all soils sampled in May 2006. The highest endosulfan sulfate concentration was detected at sites 23 (1.784±0.112 μg/kg) followed by site 33 (1.521 ± 0.032 μg/kg).

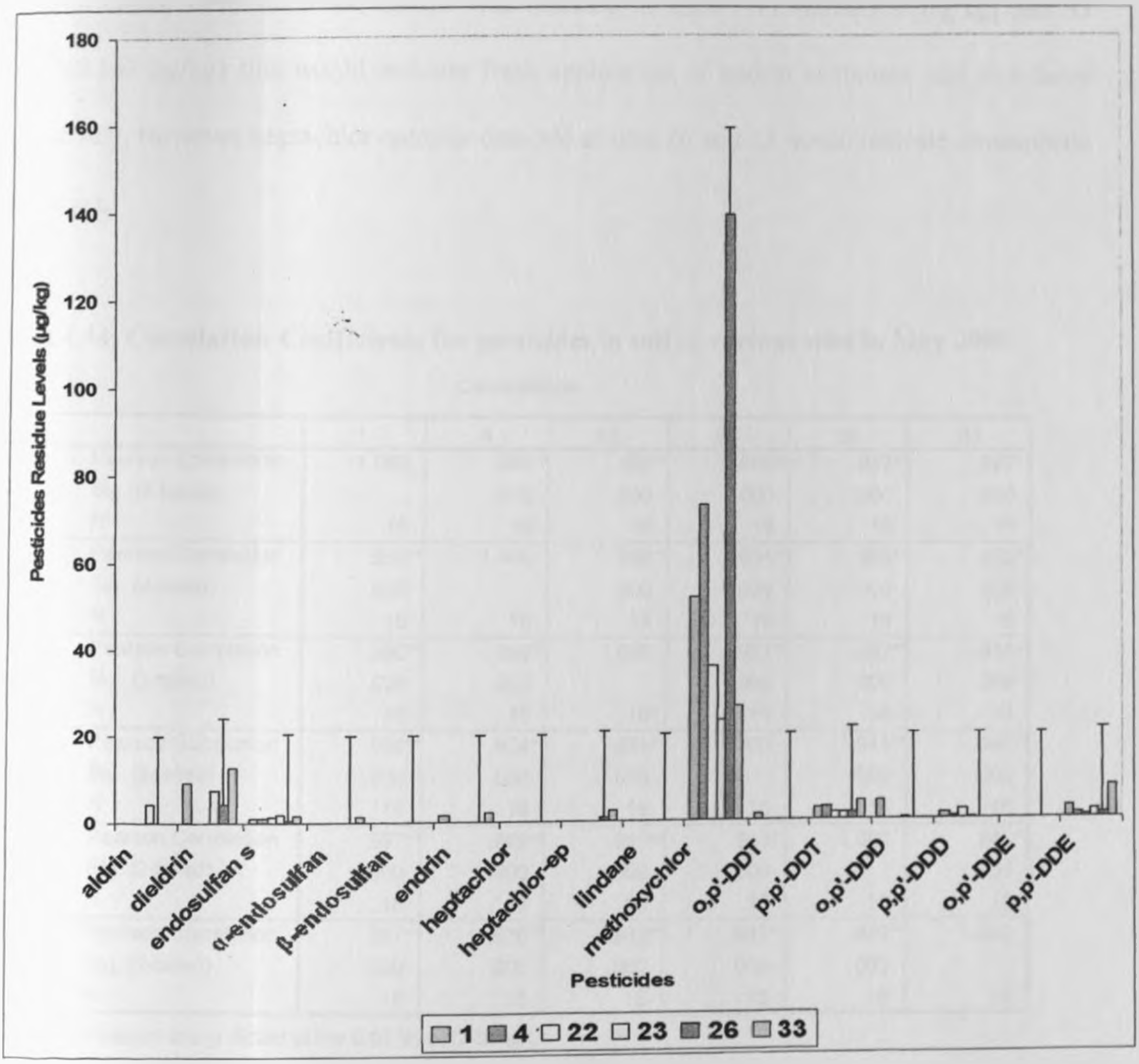

Figure 4.26: Pesticide residue levels (μg/kg, dw) in soil at various sites in May 2006

The highest p,p'-DDT was detected at site 33 (4.438 ±0.315 μg/kg) and lowest at site 22 (1.621±0.145 μg/kg). The levels detected do not reveal fresh application of endosulfan sulfate and DDT in May 2006. Methoxychlor was detected in all soils sampled in 2006 with the highest concentration at site 26 (138.970±1.517 μg/kg). followed by site 4 (72.600 ±0.387 μg/kg) and site 1 (51.587±2.918 μg/kg), implying that methoxychlor was applied in all the fields in May 2006. Aldrin was detected only at site 23 (4.444±0.051 μg/kg), indicates fresh application of aldrin in coffee farm in 2006. Endrin was detected at sites 1 (1.720±0.309 μg/kg) and 33 (2.117±0.163 μg/kg) this would indicate fresh application of endrin in tomato and rice farms respectively. However heptachlor epoxide detected at sites 26 and 33 would indicate atmospheric deposition.

Table 4.44: Correlation Coefficients for pesticides in soil at various sites in May 2006

Correlations

		1	4	22	23	26	33
1	Pearson Correlation	1.000	.982**	.980**	.966**	.987**	.927**
	Sig. (2-tailed)	.	.000	.000	.000	.000	.000
	N	16	16	16	16	16	16
4	Pearson Correlation	.982**	1.000	.999**	.934**	.999**	.870**
	Sig. (2-tailed)	.000	.	.000	.000	.000	.000
	N	16	16	16	16	16	16
22	Pearson Correlation	.980**	.999**	1.000	.931**	.997**	.865**
	Sig. (2-tailed)	.000	.000	.	.000	.000	.000
	N	16	16	16	16	16	16
23	Pearson Correlation	.966**	.934**	.931**	1.000	.943**	.943**
	Sig. (2-tailed)	.000	.000	.000	.	.000	.000
	N	16	16	16	16	16	16
26	Pearson Correlation	.987**	.999**	.997**	.943**	1.000	.880**
	Sig. (2-tailed)	.000	.000	.000	.000	.	.000
	N	16	16	16	16	16	16
33	Pearson Correlation	.927**	.870**	.865**	.943**	.880**	1.000
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.
	N	16	16	16	16	16	16

**. Correlation is significant at the 0.01 level (2-tailed).

4.1.4 Pesticides residues in soil samples at various sites in December

December was a wet period with monthly rainfall value 100.65 mm as shown in Figure 4.5. Out of the sixteen organochlorine pesticides monitored in December 2005, sites 4, 26 and 33 had the highest number (5) of residues detected followed by site 1 which showed four pesticide residues while site 22 and 23 showed three pesticides and sites 22 and 23 showed three pesticide residues each in 2005 (Table 4.51). Figure 4.27 show the residue concentrations detected in December 2005.

Table 4.51: Pesticide residue levels (μg/kg, dw) in soil at various sites in December 2005

Pesticides/sites	1	4	22	23	26	33
Aldrin	BDL	BDL	BDL	BDL	BDL	BDL
Dieldrin	12.236±0.135	BDL	BDL	BDL	10.693±0.164	10.448±0.344
endosulfan S	1.175±0.032	2.149±0.069	3.666±0.150	2.965±0.119	2.247±0.067	2.478±0.024
α-endosulfan	BDL	BDL	BDL	BDL	BDL	BDL
β-endosulfan	BDL	BDL	BDL	BDL	28.791±0.553	BDL
Endrin	BDL	2.872±0.546	BDL	BDL	BDL	BDL
heptachlor	BDL	BDL	BDL	BDL	BDL	BDL
heptachlor-epoxide	BDL	BDL	BDL	BDL	BDL	BDL
Lindane	BDL	BDL	BDL	BDL	BDL	BDL
methoxychlor	BDL	76.441±3.088	BDL	BDL	21.434±0.614	5.679±0.029
O'P-DDT	BDL	BDL	BDL	BDL	BDL	BDL
P'P-DDT	7.312±0.110	5.399±0.293	5.234±0.066	4.368±0.023	4.396±0.368	6.896±0.007
O'P-DDD	BDL	BDL	BDL	BDL	BDL	BDL
P'P-DDD	0.788±0.054	2.836±0.014	0.515±0.007	0.356±0.004	BDL	4.557±0.172
O'P-DDE	BDL	BDL	BDL	BDL	25.994±0.395	BDL
P'P-DDE	BDL	BDL	BDL	BDL	BDL	BDL

BDL = below detection limits n = 6, mean ± Sd, dw = dry weight

Only two sampling sites showed strong positive Pearson correlation (P<0.01) to each other with the coefficient value of 0.861 (Table 4.52). The correletion value of 0.861 was obtained for sites 1 and 33. At sites 1 and 33, the concentrations of dieldrin (12.236±0.135 μg/kg and 10.448±0.344±0.170 μg/kg), endosulfan sulfate (1.175±0.032 μg/kg and 2.478±0.024 μg/kg), p,p'-DDT (7.312±0.110 µg/kg and 6.896±0.007 µg/kg) and p,p'-DDD (0.788±0.054 µg/kg and 4.557±0.172 µg/kg) respectively were obtained. The result shows significant use of dieldrin in tomato, sugar cane and rice farms in December 2005 and no fresh application of DDT. Endosulfan sulfate and p,p'-DDT were detected in all the soils sampled.

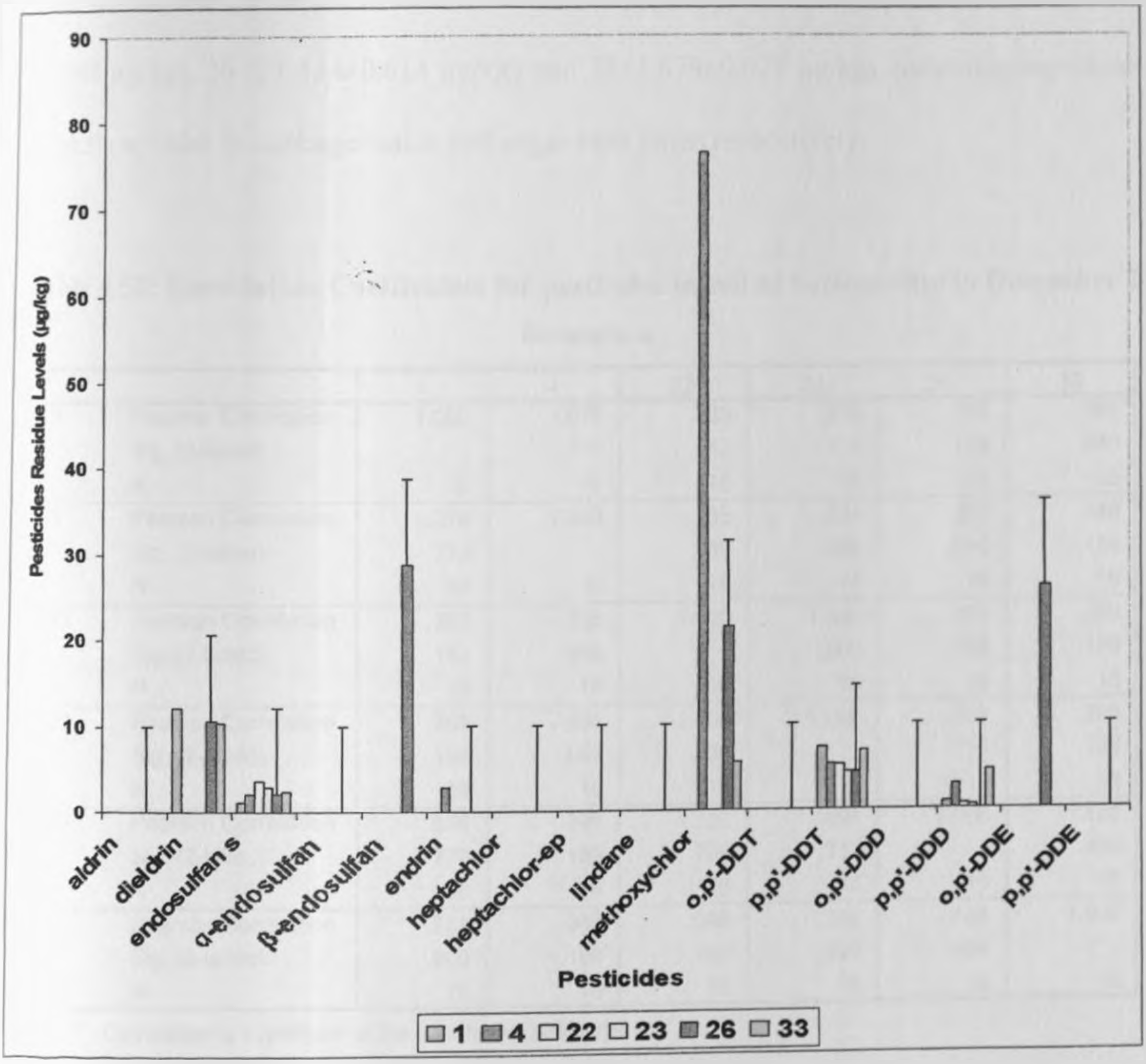

Figure 4.27: Pesticide residue levels (µg/kg, dw) in soil at various sites in December 2005

The highest concentration of endosulfan and p,p'-DDT in soils were detected at sites 1 and 33 while the lowest values were obtained for sites 4 (2.149±0.069 µg/kg) and 23 (4.368±0.023

μg/kg). β –endosulfan and o,p'-DDE were detected at site 26 (28.791±0.553 μg/kg and 25.994±0.395 μg/kg respectivel). This shows significant application of β –endosulfan in tea farms. In the absence of fresh application of DDT to the soils, the metabolites detected are thought to be from previous use. Heptachlor, heptachlor epoxide, lindane, o,p'-DDT, o,p'-DDD and p,p'-DDE were below the detection limits, this implies that heptachlor, lindane and DDT were not in use on farms in December 2005. Methoxychlor was detected at sites 4 (76.411 ±3.088 μg/kg), 26 (21.434±0.614 μg/kg) and 33 (5.679±0.029 μg/kg), indicating significant use of methoxychlor in cabbage/maize and sugar cane farms respectively.

Table 4.52: Correlation Coefficients for pesticides in soil at various sites in December 2005

Correlations

		1	4	22	23	26	33
1	Pearson Correlation	1.000	-.078	.383	.388	.076	.861**
	Sig. (2-tailed)	.	.773	.143	.138	.779	.000
	N	16	16	16	16	16	16
4	Pearson Correlation	-.078	1.000	-.035	-.034	.395	.346
	Sig. (2-tailed)	.773	.	.899	.902	.130	.189
	N	16	16	16	16	16	16
22	Pearson Correlation	.383	-.035	1.000	1.000**	-.101	.396
	Sig. (2-tailed)	.143	.899	.	.000	.709	.129
	N	16	16	16	16	16	16
23	Pearson Correlation	.388	-.034	1.000**	1.000	-.098	.396
	Sig. (2-tailed)	.138	.902	.000	.	.717	.129
	N	16	16	16	16	16	16
26	Pearson Correlation	.076	.395	-.101	-.098	1.000	.188
	Sig. (2-tailed)	.779	.130	.709	.717		.486
	N	16	16	16	16	16	16
33	Pearson Correlation	.861**	.346	.396	.396	.188	1.000
	Sig. (2-tailed)	.000	.189	.129	.129	.486	
	N	16	16	16	16	16	16

**. Correlation is significant at the 0.01 level (2-tailed).

Out of the sixteen organochlorine pesticides monitored in December 2006, site 33 had the highest number (9) of residues detected followed by site 4 which showed eight pesticide residues while site 26 showed four pesticides and sites 22 and 23 showed three pesticide residues each in in 2006 (Table 4.53).

Table 4.53: Pesticide residue levels (μg/kg, dw) in soil at various sites in December 2006

Pesticides/sites	1	4	22	23	26	33
Aldrin	BDL	1.223±0.234	BDL	BDL	13.811±0.601	18.317±0.276
Dieldrin	BDL	13.321±0.234	BDL	BDL	BDL	12.386±0.276
endosulfan S	BDL	2.941±0.546	BDL	BDL	BDL	BDL
α-endosulfan	BDL	BDL	BDL	BDL	BDL	BDL
β-endosulfan	BDL	BDL	BDL	BDL	BDL	BDL
Endrin	BDL	2.470±0.636	BDL	BDL	BDL	10.155±0.860
heptachlor	BDL	BDL	BDL	BDL	BDL	BDL
heptachlor-epoxide	BDL	4.855±0.099	1.649±0.764	2.268±0.291	0.981±0.027	1.675±0.383
Lindane	BDL	8.985±1.318	BDL	7.015±0.047	6.418±1 912	BDL
methoxychlor	126.935±2.742	71.335±0.071	29.433±0.743	80 183±0.207	31.667±2.656	27.482±3.452
O'P-DDT	BDL	BDL	BDL	BDL	BDL	5.436±0.161
P'P-DDT	4.884±1.245	9.701±0.111	6.196±0.624	BDL	BDL	6.698±0.826
O'P-DDD	BDL	BDL	BDL	BDL	BDL	BDL
P'P-DDD	BDL	BDL	BDL	BDL	BDL	6.969±0.630
O'P-DDE	BDL	BDL	BDL	BDL	BDL	BDL
P'P-DDE	BDL	BDL	BDL	BDL	BDL	15.217±0 652

BDL = below detection limits   n = 6, mean ± Sd . dw = dry weight

Figure 4.28 show the residue concentrations detected in December 2006. All the sampling sites showed strong positive Pearson correlation ($P<0.01$) to each other with the coefficient values ranging from 656 to 995 (Table 4.54). The highest correletion value of 0.995 was obtained for sites 1 and 23. Aldrin was detected at sites 4 (1.223±0.234 μg/kg), 26 (13.811±0.601 μg/kg) and 33 (18.317±0.276 μg/kg). This indicates fresh application of aldrin in tomato, tea and rice farms respectively in December 2006. Dieldrin, a metabolite of aldrin was detected at sites 4 (13.321±0.234 μg/kg) and 33 (12.386±0.276 μg/kg). This indicates significant application of dieldrin in cabbage/maize and rice farms respectively. α –endosulfan, β –endosulfan, o,p'-DDD and o,p'-DDE were below the detection limits, this implies that endosulfan (α and β) and heptachlor were not in use on farms in December 2006. The ratio of DDE to DDT was < 1.0.

ndicating no fresh application of DDT.

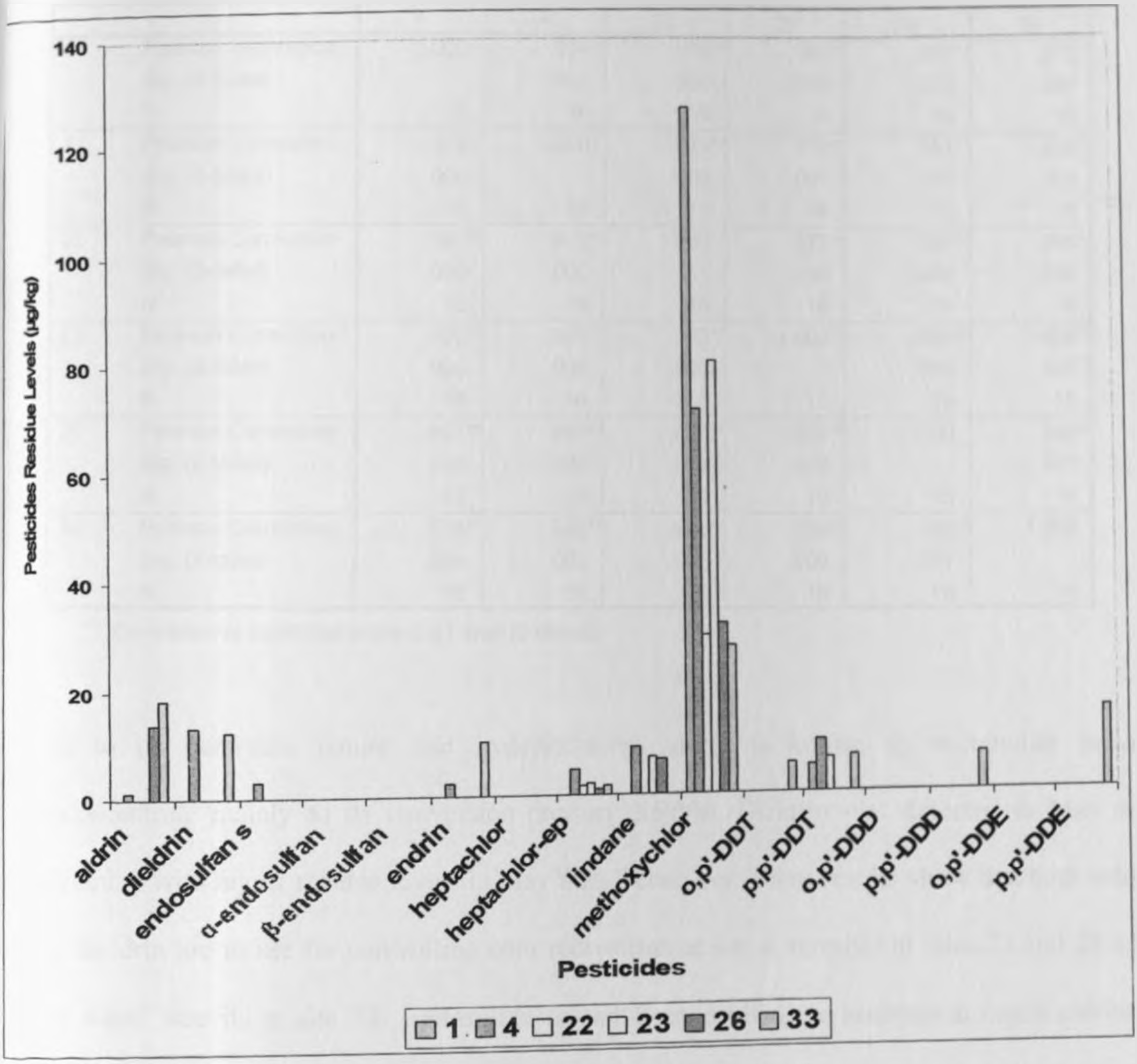

Figure 4.28: Pesticide residue levels (µg/kg, dw) in soil at various sites in December 2006

Lindane was detected at sites 4 (8.985±1.318 µg/kg), 23 (7.015±0.047 µg/kg) and 26 (6.418±1.912 µg/kg). Methoxychlor was detected in all the soils anaysed, with the highest residue concentration at site 1 (126.935±2.742 µg/kg) and lowest value at site 33 (27.482±3.452 µg/kg). This indicates significant application of methoxychlor in tomatoe, cabbage/maize, sugar cane, coffee, tea and rice farms.

Table 4.54: Correlation Coefficients for pesticides in soil at various sites in December 2006

Correlations

		1	4	22	23	26	33
1	Pearson Correlation	1.000	.974**	984**	995**	897**	678*
	Sig. (2-tailed)		000	000	000	000	004
	N	16	16	16	16	16	16
4	Pearson Correlation	.974**	1.000	972**	976**	881**	686**
	Sig (2-tailed)	000		000	000	000	003
	N	16	16	16	16	16	16
22	Pearson Correlation	984**	972**	1 000	973**	869**	665*
	Sig. (2-tailed)	000	.000		000	000	005
	N	16	16	16	16	16	16
23	Pearson Correlation	.995**	.976**	973**	1.000	909**	656*
	Sig. (2-tailed)	.000	.000	000		000	006
	N	16	16	16	16	16	16
26	Pearson Correlation	.897**	.881**	869**	909**	1 000	748*
	Sig. (2-tailed)	000	.000	000	.000		001
	N	16	16	16	16	16	16
33	Pearson Correlation	.678**	.686**	665**	.656**	748**	1 000
	Sig. (2-tailed)	.004	.003	.005	006	001	
	N	16	16	16	16	16	16

**. Correlation is significant at the 0 01 level (2-tailed).

Due to its persistent nature and hydophobicity, aldrin is known to accumulate and/or bioconcentrate mainly as its conversion product dieldrin. Dieldrin was detected in May and December with higher residue levels in May than December. These results show that both aldrin and dieldrin are in use for controlling corn rootworms at site 4, termites at sites 23 and 26 and rice water weevils at site 33. Endosulfan (α-and β-endosulfan), a neurotoxin organochlorine insecticide used in agriculture around the world to control insect pests including aphids, leafhoppers, potato beetles, cabbage worms and other pests was detected only at site 26 as β-endosulfan in May and December where as α-endosulfan was not detected in the soils sampled during the rainy periods. Endosulfan sulfate was detected from the all sampling sites with site 33 reporting the highest and site 1 the lowest residue levels in May. In December, site 4 showed the highest and site 1 the lowest residue levels. The result shows that β-endosulfan was used at site 26; however endosulfan sulfate was not in use but could be a breakdown product.

Endrin, a foliar insecticide used mainly on field crops such as cotton and grains and also as rodenticide to control mice and voles was detected at sites 1 in May and 4 in December. Higher residue levels were detected in December than in May. Heptachlor, a non-systemic stomach and contact insecticide used primarily against soil insects and termites was not detected in the soils collected in May and December in both years. However its metabolite heptachlor epoxide was detected in sites 26 and 33 in May and in all the sampled soils except site 1 in December. Higher residue levels were detected in December than in May. Since there was no fresh application of heptachlor, residues of epoxide detected may be attributed to old applications in the soil or atmospheric deposition. Lindane an insecticide used on fruits, vegetables, forest crops and animal premises and also available as prescription medicine (lotion, cream or shampoo) to treat and/or control scabies and head lice in human was not detected in any of the sampling sites in May but was present in sites 4, 23 and 26 in December. The compound may have been in use in December in vegetables, coffee and tea fields respectively. Methoxychlor an insecticide applied to protect crops, livestock and pets against fleas, mosquitoes, cockroaches and other insects worldwide (ATSDR, 2005) was detected from all the sampling stations in May and December. The levels detected in December were higher than those detected in May. According to Smith (1991), methoxychlor biodegrade more easily and therefore does not lead to significant bioaccumulation, from the results obtained in this study it can be concluded that the compound was in use during wet and short rainy periods.

p,p-DDT and p,p-DDE were detected from all sites in May. In December, only p,p-DDT was detected from all sites while p,p-DDE was only present in site 33. The ratios of DDE to

DDT was less than 1, indicating no fresh application of DDT during the rainy periods. Studies carried out by Getenga *et al.*, (2004) revealed that two months after application of pesticides, the highest concentration of heptachlor was 7.924±1.592 ppm and methoxychlor was at lowest concentration of 1.026±0.118 ppm from the sugarcane farm along the Nyando basin. Aldrin and dieldrin were 4.088±0.760 ppm and 3.512±0.559 ppm respectively. β-endosulfan was still highest in concentration after two months in the soil. All the compounds in the soil rapidly dissipated after six months but thereafter the dissipation rate was low, having attained a steady state in the soil. All the compounds were still in the soil after five years with the highest concentration of endosulfan (0.513±0.139ppm) followed by lindane (1.294±0.346ppm). Heptachlor concentration was least (0.243±0.032ppm) in the soil after five years.

Other studies have shown that the cyclodienes, heptachlor, aldrin, endrin and dieldrin are the most persistent and were found to persist in field crop soils for long periods of time with long-half lives of disappearance ranging from 0.3-2.8 years in temperate soils (Wandiga *et al.*, 1995). Study by Getenga *et al.*, (2004) showed that aldrin and heptachlor were in higher concentrations than their metabolically formed analogs dieldrin and heptachlore epoxide respectively. Other studies by other researchers have also shown that aldrin and heptachlor were in higher concentration than their converted products (Barlas, 2002; Barlas, 1999, Ayes *et al.*, 1997). In this study, the concentrations of dieldrin, heptachlor epoxide and endosulfan sulfate were notably higher than aldrin, heptachlor and endosulfan in most samples. However, the former being the degradation products signified no possible significant transformation process taking place. The most frequently detected pesticide during the wet periods were endosulfan sulfate, methoxychlor, p,p'-DDT, p,p'-DDD and p,p'-DDE. However dieldrin is also commonly used during the wet period except at sites 4 and 22.

Studies aimed at providing baseline information on the levels of organochlorine pesticides in aquatic system of Lake Victoria showed ratios of DDE to DDT suggesting previous use of the pesticides and significant use of lindane and endosulfan within the lake region (Kasozi. 2001: Mbabazi. 1998). Lindane is known to degrade to α-HCH on exposure to sunlight in the environment. γ-HCH is commonly used in Kenya for seed dressing to protect crops against ants, but is currently under restrictions due to its persistence and toxicity. The major sources of organochlorine pesticide residues in Lake Victoria region are agricultural activities and aerial sprays in public health vector control. DDT was extensively applied in aerial sprays against mosquitoes to control malaria in the 1960s and early 1970s (Mitema and Gitau. 1990); where as aldrin and dieldrin are used in termite control in industrial buildings (Getenga *et al*.. 2004). Lindane has been in long term use for seed dressing. whereas endosulfan. heptachlor, and endrin were used as insecticide (PCPB. 1992). The importation. distribution and public use of some of these compounds was banned or restricted in Kenya in 1986.

The results indicates that aldrin has not been in use along the Nyando basin. however the detection of higher levels in December 2006 at sites 26 (Tea Estate) in Nandi and 33 (rice farm) in Nyando districts suggests that there has been the reintroduction of this pesticide by the farmers in these two areas. Dieldrin is in use along the Nyando drainage basin mainly around Kedowa area in tomatoes, tea estates in Nandi and in rice farms near Ahero Town and was detected as dieldrin and not as a result of degradation of aldrin. Endosulfan is used as β-endosulfan mainly in the tea growing areas in Nandi and its metabolite endosulfan sulfate was mostly detected around Kedowa and Ahero where it could be used in tomatoes and rice fields respectively. There has not been any recent application of endrin along the Nyando drainage basin: any that was detected is old in the soil.

Heptachlor which was banned in Kenya has not been in use along the Nyando drainage basin recently since there was no residue level detected in the soil sampled for the two consecutive years. However its metabolite, heptachlor epoxide was detected in all sites except site 1 (tomato farm). In the absence of fresh application of heptachlor the epoxide could be mainly a degradation product that has been persistent in the soil from "dry" or "wet" depositions. The lindane detected in this study was from sites 1, 4, 23, 26 and 33 in February (dry season) and December (short rain season). Lindane is mainly used to kill fungi that affect crops and also used for seed dressing in agriculture. It is most likely that it is used in tomatoes, cabbage/maize, coffee, tea and rice farms respectively in February and December.

Methoxychlor is widely used in the Nyando catchment area and was detected in all the soils from various sites. The chemical could have been used to some degree as a replacement for DDT because it is faster metabolized, does not lead to bioaccumulation (Smith, 1991), has chemical structure and properties similar to those of DDT and it biodegrades more easily. There is no fresh application of DDT along the Nyando drainage basin. In the absence of direct applications, inputs to the soil may be thought of coming from the atmosphere. These may reach the soil by "dry" (particle deposition or condensation from vapour phase) or "wet" (associated with precipitation) deposition. In addition the existing residues may be redistributed by wind, erosion, and run-off.

Since most pesticide residues were detected in the soils during short rain and the dry periods, it implies that along the River Nyando drainage basin most pesticides are used during the period between December and February. Pesticide application to the fields followed the observed trend of; dry seasons>short rain seasons>wet seasons. Not much pesticide is used during the wet season in May. Among the organochlorine pesticide residues monitored, dieldrin, methoxychlor, lindane, endosulfan and DDT were detected from most soils in the order endosulfan>DDT>methoxychlor >dieldrin> lindane, however DDT concentrations were lower than the values obtained for the others. The pesticide residues were detected mostly in soil from rice > tea > tomatoes > vegetables/maize > coffee> sugar cane farms in that order. This implies that the rice farmers use most pesticides followed by tea farmers.

CHAPTER FIVE

5.0 ORGANOCHLORINE PESTICIDE RESIDUES IN WATER, SEDIMENTS AND AQUATIC FLORA

5.1 Results and Discussions

The River Nyando drainage basin is discussed under two sub-catchment areas, the Kericho-Upper Nyando and Nandi-Lower Nyando sub-catchment areas. This enables effort in designing ways of improving or rehabilitating the River Nyando and Lake Victoria ecosystem. Five weed species were dominant at the twenty six sampling sites. They were identified as Cyperus Dischrostachyus Cyperaceal found mainly at sites 1, 9, 10, 15, 16, 22, 25. Cyperus Distaus found dominantly at sites 3, 4, 5, 6, 7, 8, 11, 12, 13, 14, 17, 21, 23 and 27. Cyperus Dives Cyperaceal was found at sites 19, 22 and 26 while Asystasia Gangetical was only found at site 30 and water hyacinth (Eichhornia Crassipes) at site 33. Table 5.11 gives the percentage recoveries of pesticide residues in water, seediments and aquatic weeds samples.

Table 5.11: Percentage recoveries of pesticides residues in water, seediments and weeds

Pesticides	Water (µg/L)	Sediments (µg/kg. dw)	Weeds (µg/kg. dw)
Lindane	88.152±2.642	78.401±1.009	76.409±1.012
p.p'-DDT	96.124±3.052	80.483±2.227	79.211±1.021
o.p'DDE	96.101±2.015	81.515±1.605	79.052±2.061
p.p'-DDD	92.025±2.251	88.043±2.225	85.245±1.043
α-endosulfan	90.545±3.215	84.213±2.014	80.21±1.035
β-Endosulfan	89.113±4.312	86.023±2.702	83.601±2.026
Endosulfan Sulfate	90.089±3.325	83.381±2.037	80.712±1.045
Aldrin	86.411±1.115	85.363±1.298	79.245±0.871
Dieldrin	94.243±4.254	79.266±1.427	77.324±1.210
Endrin	88.226±2.013	78.659±2.127	77.210±2.011
Heptachlor	90.024±1.561	80.752±1.357	78.123±1.013
Heptachlor-epoxide	89.162±1.093	81.488±3.165	79.056±1.056
Methoxychlor	94.188±2.2123	89.192±1.127	87.106±1.034

n = 6

The pesticide residue levels detected in the samples were not corrected since all recovery values (Table 5.11) were within the acceptable range of 70-120% (Hill, 2000). Appendix 5.1 (Table 5.12) represents guidelines for pesticide residue levels in drinking water for some organizations (IUPAC, 2003). The mean organochlorine pesticide residues concentrations in water, sediment and weed samples are represented as shown in Tables 5.21-5.26, 5.31-5.36, 5.41-5.46, 5.51-5.56 for the months of February, May, Septmber and December respectively. Appendix 5.3 (Tables 5.21.1-5.56-1) shows the Pearson correlation coefficients obtained for the samples. The chromatograms of the representative pesticides residue concentrations in soil, water, sediment and weed samples are as shown in Appendix 5.3 (Figures 5.61-5.65). A total of 16 organonchlorine pesticides and their metabolites were monitored and detected in the samples at frequencies ranging from 19% (site 30) to 56% (sites, 13, 15 and 17) for water, from 28 % (site 3) to 89 % (site 33) for sediment and 53% (sites 8 and 13) to 28 % (site 3) for weeds. The frequencies of pesticide residues detected in weed samples were higher than those in water but lower than in sediments.

5.1.1 Pesticides residue levels in water, sediments and weed samples in February

Tables 5.21-5.26 and Figures 5.21-5.26, show the mean pesticide residue leveals detected in water, sediments and aquatic weeds from Kericho-Upper Nyando sub-catchments area. Out of the sixteen pesticides monitored in February 2005 and 2006, site 8 (Nyando at Kipkelion) showed the highest number (9) of pesticides detected in water samples (Table 5.21 and Figure 5.21) followed by sites 1, 3, 4, 7, 9, 13 and 14 which showed eight pesticide residues each.

Table 5.21: Pesticides residue levels (µg/L) in water from Kericho-Upper Nyando in February

Pesticide/Sites	1	3	4	5	6	7	8	9	10	11	12	13	14
aldrin	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
dieldrin	0.018±0.002	0.024±0.002	0.015±0.002	0.011±0.001	0.085±0.002	0.068±0.002	0.064±0.002	0.152±0.002	0.301±0.001	0.085±0.002	0.040±0.004	0.146±0.005	0.170±0.005
endosulfan S	0.019±0.001	0.018±0.001	0.037±0.001	BDL	BDL	0.039±0.001	0.058±0.001	BDL	BDL	BDL	BDL	0.009±0.001	0.017±0.001
α-endosulfan	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
β-endosulfan	0.010±0.001	0.011±0.006	0.128±0.003	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.014±0.001	0.026±0.001	0.013±0.001
endrin	0.016±0.001	0.015±0.006	0.281±0.003	0.034±0.004	0.027±0.001	0.041±0.004	0.040±0.002	0.054±0.001	BDL	BDL	BDL	BDL	BDL
heptachlor	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
heptachlor-epoxide	BDL	BDL	BDL	BDL	BDL	BDL	0.013±0.001	0.034±0.002	0.013±0.003	0.047±0.001	BDL	BDL	BDL
lindane	0.056±0.007	0.052±0.006	0.038±0.003	0.034±0.004	0.027±0.001	0.041±0.004	0.140±0.002	0.054±0.001	BDL	BDL	0.035±0.001	0.035±0.001	0.144±0.006
methoxychlor	0.053±0.001	0.024±0.002	0.059±0.003	0.058±0.001	0.068±0.001	0.035±0.001	0.060±0.001	0.030±0.001	0.039±0.001	0.013±0.001	0.029±0.001	0.042±0.002	0.044±0.001
o,p'-DDT	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
p,p'-DDT	0.022±0.001	0.012±0.002	0.045±0.003	0.034±0.002	0.056±0.003	0.058±0.001	0.068±0.001	0.035±0.001	0.060±0.001	BDL	0.053±0.001	0.069±0.001	0.093±0.007
o,p'-DDD	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
p,p'-DDD	BDL	BDL	BDL	0.049±0.001	BDL	0.030±0.001	0.075±0.004	0.026±0.002	0.042±0.002	BDL	0.07±0.004	0.071±0.001	0.102±0.003
o,p'-DDE	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
p,p'-DDE	0.013±0.001	0.014±0.002	0.030±0.003	0.041±0.001	0.008±0.001	0.021±0.001	0.010±0.001	0.035±0.001	0.019±0.001	0.023±0.001	0.022±0.001	0.012±0.002	0.027±0.001

BDL = below detection limits   n = 6, mean ± standard deviation

The pesticides concentrations detected showed strong positive bivariate Pearson correlation coefficients ($P<0.01$) in the range 0.511-0.912 (Appendix 5.3, Table 5.21.1). The highest correlation value of 0.912 was obtained for sites 1 and 3, the lowest value of 0.511 was obtained for sites 6 and 11. For two sites which showed strong correlation coefficient, same pesticides were detected in the samples. The levels detected for endosulfan sulfate, β-endosulfan, endrin, heptachlor-epoxide, lindane, methoxychlor, and DDT in water in February (dry period), were slightly lower than the WHO guidelines (Appendix 5.1, Table 5.12) for daily intake of drinking water except for dieldrin (range 0.011±0.001-0.301±0.001 μg/L). However these low concentrations become significant considering magnification through the food chains. High levels of dieldrin (Table 5.21), were detected at sites, 10 (0.301±0.001 μg/L) and 14 (0.170±0.005 μg/L). The magnitudes were followed by those of methoxychlor at sites 6 (0.068±0.001 μg/L) and 4 (0.059±0.003 μg/L).

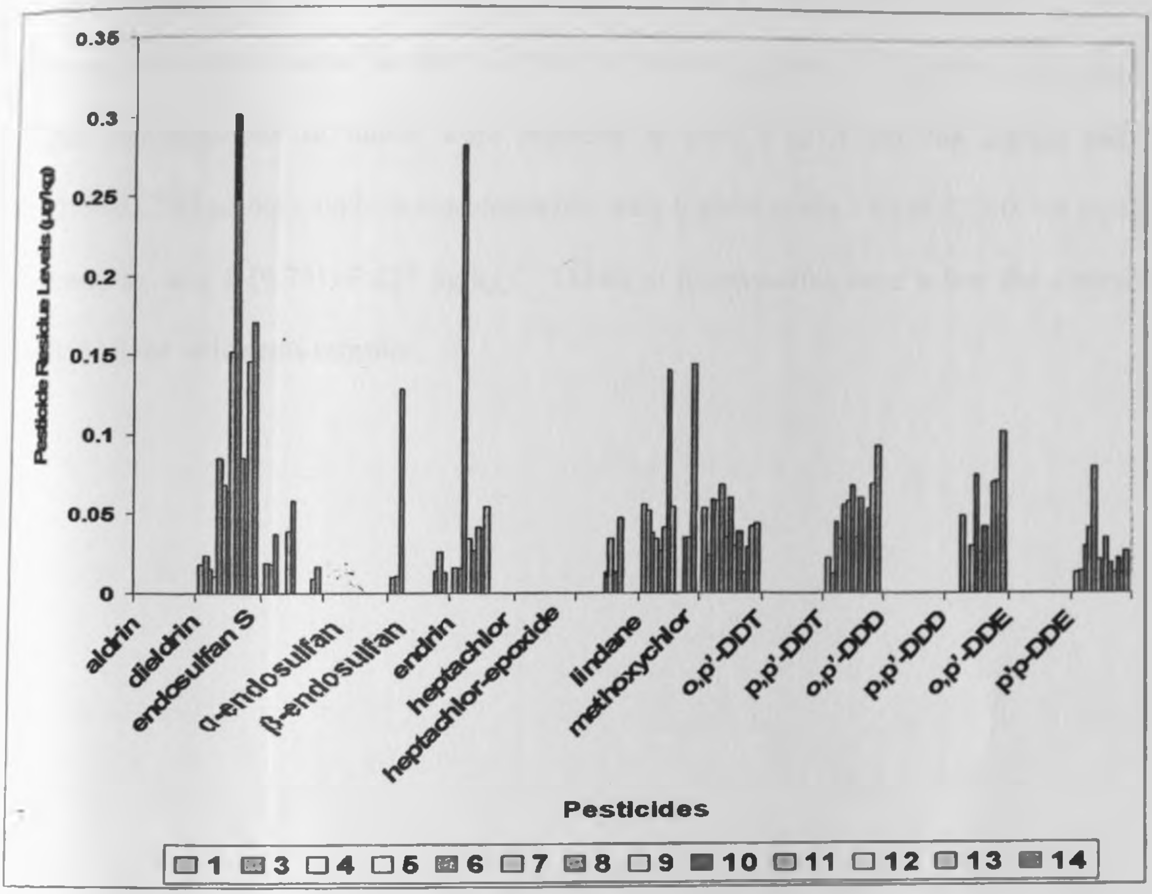

Figure 5.21: Pesticides residue levels in water from Kericho-Upper Nyando in February

Residue levels of α-endosulfan, heptachlor, o,p'-DDT, o,p'-DDD and o,p'-DD were below the detection limits and are therefore reported as BDL. The concentration of total DDT (∑DDT, 1.345 µg/L) in Kericho-Upper Nyando in February is statistically significant given its restricted use in Kenya. This value although is lower than the WHO guidelines (2 µg/L) for daily intake of drinking water, it is over 6 times higher than the EPA (0.2 µg/L) guidelines and over 20 times the Australian limits of 0.06 µg/L (Table 5.12).

The detected pesticides levels in sediments (Table 5.22 and Figure 5.22), were considerably higher than those found in water. The detected concentrations showed strong positive Pearson correlation coefficients (P<0.01) in the range 0.576-0.999 (Appendix 5.3,

Table 5.22.1). The highest correlation value of 0.999 was obtained for sites 7 and 14. the lowest value of 0.576 was obtained for sites 1 and 9. The highest residue levels of methoxychlor were detected at sites 13 (94.619±3.882μg/kg) and 14 (92.893±3.039 μg/kg). Higher concentrations of aldrin were recorded at sites 3 (21.172±0.788 μg/kg) and 1 (16.399±0.1.580 μg/kg). lindane concentrations were highest at site 14 (10.971±0.104 μg/kg) followed by site 6 (9.741±0.424 μg/kg). Levels of α-endosulfan were below the detection limit in all the sediments samples.

Table 5.22: Pesticides residue levels (µg/kg, dw) in sediments from Kericho-Upper Nyando in February

Pesticides/ Sites	1	3	4	5	6	7	8	9	10	11	12	13	14
aldrin	16.339±1.58	21.172±0.788	9.455±1.209	8.169±1.494	9.401±1.568	0.971±0.017	2.3655±0.425	0.712±0.332	1.956±0.026	2.979±1.246	3.922±0.280	BDL	0.18±0.072
dieldrin	6.087±0.125	2.673±0.439	BDL	BDL	6.808±0.368	0.059±0.007	1.554±0.569	0.035±0.071	6.769±0.967	1.511±0.666	0.043±0.005	0.154±0.052	1.236±0.020
endosulfan S	0.3±0.028	0.282±0.190	0.039±0.003	0.265±0.078	1.867±0.110	1.204±0.221	0.049±0.013	3.980±0.649	0.040±0.008	4.462±0.737	1.666±0.033	0.266±0.073	2.131±0.177
α-endosulfan	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
β-endosulfan	BDL	1.061±0.057	2.225±0.290	0.065±0.007	BDL	0.187±0.014	2.499±0.215	1.492±0.416	0.015±0.007	0.104±0.001	1.156±0.066	0.014±0.002	BDL
endrin	1.154±0.154	0.030±0.003	1.611±0.994	0.182±0.011	0.288±0.014	0.351±0.008	0.03±0.014	BDL	0.86±0.105	1.900±0.124	1.352±0.120	BDL	1.662±0.139
heptachlor	BDL	BDL	0.037±0.005	BDL	0.064±0.011	BDL	0.083±0.011	BDL	BDL	BDL	BDL	BDL	0.610±0.091
Heptachlor-epoxide	BDL	BDL	0.059±0.007	0.164±0.014	0.179±0.006	1.005±0.131	BDL	1.387±0.408	0.539±0.167	0.450±0.072	0.08±0.014	0.222±0.014	0.429±0.086
lindane	1.877±0.051	BDL	9.401±0.900	4.351±0.459	9.741±0.424	5.765±1.025	2.839±0.992	3.343±0.833	0.873±0.042	5.440±0.647	8.154±1.238	0.945±0.071	10.971±0.104
methoxychlor	14.330±1.658	17.328±2.915	61.527±3.656	67.439±4.700	65.454±1.881	50.825±2.745	19.796±1.249	29.752±1.782	44.694±0.479	52.411±3.865	58.101±5.546	94.619±3.882	92.893±3.039
o,p'-DDT	BDL	0.024±0.012	BDL	BDL	BDL	BDL	BDL	BDL	0.184±0.008	0.256±0.015	BDL	BDL	1.245±0.47
p,p'-DDT	0.485±0.118	1.454±0.311	2.894±0.324	0.993±0.009	0.983±0.022	1.178±0.021	0.344±0.030	1.430±0.315	0.319±0.010	0.900±0.113	1.178±0.017	0.433±0.049	2.761±0.146
o,p'-DDD	0.162±0.010	0.289±0.003	0.902±0.119	BDL	0.360±0.002	BDL	BDL	0.902±0.050	0.170±0.003	0.0033±0.007	0.363±0.050	BDL	0.382±0.076
p,p'-DDD	0.199±0.066	0.122±0.017	BDL	BDL	0.361±0.003	0.288±0.013	0.155±0.070	1.302±0.066	1.143±0.048	BDL	0.869±0.163	0.664±0.067	1.531±0.487
o,p'-DDE	0.683±0.036	BDL	0.567±0.152	0.314±0.001	BDL	BDL	0.590±0.004	0.764±0.188	0.214±0.007	BDL	1.885±0.140	BDL	0.965±0.016
p,p'-DDE	1.193±0.008	0.361±0.052	5.203±0.305	1.174±0.008	0.729±0.239	2.313±0.4669	0.395±0.093	0.237±0.037	0.255±0.052	0.915±0.104	3.967±0.256	0.259±0.009	1.902±0.112

BDL = below detection limits n = 6, mean ± standard deviation

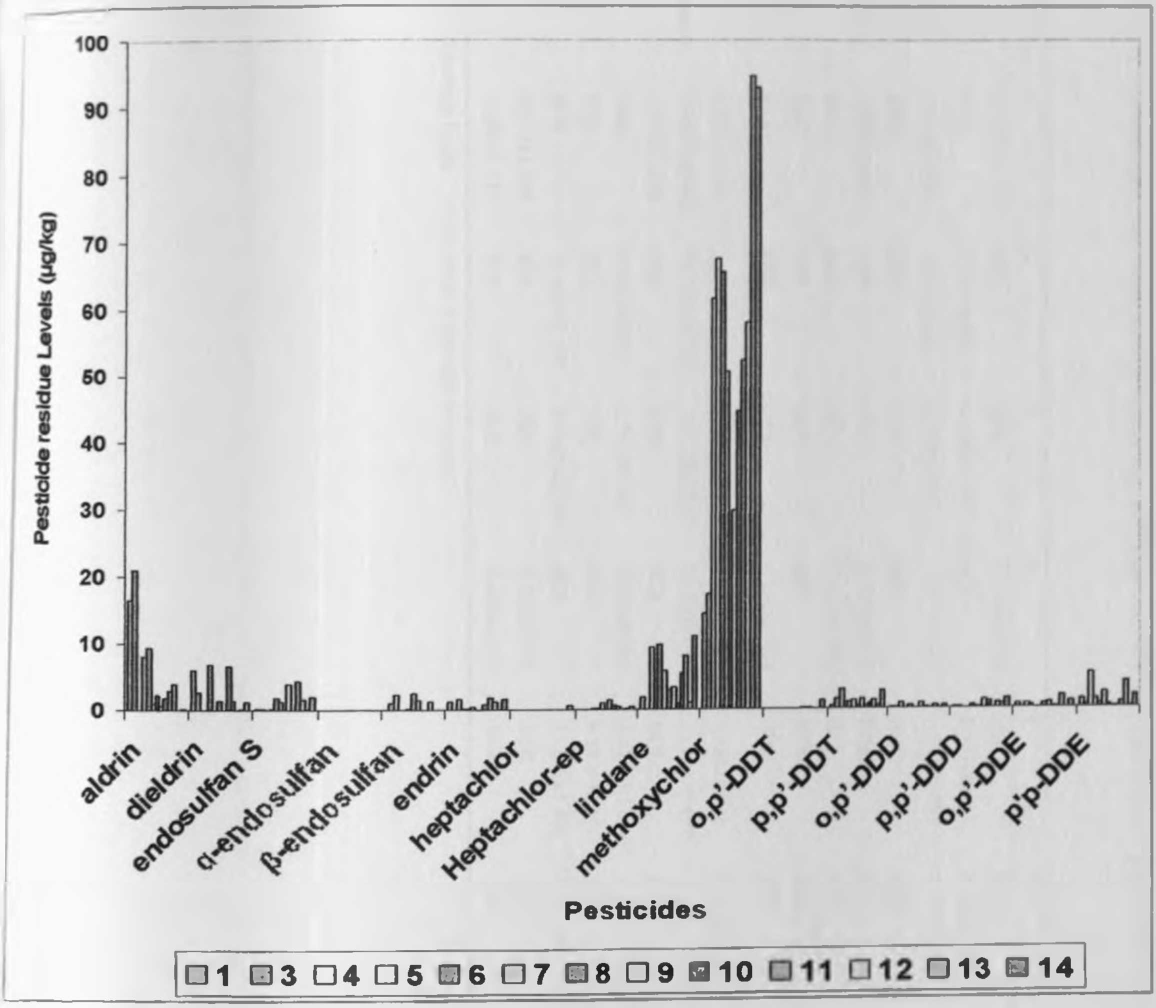

Figure 5.22: Pesticides residue levels in sediments from Kericho-Upper Nyando in February

In sediment samples (Table 5.22 and Figure 5.22), the concentrations of dieldrin, endosulfan sulfate and endrin detected were generally lower compared to that of lindane at various sites. In aquatic bodies, pesticides that are non-polar tend to be pushed out of water to the sediments making their concentrations decrease rapidly in water column and sediments act as sinks for pollutants and do release to water the same pesticides in order to keep the equilibrium balance (Linde, 1994). Table 5.23 and Figure 5.23 show mean pesticide concentrations in weed samples from Kericho-Upper Nyando in February.

Table 5.23: Pesticides residue levels (µg/kg, dw) in weeds in Kericho-Upper Nyando in February

Pesticides Sites	1	3	4	5	6	7	8	9	10	11	12	13	14
aldrin	15.519±3.756	BDL	BDL	9.216±1.504	BDL	BDL	BDL	1.874±0.002	BDL	BDL	BDL	BDL	0.928±0.068
dieldrin	BDL	5.129±0.909	6.151±0.665	BDL	8.001±0.303	2.905±6.530	7.431±0.305	0.935±0.008	8.275±0.353	BDL	1.526±1.152	BDL	3.516±0.739
endosulfan S	9.433±2.470	5.836±2.605	6.758±0.941	1.205±0.031	6.559±0.053	7.427±1.909	3.948±0.408	4.104±0.021	BDL	BDL	BDL	BDL	BDL
α-endosulfan	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
β-endosulfan	3.818±0.454	BDL	BDL	0.197±0.016	BDL	BDL	BDL	2.012±0.132	BDL	BDL	BDL	BDL	BDL
endrin	BDL	BDL	BDL	0.273±0.091	BDL	BDL	8.200±1.474	BDL	7.001±0.203	BDL	BDL	BDL	BDL
heptachlor	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Heptachlor-epoxide	BDL	BDL	BDL	0.164±0.014	BDL	BDL	BDL	1.387±0.408	BDL	BDL	BDL	BDL	2.102±0.380
lindane	5.613±1.580	2.801±0.755	2.944±0.378	4.351±0.459	2.658±0.116	8.387±1.04	8.160±0.460	3.343±0.833	7.117±0.216	BDL	BDL	BDL	7.068±0.451
methoxychlor	39.641±8.045	36.499±8.460	13.378±1.361	23.430±1.001	25.326±0.460	34.798±0.913	42.094±4.015	29.752±1.782	8.311±1.26	BDL	8.572±2.217	BDL	29.039±2.801
o,p'-DDT	4.894±1.854	BDL	BDL	BDL	BDL	BDL	1.757±0.360	BDL	BDL	BDL	BDL	BDL	BDL
p,p'-DDT	BDL	4.849±0.427	3.741±0.267	0.193±0.001	5.971±1.524	11.663±2.711	8.817±2.305	1.430±0.315	9.416±0.394	BDL	4.955±0.689	BDL	6.428±1.724
o,p'-DDD	BDL	BDL	BDL	BDL	6.282±1.350	BDL	BDL	0.902±0.050	BDL	BDL	BDL	BDL	2.569±0.676
p,p'-DDD	BDL	10.913±2.142	14.805±2.930	BDL	15.047±1.810	8.840±2.559	4.509±0.927	2.302±0.010	1.943±0.319	BDL	0.394±0.041	BDL	8.795±1.633
o,p'-DDE	6.624±1.308	BDL	BDL	0.512±0.001	BDL	BDL	BDL	0.704±0.141	BDL	BDL	BDL	BDL	BDL
p,p'-DDE	5.493±1.212	BDL	BDL	2.356±0.011	BDL	BDL	BDL	1.237±0.129	BDL	BDL	BDL	BDL	2.937±0.550

BDL = below detection limits n = 6, mean ± standard deviation

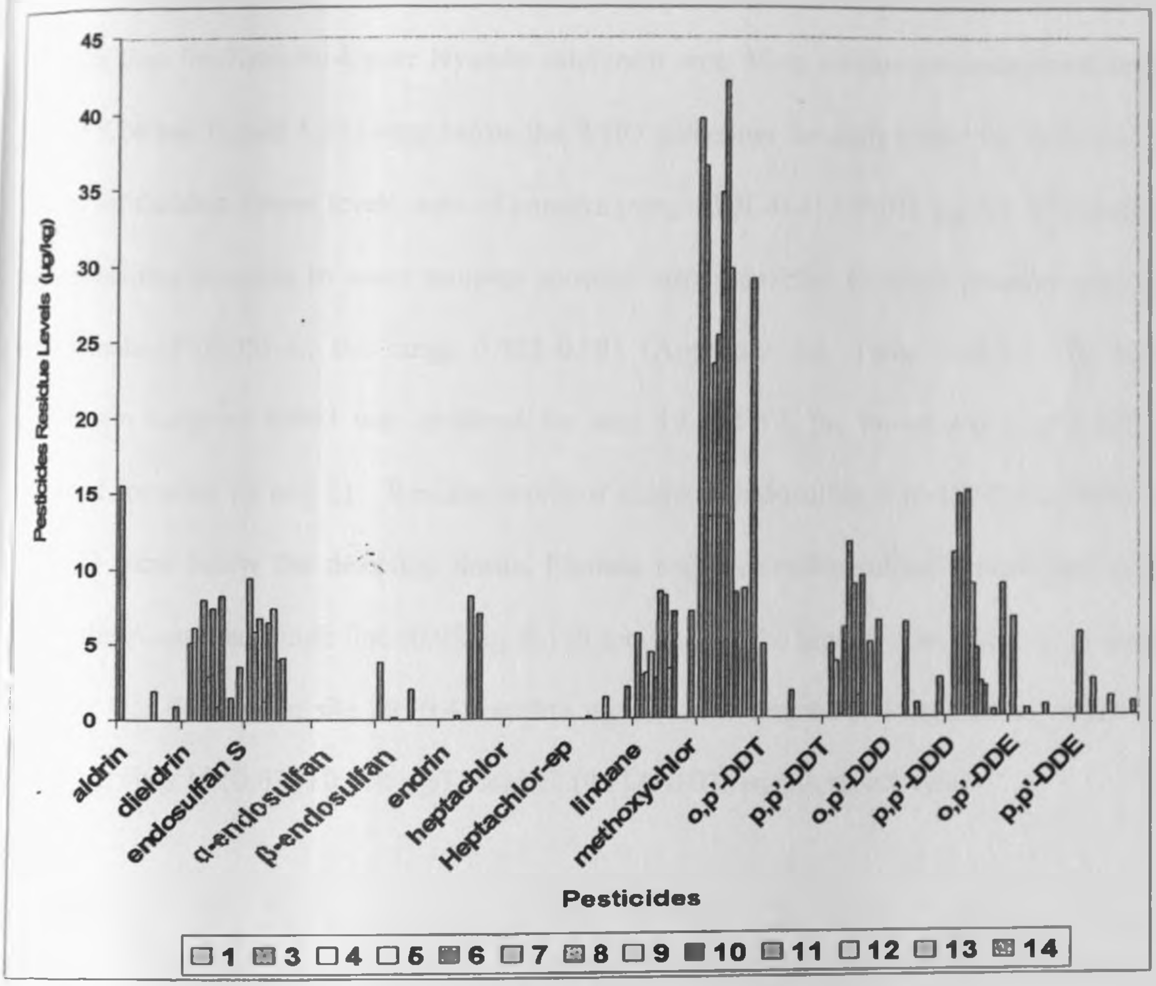

Figure 5.23: Pesticides residue levels in weeds in Kericho-Upper Nyando in February

The pesticides concentrations detected in weed samples showed strong positive bivariate Pearson correlation coefficients ($P<0.05$) in the range 0.548-0.963 (Appendix 5.3, Table 5.23.1). The highest correlation value of 0.963 was obtained for sites 3 and 14, the lowest value of 0.548 was obtained for sites 4 and 5. In the case of the weed samples (Table 5.23), the highest residue concentrations were those of methoxychlor detected at site 1 (39.641±3.045 µg/kg). This was followed by aldrin at the same site (15.519±3.756 µg/kg). Concentrations of α-endosulfan and heptachlor were below the detection limits in all the sites. The concentrations of pesticides intermediate in magnitude between those of sediments and water.

wer Nyando catchment area showed sightly higher pesticide residue concentrations
the Kericho-Upper Nyando catchment area. Most residue concentrations detected
nd Figure 5.24) were below the WHO guidelines for daily intake for drinking water
ldrin whose levels were of concern (range BDL-0.413±0.011 μg/L). The pesticides
is detected in water samples showed strong positive bivariate Pearson correlation
(P<0.05) in the range 0.525-0.993 (Appendix 5.3, Table 5.24.1). The highest
alue of 0.993 was obtained for sites 15 and 17, the lowest value of 0.525 was
sites 15 and 21. Residue levels of aldrin, α-endosulfan, o,p'-DDT, o,p'-DDD and
e below the detection limits. Lindane and endosulfan sulfate concentrations were
istralian guide line (0.05 μg /L) in some sites. The highest concentration of dieldrin
detected at site 26 (0.413±0.011 μg/L) while lindane and endosulfan sulfate were
es 16 (0.074±0.010 μg/L) and 22 (0.114±0.032 μg/L), repectively.

Table 5.24: Pesticides residue levels (µg/L) in water from Nandi-Lower Nyando in February

Pesticide Residues	15	16	17	18	19	21	22	23	25	26	27	30	33
aldrin	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
dieldrin	0.219±0.011	0.178±0.020	0.181±0.022	0.124±0.002	0.136±0.003	0.192±0.015	0.353±0.062	0.320±0.075	0.080±0.019	0.413±0.011	0.417±0.035	BDL	0.336±0.032
endosulfan S	0.016±0.002	0.019±0.070	0.026±0.032	0.013±0.002	0.108±0.019	0.067±0.015	0.114±0.032	0.026±0.014	0.029±0.001	0.031±0.001	0.029±0.001	BDL	0.009±0.001
α-endosulfan	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
β-endosulfan	BDL	BDL	BDL	BDL	0.026±0.002	0.168±0.013	0.210±0.032	0.126±0.001	BDL	BDL	BDL	BDL	0.040±0.004
endrin	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.023±0.008
heptachlor	0.010±0.003	0.013±0.006	0.011±0.006	0.013±0.004	BDL	0.012±0.005	0.026±0.002	0.013±0.006	0.091±0.006	0.013±0.004	BDL	BDL	0.140±0.004
heptachlor-epoxide	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.060±0.004
lindane	0.066±0.001	0.074±0.010	0.050±0.002	0.044±0.003	0.025±0.004	0.056± 0.004	0.054±0.009	0.058±0.003	0.033±0.002	0.056±0.004	0.051±0.003	BDL	0.039±0.001
methoxychlor	0.044±0.002	BDL	0.036±0.001	BDL	0.043±0.003	0.021±0.001	BDL	0.040±0.009	BDL	0.048±0.002	0.044±0.008	BDL	0.032±0.004
o,p'-DDT	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
p,p'-DDT	0.097±0.009	0.085±0.005	0.066±0.020	BDL	0.019±0.005	0.018±0.002	0.027±0.007	0.013±0.009	0.043±0.006	0.061±0.006	0.063±0.004	BDL	0.014±0.061
o,p'-DDD	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
p,p'-DDD	0.122±0.004	0.085±0.015	0.092±0.014	0.056±0.018	0.073±0.003	BDL	0.119±0.070	0.126±0.032	0.031±0.002	0.167±0.019	0.168±0.013	BDL	0.088±0.040
o,p'-DDE	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
p,p'-DDE	0.010±0.004	0.015±0.015	0.019±0.001	0.022±0.008	0.087±0.001	0.024±0.003	0.019±0.007	0.013±0.002	0.031±0.002	0.067±0.019	0.017±0.013	BDL	0.088±0.040

BDL = below detection limits n = 6, mean ± standard deviation

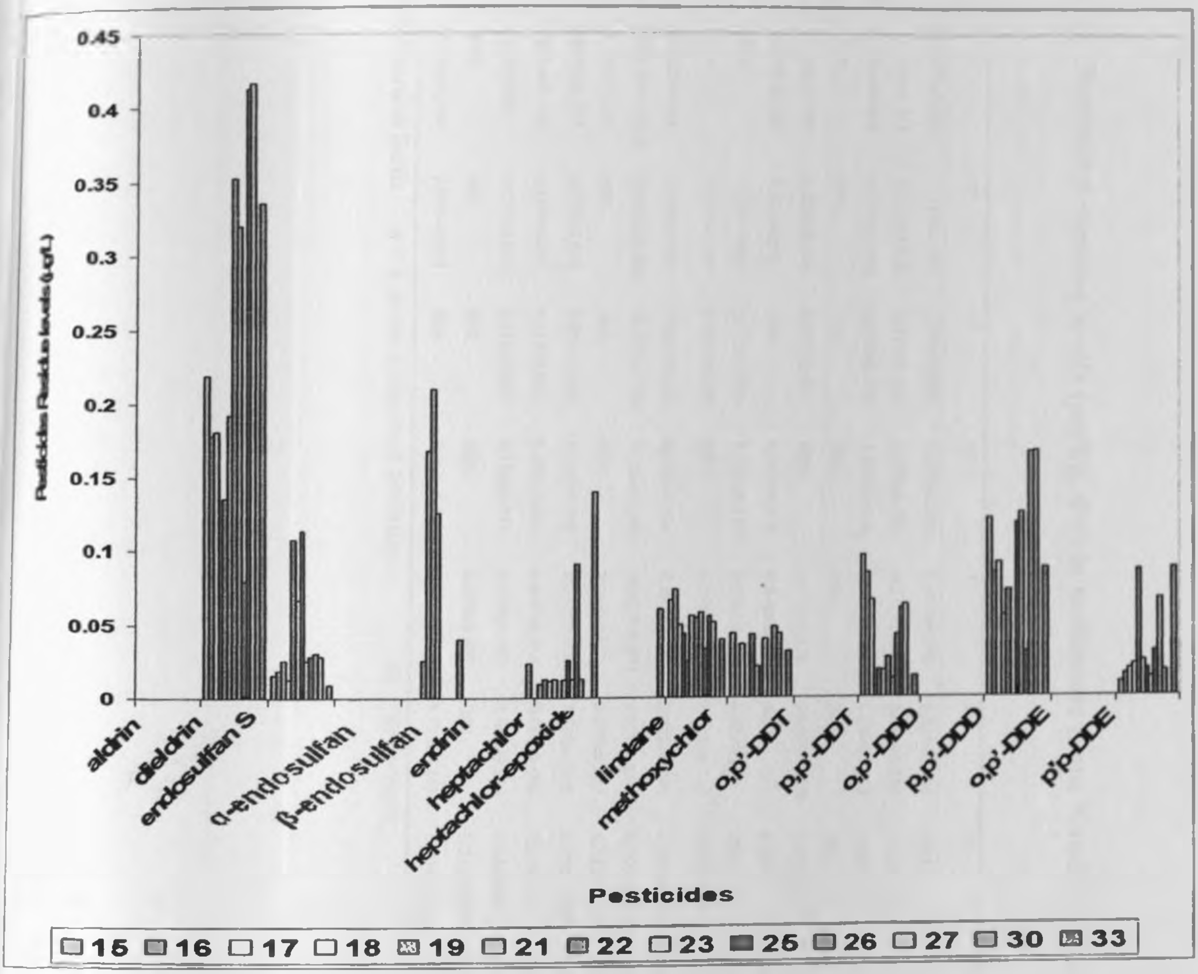

Figure 5.24: Pesticides residue levels in water from Nandi-Lower Nyando in February

In sediment samples (Table 5.25 and Figure 5.25) methoxychlor, β-endosulfan, lindane among others were detected at high concentrations in February. The concentrations detected in the samples showed strong positive bivariate Pearson correlation coefficients ($P<0.05$) in the range 0.499-0.999 (Appendix 5.3, Table 5.25.1). The highest correlation value of 0.999 was obtained for sites 15 and 18, the lowest value of 0.499 was obtained for sites 15 and 33. The highest concentrations detected were methoxychlor at site 19 (98.627±3.654 µg/kg), β-endosulfan at site 21 (10.502±0.800 µg/kg) and lindane at site 16 (6.565±0.825 µg/kg).

Table 5.25: Pesticides residue levels (µg/kg, dw) in sediments from Nandi-Lower Nyando in February

Pesticides/ Sites	15	16	17	18	19	21	22	23	25	26	27	30	33
aldrin	0.039±0.009	4.219±1.082	2.548±0.550	0.838±0.053	1.611±0.090	0.015±0.006	BDL	BDL	3.127±0.862	0.292±0.010	0.016±0.008	BDL	0.043±0.535
dieldrin	7.151±1.318	0.153±0.036	0.314±0.188	1.775±0.288	8.232±1.278	0.826±0.213	1.624±0.383	0.346±0.037	0.193±0.007	1.457±0.062	0.037±0.007	0.407±0.020	0.324±0.0169
endosulfan S	2.063±0.038	4.129±0.054	3.141±0.912	1.798±0.140	0.463±0.053	1.244±0.014	4.657±0.793	0.065±0.041	0.189±0.013	1.705±0.851	BDL	BDL	6.419±0.760
α-endosulfan	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
β-endosulfan	0.426±0.039	0.036±0.006	0.018±0.001	BDL	1.874±0.438	10.502±0.800	0.013±0.001	BDL	0.360±0.070	0.083±0.006	BDL	BDL	1.087±0.011
endrin	0.902±0.114	0.32±0.156	BDL	0.361±0.072	0.048±0.007	BDL	0.295±0.086	0.192±0.008	0.537±0.056	0.298±0.124	BDL	BDL	2.974±0.300
heptachlor	BDL	1.154±0.063	0.172±0.006	1.718±0.194	0.276±0.051	0.42±0.156	BDL	BDL	BDL	BDL	BDL	BDL	0.699±0.065
Heptachlor-epoxide	BDL	3.939±0.466	0.406±0.009	BDL	0.188±0.016	1.888±0.125	0.661±0.073	0.872±0.104	0.384±0.116	1.090±0.172	BDL	0.069±0.018	0.900±0.077
lindane	3.032±0.581	6.555±0.825	0.813±0.142	0.050±0.006	0.802±0.142	2.925±0.081	4.645±0.564	0.871±0.076	4.582±0.776	0.822±0.1446	0.016±0.001	7.403±0.694	10.619±0.595
methoxychlor	278.327±1.014	66.018±4.486	68.695±7.552	77.264±2.601	98.627±3.654	49.791±2.479	0.797±0.042	53.584±2.184	3.024±0.084	27.975±5.553	10.526±2.011	4.097±0.139	8.640±0.759
o,p'-DDT	1.084±0.155	BDL	BDL	BDL	0.268±0.079	0.179±0.011	0.182±0.023	0.290±0.004	1.276±0.030	BDL	BDL	BDL	1.117±0.010
p,p'-DDT	3.097±0.157	4.378±0.544	1.871±0.069	1.497±0.405	0.278±0.030	1.560±0.295	2.956±0.236	0.925±0.088	1.219±0.046	2.008±0.129	1.68±0.200	3.857±0.377	1.927±0.085
o,p'-DDD	0.920±0.003	1.157±0.011	0.313±0.021	0.156±0.015	0.839±0.163	0.488±0.004	0.640±0.068	0.638±0.055	0.444±0.065	0.317±0.007	0.464±0.071	BDL	3.062±0.086
p,p'-DDD	0.92±0.003	1.157±0.012	0.313±0.021	0.156±0.015	0.839±0.163	0.488±0.004	0.64±0.068	0.638±0.055	0.444±0.065	0.317±0.07	0.464±0.071	BDL	3.062±0.086
o,p'-DDE	BDL	BDL	BDL	BDL	0.427±0.007	BDL	0.252±0.003	BDL	BDL	0.249±0.055	BDL	0.433±0.062	0.951±0.052
p,p'-DDE	3.145±0.330	3.918±0.814	BDL	2.711±0.674	0.585±0.015	1.775±0.291	0.904±0.054	BDL	0.441±0.060	1.023±0.016	BDL	4.139±0.344	3.379±0.649

BDL = below detection limits n = 6, mean ± standard deviation dw = dry weight

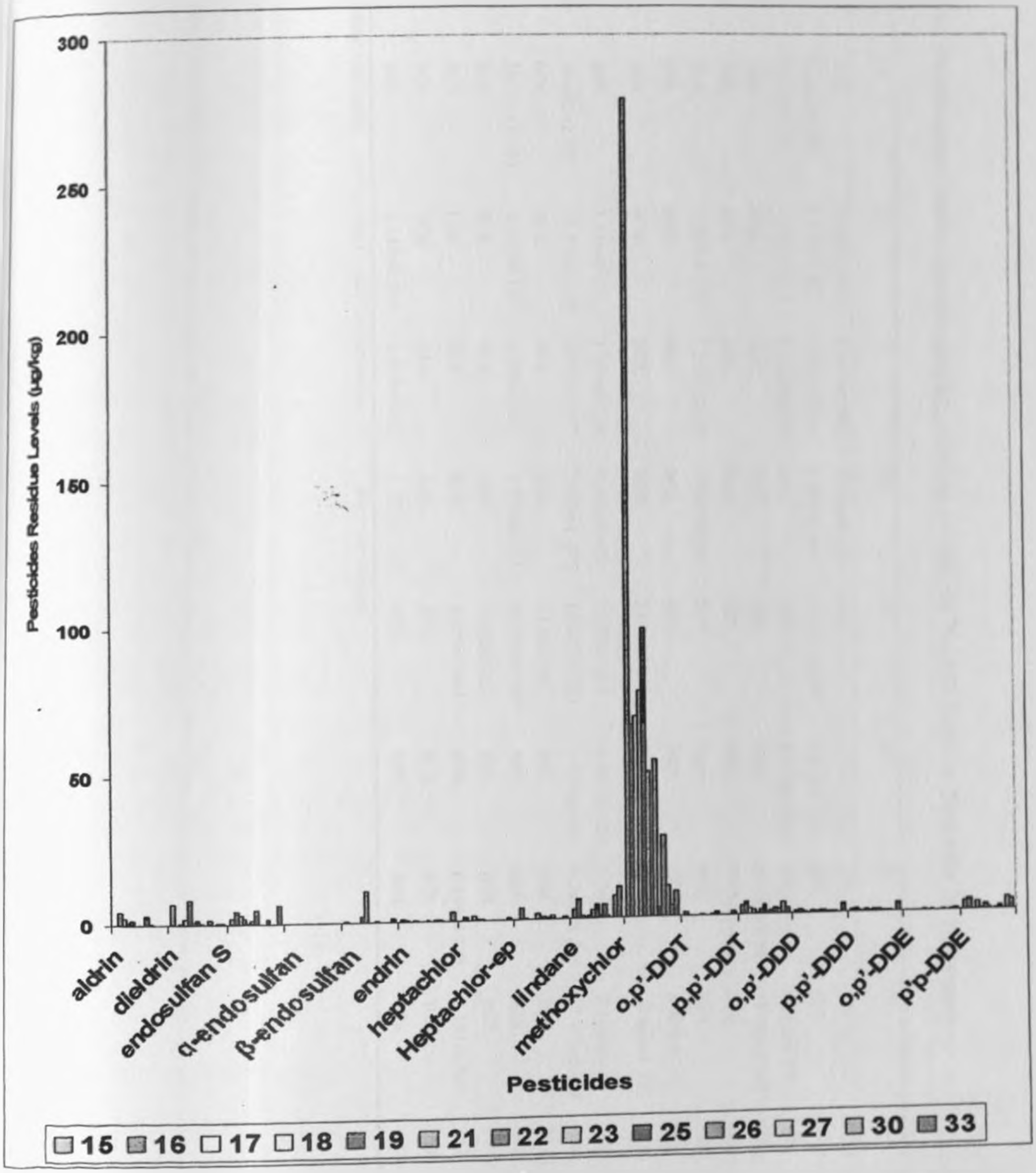

Figure 5.25: Pesticides residue levels in sediments from Nandi-Lower Nyando in February

In the weed samples (Table 5.26 and Figure 5.26) dieldrin at site 19 (32.963±4.099 µg/kg) and p,p'-DDT at site 15 (28.294±1.010 µg/kg) were the highest detected levels in Nandi-Lower Nyando catchment area.

Table 5.26: Pesticides residue levels (µg/kg, dw) in weeds in Nandi-Lower Nyando in February

Pesticides/ Sites	15	16	17	18	19	21	22	23	25	26	27	30	33
aldrin	BDL	3 067±0 014	0 911±0 402	0 996±0 105	BDL	0 067±0 010	7 917±1 409	7 095±1 237	2 883±0 417	BDL	BDL	BDL	BDL
dieldrin	5 366±0 098	6.114±1 911	1 993±0 004	6 102±0 194	32.963±4 099	2.178±1 101	BDL	BDL	5 313±1 146	BDL	31 750±1 493	BDL	BDL
endosulfan S	3 865±0 325	4 970±0 412	0 256±0 097	BDL	BDL	0.170±0 011	1 567±0 314	8 140±0 417	BDL	BDL	2.195±0 294	BDL	BDL
α-endosulfan	BDL	BDL	BDL	BDL	BDL	BDL	66 149±1 589	17 793±2 947	BDL	BDL	BDL	BDL	BDL
β-endosulfan	BDL	BDL	BDL	BDL	BDL	BDL	4 970±0 412	BDL	BDL	BDL	BDL	BDL	BDL
endrin	BDL	1 567±0.314	1 2140±0 041	1 906±0 410	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
heptachlor	BDL	BDL	BDL	BDL	BDL	BDL	BDL	6 105±0 170	BDL	BDL	BDL	BDL	BDL
heptachlor-epoxide	BDL	BDL	BDL	BDL	2 691±0 211	BDL	BDL	37 664±6 635	BDL	BDL	BDL	BDL	BDL
lindane	BDL	2 316±0 131	1 104±0 101	4 996±0 453	2.272±0 205	0 967±0 034	1 567±0 314	8 140±0 417	10 307±1 831	BDL	BDL	BDL	BDL
methoxychlor	10 087±2 925	12.219±1 309	4 787±0.997	7 029±1 972	14 902±3 221	4 614±0.681	6 149±0 589	17.793±2 947	BDL	BDL	7 323±0 907	BDL	BDL
o,p'-DDT	BDL	BDL	BDL	BDL	1.12±0 170	BDL	BDL	BDL	24 612±0 995	BDL	BDL	BDL	BDL
p,p'-DDT	28 294±1 010	4 987±0.135	6 190±0.017	4 996±0 453	10 533±0 089	BDL	BDL	BDL	BDL	BDL	17 573±1 344	BDL	BDL
o,p'-DDD	BDL	BDL	BDL	BDL	3.072±0 453	BDL	BDL	BDL	2 104±0 169	BDL	BDL	BDL	BDL
p,p'-DDD	BDL	BDL	BDL	BDL	4 010±0 994	BDL	0 149±1 589	0 793±2 947	BDL	BDL	6 253±1 490	BDL	BDL
o,p'-DDE	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
p,p'-DDE	BDL	2 543±0 162	0 419±0.012	1 223±0 145	BDL	BDL	BDL	BDL	4 80±1 149	BDL	BDL	BDL	BDL

BDL = below detection limits n = 6, mean ± standard deviation dw = dry weight

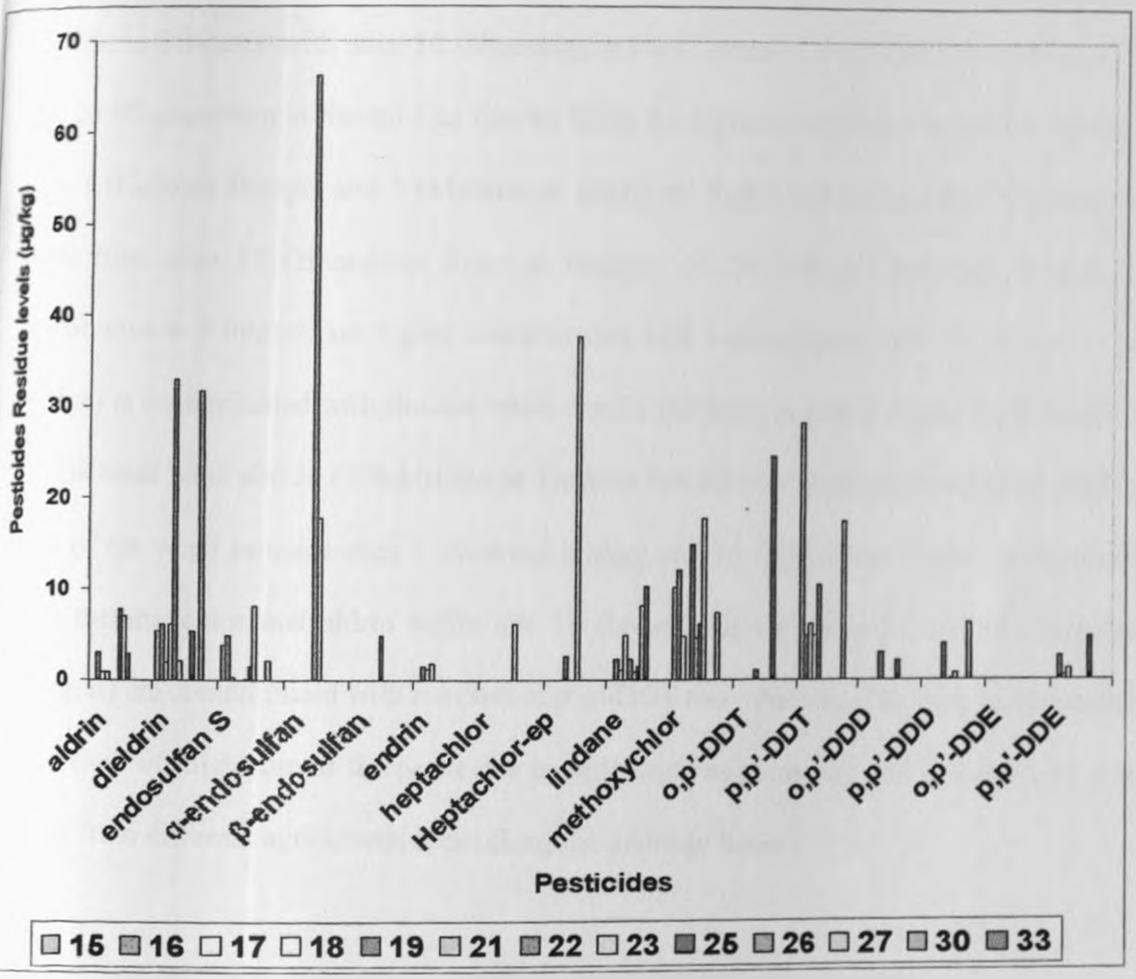

Figure 5.26: Pesticides residue levels in weeds in Nandi-Lower Nyando in February

The pesticides concentrations detected in weed samples from nandi-Upper Nyando in February, showed strong positive bivariate Pearson correlation coefficients (P<0.05) in the range 0.550-0.939 (Appendix 5.3, Table 5.26.1). The highest correlation value of 0.939 was obtained for sites 19 and 27, the lowest value of 0.550 was obtained for sites 15 and 16.

Generally conentrations of methoxychlor were higher in sediment samples from Kericho-Upper Nyando than from the Nandi-Lower Nyando. By contrast the dieldrin concentrations were higher in Nandi-Lower Nyando than in samples from the Kericho-Upper Nyando. These higher levels may be as a result of continued use of the pesticide in tea and sugarcane farms. There is potential risk of people and macroinvertebrates drinking water contaminated with dieldrin in February with sites 10 (Namuting at Fort Ternna), 14 (Nyando at Muhoroni bridge) and 26 (Kapngorium at Savani Tea Estate) being the highest risk areas. Sediment samples from sites 1 (Kedowa Bridge) and 3 (Masaita at Dam) are highly contaminated with aldrin whereas those from sites 13 (Homalime River at Bridge), 14 (Nyando at Muhoroni Bridge) and 19 (Ainamutua at Kibigori) are highly contaminated with methoxychlor. Site 16 (Nyando at Ahero Bridge) is contaminated with lindane while site 21 (Mbogo) is contaminated with β-endosulfan. On the other hand site 30 (Chebirirkut at Tinderet Forest) is contaminated with p,p'-DDE. In the case of the weed samples sites 1 (Kedowa bridge) and 15 (Nyando at Ogilo) are contaminated with methoxychlor and aldrin while site 15 (Nyando at Ogilo) and site 19 (Ainamutua at Kibigori) are contaminated with residues of p'p'-DDT and dieldrin. The high concentrations are as a result of illigal use of the pesticides in agriculture as shown by soil composition (section 4.1.1) from different agricultural areas along the drainage basin.

5.1.2 Pesticides residues in water, sediments and weed samples in May

In May (long rainy season) the Nandi-Lower Nyando sub-catchment area showed higher pesticides residue levels in water (Table 5.34 and Figure 5.34) than Kericho-Upper Nyando (Table 5.31 and Figure 5.31).

Table 5.31: Pesticides residue levels (µg/L) in water from Kericho-Upper Nyando in May

Pesticide Residues	1	3	4	5	6	7	8	9	10	11	12	13	14
aldrin	BDL	BDL	BDL	BDL	BDL	0.045±0.002	BDL	BDL	BDL	BDL	BDL	BDL	0.025±0.005
dieldrin	BDL	BDL	BDL	BDL	0.04±0.016	0.025±0.009	0.029±0.002	0.040±0.005	0.035±0.012	0.035±0.003	0.032±0.003	0.037±0.004	0.041±0.006
endosulfan S	0.053±0.001	0.028±0.003	BDL	0.038±0.005	0.061±0.004	0.305±0.003	0.018±0.001	0.307±0.047	BDL	0.369±0.031	0.005±0.001	0.053±0.002	0.299±0.027
α-endosulfan	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.01±0.001
β-endosulfan	BDL	BDL	BDL	BDL	BDL	0.036±0.05	0.018±0.001	0.042±0.001	0.008±0.001	BDL	0.006±0.002	0.009±0.001	0.016±0.006
endrin	0.047±0.003	BDL	BDL	BDL	BDL	0.147±0.004	0.038±0.001	0.013±0.002	0.011±0.002	0.006±0.001	0.028±0.001	BDL	BDL
heptachlor	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
heptachlor-epoxide	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.008±0.001	BDL	0.04±0.002	BDL	BDL
lindane	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
methoxychlor	0.042±0.004	0.033±0.004	0.864±0.068	0.026±0.001	0.031±0.001	0.017±0.002	0.382±0.007	4.050±0.138	1.19±0.016	0.17±0.001	0.285±0.074	0.403±0.028	0.799±0.013
o,p'-DDT	0.017±0.001	BDL	0.026±0.003	BDL	BDL	0.025±0.019	0.016±0.004	BDL	BDL	BDL	BDL	BDL	0.025±0.005
p,p'-DDT	0.054±0.002	BDL	0.062±0.003	0.058±0.001	0.051±0.019	0.065±0.008	0.081±0.008	0.159±0.036	0.018±0.001	0.053±0.018	0.045±0.008	0.035±0.009	0.128±0.004
o,p'-DDD	0.086±0.003	BDL	BDL	0.009±0.002	BDL	0.326±0.017	0.015±0.005	0.016±0.01	0.003±0.001	0.008±0.001	BDL	BDL	0.025±0.006
p,p'-DDD	0.005±0.002	BDL	0.013±0.004	BDL	0.029±0.002	0.05±0.015	0.031±0.002	0.031±0.005	0.009±0.001	0.033±0.005	0.027±0.003	0.014±0.004	0.028±0.003
o,p'-DDE	0.005±0.001	BDL	BDL	BDL	0.005±0.002	BDL	BDL	0.009±0.002	BDL	0.008±0.001	BDL	BDL	BDL
p,p'-DDE	0.13±0.004	BDL	0.085±0.004	0.057±0.001	0.062±0.003	0.029±0.003	0.093±0.003	0.095±0.003	BDL	0.053±0.001	0.092±0.02	0.041±0.003	0.097±0.017

BDL = below detection limits n = 6, mean ± standard deviation

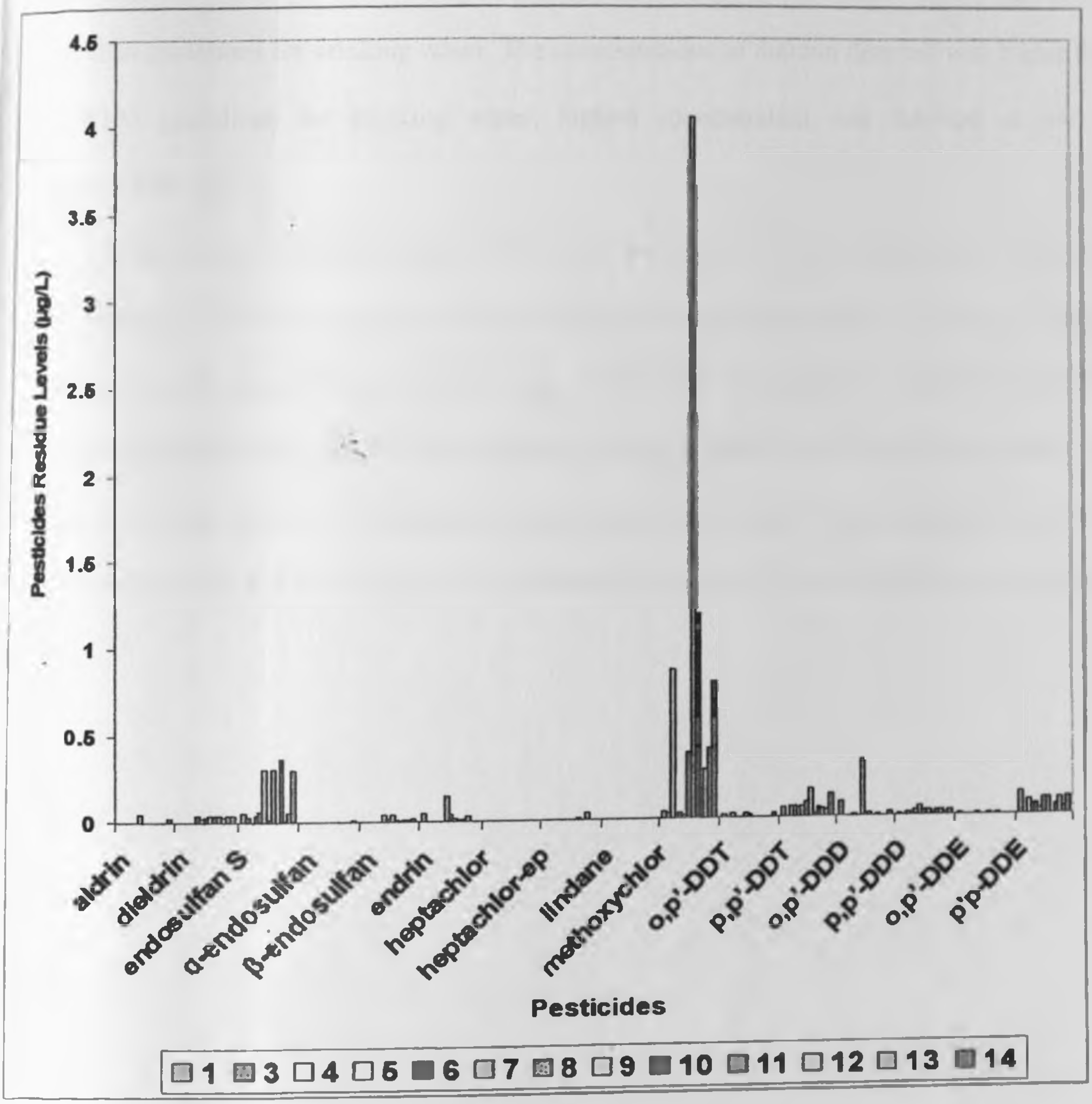

Figure 5.31: Pesticides residue levels (µg/L) in water from Kericho-Upper Nyando in May

The pesticides concentrations detected in water from Kericho-Upper Nyando in May showed strong positive bivariate Pearson correlation coefficients (P<0.05) in the range 0.507-0.993 (Appendix 5.3, Table 5.31.1). The highest correlation value of 0.993 was obtained for sites 9 and

13, the lowest value of 0.507 was obtained for sites 1 and 7. Methoxychlor was detected at highest concentration at sites 9 (4.05±0.138 µg/L), followed endosulfan sulfate (0.369±0.031 µg/L) at site11. However these concentrations are lower than the WHO but higher than Australian guidelines for drinking water. The concentrations of dieldrin detected was higher than the WHO guidelines for drinking water, highest concentration was detected at site 14 (0.041±0.006 µg/L).

In the case of sediment samples (Table 5.32 and Figure 5.32) all the pesticides monitored were detected. The pesticides concentrations detected showed strong positive bivariate Pearson correlation coefficients ($P<0.05$) in the range 0.580-0.997 (Appendix 5.3, Table 5.32.1). The highest correlation value of 0.997 was obtained for sites 4 and 7, the lowest value of 0.580 was obtained for sites 3 and 12. The highest concentration was detected for methoxychlor at site 4 (284.281±3.108 µg/kg), this magnitude was followed by lindane at site 12 (23.201±3.114 µg/kg).

Table 5.32: Pesticides residue levels (µg/kg, dw) in sediments from Kericho-Upper Nyando in May

Pesticides/ Sites	1	3	4	5	6	7	8	9	10	11	12	13	14
aldrin	10.793±1.203	BDL	11.140±1.627	19.878±2.658	7.618±0.946	BDL	BDL	4.456±1.780	BDL	BDL	BDL	12.565±2.259	11.935±2.798
dieldrin	10.271±1.859	8.182±1.697	10.973±2.826	BDL	16.760±3.808	13.053±4.227	7.747±2.257	0.483±0.257	10.041±2.766	12.559±3.562	0.207±0.084	0.145±0.035	0.210±0.016
endosulfan S	BDL	1.365±0.207	3.266±0.324	BDL	3.075±0.252	3.315±0.384	1.173±0.162	2.370±0.528	1.601±0.432	6.611±0.882	3.035±0.032	9.343±1.716	0.831±0.110
α-endosulfan	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
β-endosulfan	BDL	0.256±0.096	0.075±0.01	BDL	BDL	1.563±0.533	3.964±0.277	9.397±0.896	BDL	0.299±0.029	3.892±0.336	BDL	BDL
endrin	1.496±0.212	BDL	0.063±0.026	3.154±0.239	1.476±0.364	0.443±0.172	BDL	BDL	4.540±0.7±87	7.869±1.327	1.159±0.086	BDL	1.095±0.086
heptachlor	BDL	1.284±0.298	BDL	BDL	BDL	BDL	1.166±0.098	BDL	BDL	BDL	BDL	BDL	1.311±0.311
Heptachlor-epoxide	BDL	BDL	BDL	1.315±0.167	BDL	2.135±0.343	BDL	4.147±0.416	1.026±0.414	1.026±0.157	2.372±0.528	BDL	0.756±0.094
lindane	0.023±0.018	0.240±0.059	0.029±0.007	9.171±1.618	4.239±1.695	0.03±0.014	8.163±0.568	16.115±1.600	9.278±1.257	8.185±0.400	23.201±3.114	0.025±0.006	11.933±2.662
methoxychlor	131.332±4.799	53.557±4.848	284.281±3.108	59.610±3.803	24.027±2.951	132.217±3.258	22.757±2.783	189.614±5.172	30.134±3.134	2.011±0.209	22.383±4.271	21.526±4.809	58.536±3.472
o,p'-DDT	3.391±0.580	0.809±0.167	BDL	BDL	BDL	BDL	BDL	BDL	1.308±0.303	2.441±0.645	BDL	BDL	4.296±0.401
p,p'-DDT	6.980±0.774	5.999±0.174	5.919±0.259	5.677±0.909	4.956±0.142	4.205±1.622	2.612±0.769	11.903±2.641	4.344±1.182	5.714±1.467	4.575±0.738	6.251±1.672	3.248±1.634
o,p'-DDD	7.526±0.860	0.591±0.042	0.384±0.053	3.656±1.029	0.585±0.125	BDL	0.567±0.092	BDL	BDL	5.653±0.943	9.215±1.535	BDL	3.172±0.253
p,p'-DDD	3.147±0.251	0.683±0.043	0.504±0.116	0.05±0.001	1.094±0.140	2.101±0.106	0.072±0.004	0.029±0.004	1.357±0.446	BDL	4.214±0.204	1.320±0.352	4.554±0.640
o,p'-DDE	2.146±0.224	BDL	2.403±0.291	0.865±0.104	BDL	BDL	1.903±0.189	6.135±0.316	2.837±0.416	BDL	8.358±0.804	BDL	BDL
p,p'-DDE	12.167±1.739	5.341±0.591	4.873±1.280	6.502±0.647	3.372±0.549	4.072±0.252	6.898±0.162	10.279±1.556	4.761±1.122	BDL	4.515±0.753	BDL	5.002±0.386

BDL = below detection limits n = 6. mean ± standard deviation. dw = dry weight

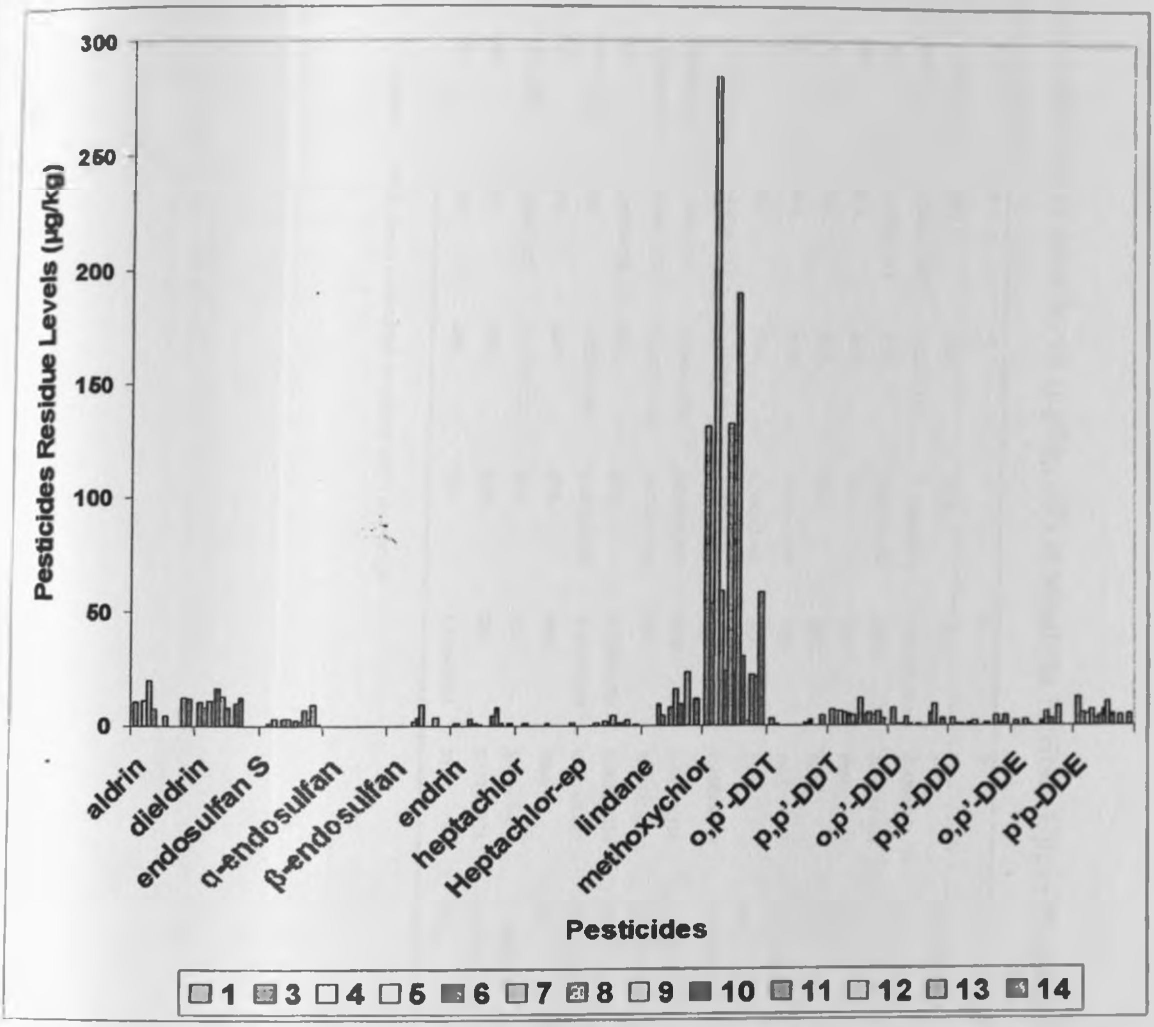

Figure 5.32: Pesticides residue levels in sediments from Kericho-Upper Nyando in May

In the case of weed samples (Table 5.33 and Figure 5.33) most pesticides monitored were detected at sites 8 and 10 which showed nine pesticides residues each. The pesticides concentrations detected showed strong positive bivariate Pearson correlation coefficients ($P<0.05$) in the range 0.577-0.985 (Appendix 5.3, Table 5.33.1). The highest correlation value of 0.985 was obtained for sites 4 and 10, the lowest value of 0.577 was obtained for sites 1 and 10.

Table 5.33: Pesticides residue levels (µg/kg, dw) in weeds in Kericho-Upper Nyando in May

Pesticides/ Sites	1	3	4	5	6	7	8	9	10	11	12	13	14
aldrin	7.843±1.239	BDL	BDL	BDL	BDL	BDL	10.999±0.479	BDL	BDL	BDL	BDL	BDL	BDL
dieldrin	9.477±1.088	3.346±0.209	6.02±1.311	9.933±1.078	9.012±1.413	7.436±0.26774	8.459±1.177	9.631±4.035	6.474±0.632	4.375±0.020	3.417±0.491	3.737±0.003	6.622±0.360
endosulfan S	BDL	3.335±0.111	BDL	3.083±1.315	BDL	5.246±1.441	9.612±1.539	4.807±1.125	2.249±0.848	5.054±0.605	2.231±0.976	BDL	BDL
α-endosulfan	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
β-endosulfan	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
endrin	BDL	BDL	BDL	7.425±1.297	BDL	BDL	2.628±0.329	1.075±0.252	48.453±1.709	6.669±1.739	15.061±1.591	5.358±1.393	6.205±1.365
heptachlor	BDL	BDL	BDL	6.546±3.400	BDL	BDL	BDL	BDL	16.558±2.366	BDL	BDL	BDL	BDL
Heptachlor-epoxide	1.935±1.040	4.939±0.781	5.785±0.985	2.158±3.036	BDL	6.270±0.646	7.913±0.777	4.077±1.410	4.816±0.07	6.116±1.694	4.812±0.687	9.137±1.167	6.048±0.810
lindane	6.585±1.357	7.769±0.307	5.160±0.554	3.010±0.043	BDL	5.109±0.126	6.841±1.237	4.942±0.586	1.249±0.063	3.785±1.565	4.251±0.312	2.713±0.949	4.816±0.709
methoxychlor	88.339±6.466	99.691±6.909	44.368±0.531	60.781±5.064	BDL	50.967±4.322	37.077±2.179	21.813±2.489	59.372±2.790	93.086±7.037	19.610±3.507	43.008±8.561	43.008±0.561
o,p'-DDT	BDL	1.769±0.008	BDL	BDL	0.458±0.001	6.302±2.324	BDL	BDL	BDL	BDL	BDL	BDL	BDL
p,p'-DDT	7.972±1.201	BDL	3.522±0.299	1.485±1.498	4.669±1.592	6.881±0.422	5.591±0.103	2.827±0.244	11.274±3.022	2.822±0.163	10.613±3.350	18.291±3.719	BDL
o,p'-DDD	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
p,p'-DDD	5.826±0.765	8.518±1.342	1.143±0.233	BDL	BDL	3.095±1.451	6.444±1.183	3.555±2.003	17.865±0.455	BDL	BDL	BDL	BDL
o,p'-DDE	BDL	BDL	BDL	BDL	BDL	5.012±0.872	15.241±3.659	BDL	45.996±3.571	9.706±3.873	BDL	BDL	BDL
p,p'-DDE	BDL	7.252	BDL	BDL	2.536±0.181	BDL	BDL	3.964±4.937	BDL	BDL	BDL	5.211±3.190	5.211±3.190

BDL = below detection limits n = 6, mean ± standard deviation, dw = dry weigh

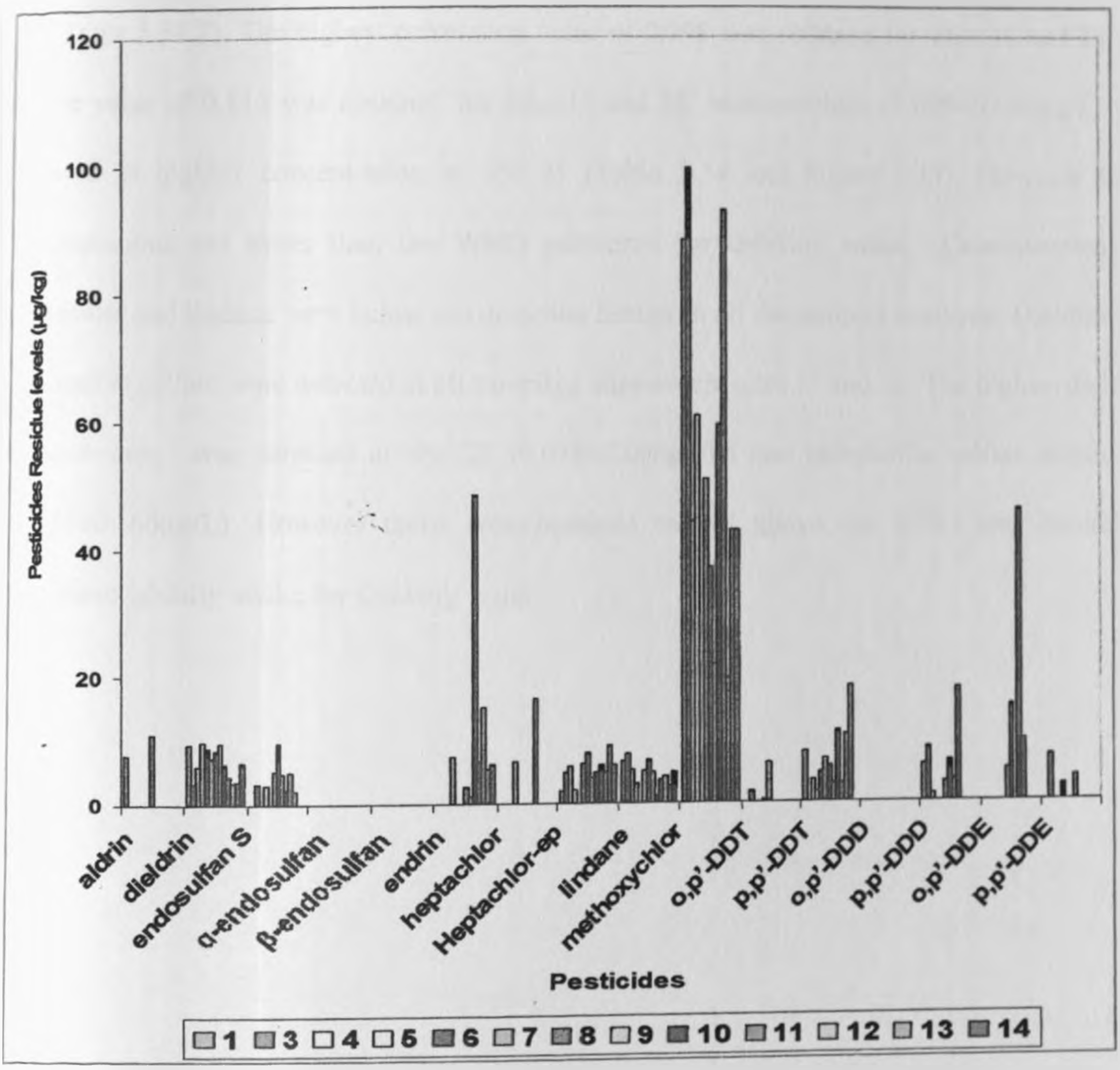

Figure 5.33: Pesticides residue levels in weeds in Kericho-Upper Nyando in May

The highest concentration was detected for methoxychlor in weed samples at site 3 (99.691±6.909 µg/kg), this magnitude was followed by that of p,p'-DDT at site 10 (11.274±3.022 µg/kg). α and β-endosulfan and o,p'-DDD concentrations were below the detection limits in all the samples analysed.

In Nandi-Lower Nyando, the pesticides concentrations detected in water samples showed strong positive bivariate Pearson correlation coefficients (P<0.05) in the range 0.813-0.998 (Appendix 5.3, Table 5.34.1). The highest correlation value of 0.998 was obtained for sites 16 and 25, the lowest value of 0.813 was obtained for sites 15 and 33. Methoxychlor (1.088±0.086μg/L) was detected at highest concentration at site 25 (Table 5.34 and Figure 5.34). However these concentrations are lower than the WHO guidelines for drinking water. Concentrations of heptachlor and lindane were below the detection limites in all the samples analysed. Dieldrin and endosulfan sulfate were detected at all sampling sites except sites 17 and 30. The highest dieldrin concentration was detected at site 25 (0.078±0.006μg/L) and endosulfan sulfate at site 26 (1.558±0.166μg/L). However these concentrations are all above the WHO and Australian guidelines of daily intake for drinking water.

Table 5.34: Pesticide residue levels (μg/L) in water from Nandi-Lower Nyando in May

Pesticide Residues	15	16	17	18	19	21	22	23	25	26	27	30	33
aldrin	BDL	BDL	BDL	0.021±0.001	BDL	BDL	BDL	BDL	0.011±0.003	0.014±0.003	BDL	BDL	BDL
dieldrin	0.04±0.001	0.045±0.005	BDL	0.051±0.005	0.041±0.005	0.033±0.003	0.042±0.003	0.070±0.015	0.078±0.006	0.046±0.005	0.032±0.001	BDL	0.033±0.007
endosulfan S	0.033±0.002	0.038±0.005	BDL	0.046±0.004	0.036±0.004	0.015±0.001	0.039±0.003	0.023±0.002	0.052±0.011	1.558±0.166	0.027±0.001	BDL	0.021±0.002
α-endosulfan	0.003±0.001	BDL	BDL	0.006±0.001	BDL	BDL	BDL	BDL	0.012±0.001	BDL	BDL	BDL	BDL
β-endosulfan	0.009±0.002	BDL	BDL	BDL	BDL	0.006±0.001	0.04±0.001	0.03±0.006	BDL	0.029±0.002	BDL	BDL	BDL
endrin	BDL	BDL	BDL	BDL	0.027±0.001	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
heptachlor	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
heptachlor-epoxide	0.023±0.003	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.005±0.001	0.012±0.003	BDL	BDL	BDL
lindane	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
methoxychlor	0.016±0.001	0.912±0.071	BDL	0.353±0.02	0.015±0.013	0.246±0.040	0.351±0.057	8.817±0.002	1.088±0.086	0.711±0.002	BDL	BDL	BDL
o,p'-DDT	BDL	BDL	BDL	0.021±0.001	BDL	BDL	BDL	BDL	0.011±0.001	0.014±0.003	BDL	BDL	BDL
p,p'-DDT	0.036±0.004	0.065±0.001	BDL	BDL	0.023±0.008	0.043±0.006	0.032±0.002	0.051±0.006	0.075±0.013	0.031±0.004	0.030±0.003	0.032±0.005	0.0456±0.002
o,p'-DDD	BDL	BDL	BDL	0.021±0.002	BDL	BDL	BDL	0.032±0.001	0.055±0.001	0.014±0.005	BDL	0.035±0.005	BDL
p,p'-DDD	0.016±0.001	0.037±0.008	BDL	0.013±0.003	0.029±0.03	0.026±0.001	0.027±0.002	0.029±0.003	0.044±0.013	0.031±0.002	0.027±0.001	0.034±0.010	BDL
o,p'-DDE	0.014±0.002	BDL	BDL	BDL	BDL	BDL	0.006±0.001	0.009±0.002	0.058±0.002	0.013±0.001	BDL	0.028±0.003	BDL
p,p'-DDE	0.08±0.004	0.018±0.002	BDL	BDL	BDL	BDL	0.019±0.002	0.031±0.002	0.035±0.001	0.044±0.004	BDL	BDL	0.035±0.001

BDL = below detection limits. n = 6. mean ± standard deviation

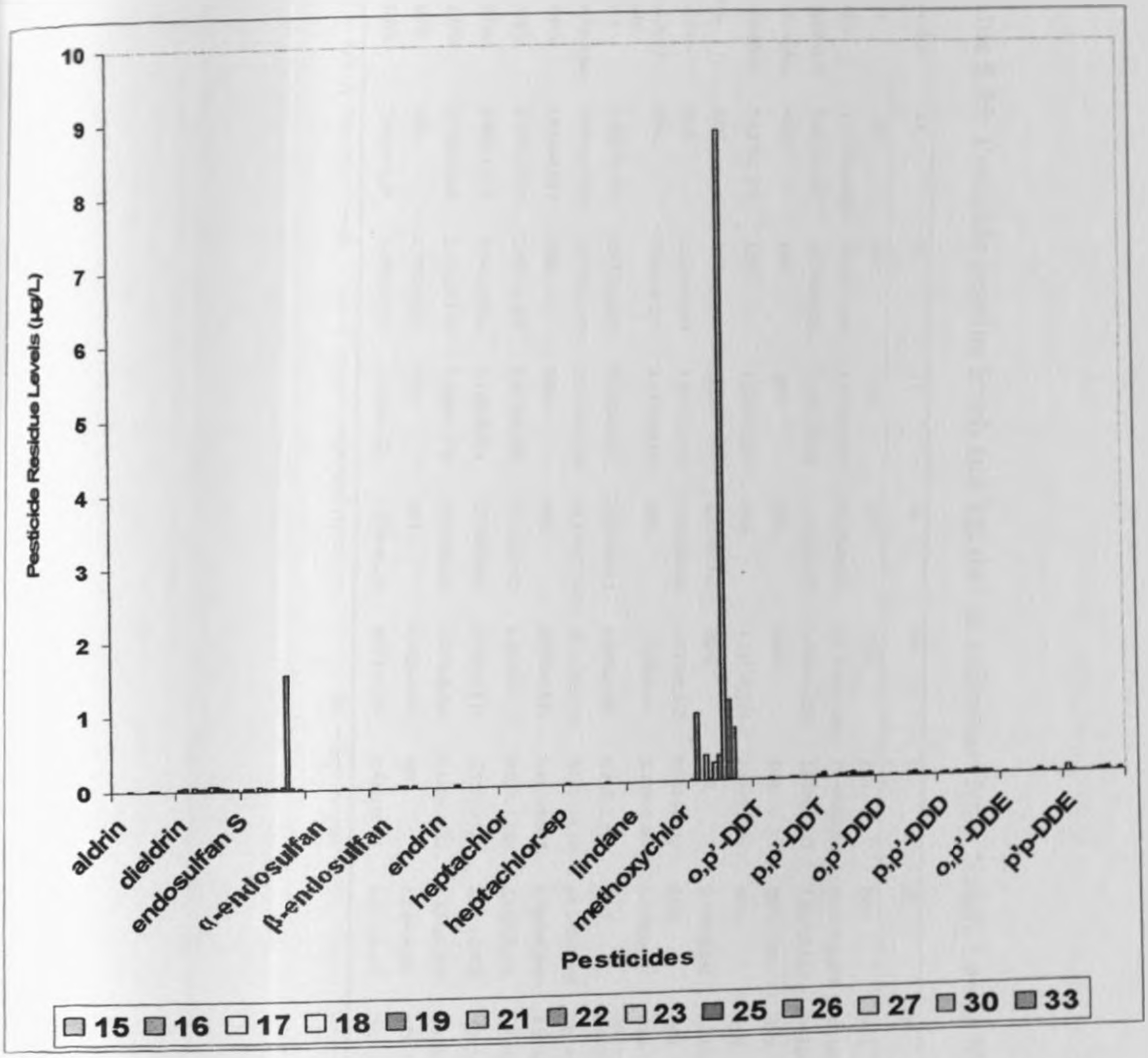

Figure 5.34: Pesticide residue levels (µg/L) in water from Nandi-Lower Nyando in May

For sediment samples, aldrin was detected in more samples (Tables 5.35 and Figure 5.35) in Kericho-Upper Nyando than Nandi-Lower Nyando. The pesticides concentrations detected showed strong positive bivariate Pearson correlation coefficients ($P<0.05$) in the range 0.532-0.993 (Appendix 5.3, Table 5.35.1). The highest correlation value of 0.993 was obtained for sites 18 and 25 and sites 15 and 22, the lowest value of 0.532 was obtained for sites 21 and 25.

Table 5.35: Pesticide residue levels (µg/kg, dw) in sediments from Nandi-Lower Nyando in May

Pesticides/ Sites	15	16	17	18	19	21	22	23	25	26	27	30	33
aldrin	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	10.785±2.058	16.048±1.484
dieldrin	23.620±4.810	6.172±1.406	1.384±0.571	0.115±0.013	10.151±1.435	15.454±2.360	22.015±2.350	12.313±2.820	1.557±0.675	0.362±0.072	0.359±0.082	10.316±1.892	15.038±3.821
endosulfan S	3.022±0.167	6.575±0.836	3.146±0.208	1.132±0.188	2.942±0.209	2.029±0.057	1.092±0.116	0.033±0.005	2.032±0.004	3.425±0.557	4.054±0.035	BDL	2.445±0.639
α-endosulfan	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
β-endosulfan	2.137±0.176	BDL	1.128±0.227	BDL	4.131±0.208	42.095±0.817	BDL	BDL	0.319±0.029	1.093±0.147	2.092±0.034	BDL	1.587±0.309
endrin	BDL	BDL	BDL	0.998±0.122	BDL	BDL	0.750±0.082	3.313±0.314	4.650±0.922	1.257±0.231	1.077±0.115	BDL	3.223±0.034
heptachlor	BDL	2.324±0.463	1.065±0.166	1.064±0.166	4.723±1.127	0.783±0.212	BDL	BDL	BDL	BDL	BDL	BDL	2.032
Heptachlor-epoxide	BDL	3.063±0.237	1.247±0.219	BDL	1.310±0.21	2.249±0.367	1.478±0.396	BDL	2.014±0.056	1.267±0.242	BDL	3.182±0.271	3.360±0.380
lindane	0.032±0.017	0.037±0.008	0.030±0.012	0.029±0.013	0.037±0.009	9.407±1.955	BDL	0.037±0.01	0.049±0.001	0.031±0.002	0.052±0.006	10.530±1.871	10.530±0.695
methoxychlor	73.702±7.893	32.798±3.975	25.406±3.350	45.392±7.749	31.313±1.796	34.435±3.389	65.275±5.308	21.146±1.565	44.989±4.323	24.161±3.821	65.754±4.019	1.253±0.314	64.224±5.917
o,p'-DDT	2.050±0.097	BDL	BDL	BDL	0.908±0.024	1.667±0.097	1.266±0.343	3.267±0.359	BDL	BDL	BDL	BDL	BDL
p,p'-DDT	4.185±1.539	3.977±1.261	2.063±0.101	5.911±0.172	1.184±0.197	9.837±1.185	3.619±0.696	3.776±0.507	7.937±1.265	2.699±3.589	0.154±0.013	4.518±0.589	32.172±2.911
o,p'-DDD	5.980±1.275	0.142±0.022	0.140±0.024	0.710±0.053	1.983±0.121	3.950±0.510	6.630±0.940	1.582±0.484	BDL	2.214±0.278	BDL	1.406±0.548	BDL
p,p'-DDD	0.658±0.065	3.158±0.103	1.498±0.574	0.053±0.005	1.475±0.568	1.130±0.202	6.834±0.403	0.123±0.005	3.250±0.310	0.138±0.041	0.179±0.016	BDL	7.815±1.028
o,p'-DDE	BDL	4.747±0.352	BDL	BDL	0.842±0.075	BDL	1.240±0.201	BDL	BDL	3.515±0.439	BDL	2.022±0.230	23.046±3.003
p,p'-DDE	7.995±0.129	7.489±0.741	4.190±0.373	2.259±0.234	4.623±1.024	4.315±0.471	4.315±0.471	BDL	3.136±0.341	6.165±0.279	BDL	5.153±1.378	33.478±4.737

BDL = below detection limits   n = 6, mean ± standard deviation   dw = dry weight

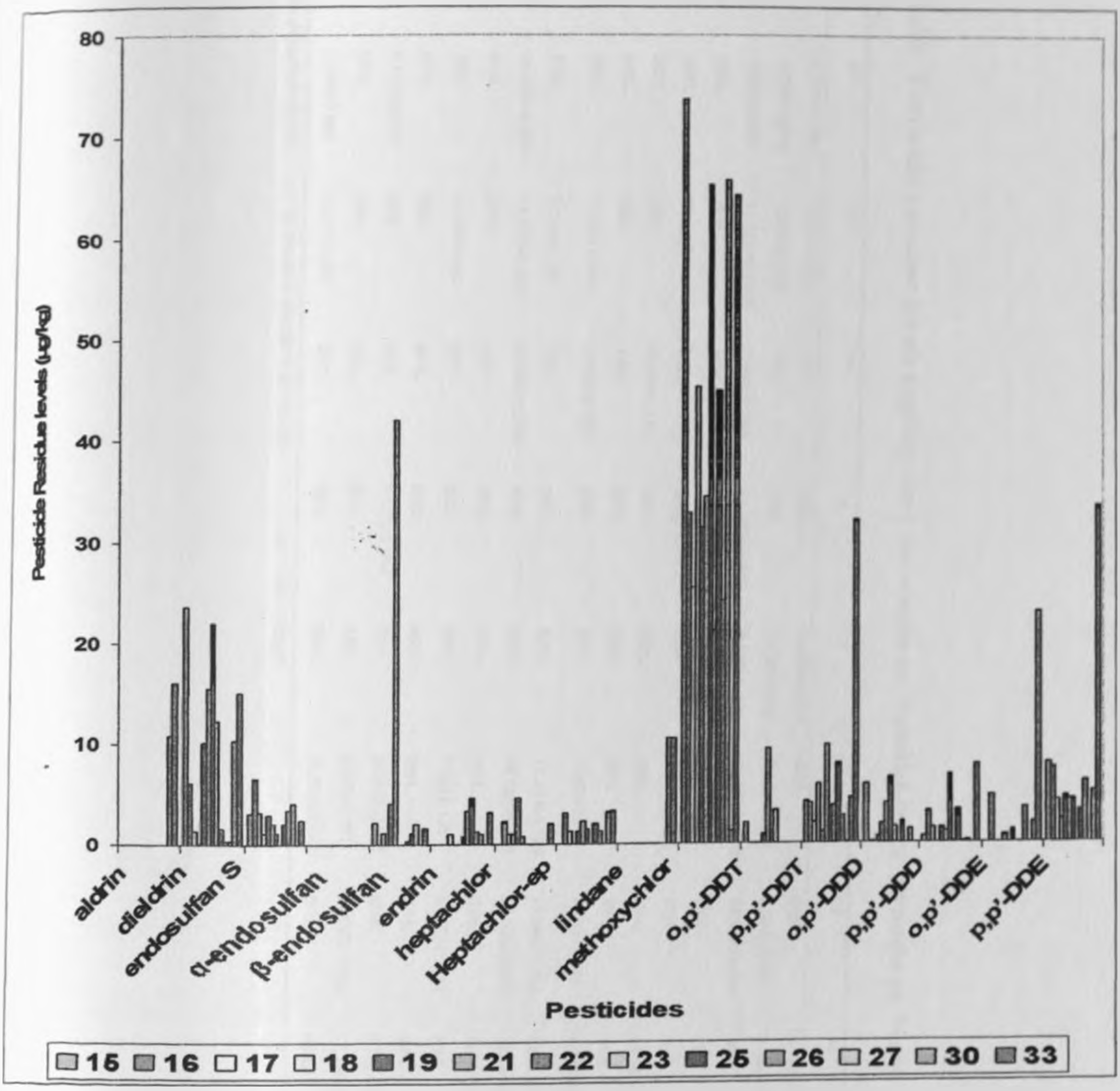

Figure 5.35: Pesticide residue levels in sediments from Nandi-Lower Nyando in May

Aldrin in sediment samples at site 33 (16.048±1.484 µg/kg) and methoxychlor (73.702±7.893µg/kg) at site 15 and lindane (10.530±1.871 µg/kg) at site 30, were the highest frequencies of detection. In weed samples (Table 5.36 and Figure 5.36) most pesticides residues were detected in weeds from site 25 (Chemwanabei).

Table 5.36: Pesticide residue levels (µg/kg, dw) in weeds in Nandi-Lower Nyando in May

Pesticides/ Sites	15	16	17	18	19	21	22	23	25	26	26	30	33
aldrin	2.509±0.064	3.115±0.12 6	BDL	BDL	1.495±0.104	BDL	BDL	4.732±0.069	BDL	BDL	BDL	BDL	5.467±0.279
dieldrin	1.980±0.096	7.031±0.623	BDL	BDL	3.120±0.092	7.172±1.623	3.030±0.657	8.701±1.384	6.628±1.366	9.478±0.82	4.138±0.293	8.556±3.586	5.532±0.959
endosulfan S	1.069±0.089	11.316±0.2610	9.964±1.293	15.897±0.385	9.123±1.521	10.683±2.239	15.989±4.166	BDL	7.785±1.750	5.730±1.157	7.305±2.743	BDL	BDL
α-endosulfan	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
β-endosulfan	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	6.461±2.435	BDL
endrin	BDL	BDL	5.003±1.254	BDL	BDL	BDL	BDL	17.745±1.023	7.361±2.791	BDL	24.708±6.364	13.657±0.065	6.885±1.669
heptachlor	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Heptachlor-epoxide	BDL	5.141±1.110	3.966±0.215	BDL	BDL	8.652±0.089	4.148±0.367	5.346±0.374	6.355±1.204	3.103±0.543	6.910±1.514	7.417±1.812	9.284±0.917
lindane	BDL	8.231±1.451	BDL	BDL	BDL	11.104±1.719	19.088±7.716	14.013±3.247	13.922±4.491	43.307±0.549	17.560±2.918	10.623±1.596	22.021±8.609
methoxychlor	45.083±1.021	34.102±1.231	35.383±2.921	BDL	BDL	44.532±5.879	20.346±0.889	27.407±10.932	49.238±2.487	41.492±8.302	77.279±8.661	10.509±2.274	62.934±8.099
o,p'-DDT	BDL	BDL	BDL	BDL	BDL	BDL	BDL	16.947±5.904	BDL	BDL	BDL	BDL	BDL
p,p'-DDT	BDL	9.058±0.664	BDL	BDL	BDL	9.86±6.135	6.462±11.921	BDL	23.564±5.164	38.025±1.959	10.394±2.403	10.570±2.577	15.200±5.179
o,p'-DDD	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	2.180±0.796	BDL	BDL	BDL	5.298±3.100
p,p'-DDD	0.564±0.064	BDL	BDL	0.622±0.094	BDL	16.965±2.945	BDL	5.776±0.076	17.069±3.569	BDL	14.778±0.728	4.387±0.874	7.106±2.861
o,p'-DDE	BDL	BDL	BDL	BDL	BDL	8.403±0.991	59.567±7.424	17.395±6.395	2.850±0.897	BDL	BDL	BDL	BDL
p,p'-DDE	1.009±0.009	9.341±1.443	BDL	BDL	BDL	18.553±1.661	BDL	BDL	BDL	BDL	BDL	BDL	BDL

BDL = below detection limits   n = 6, mean ± standard deviation   dw = dry weight

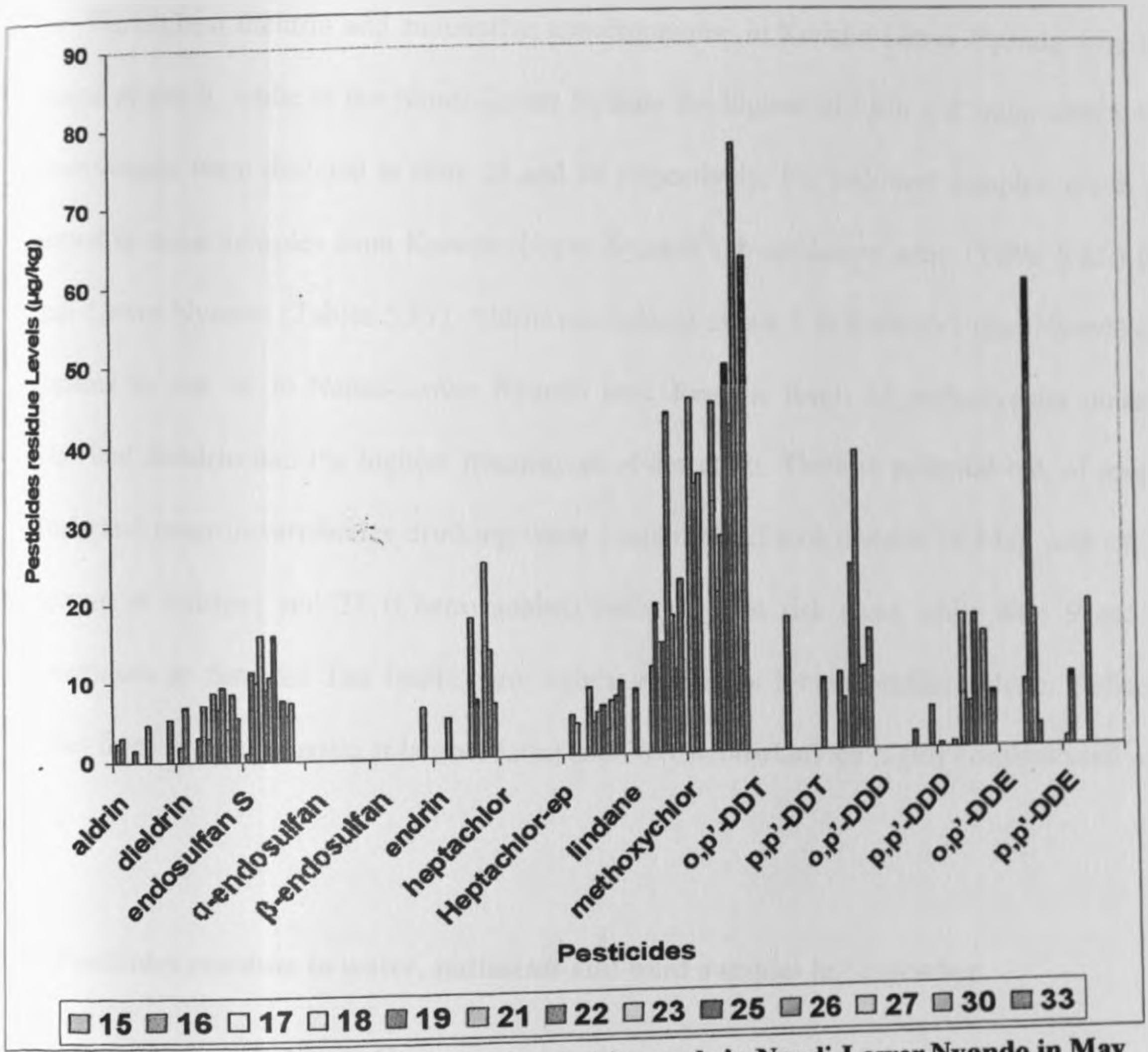

Figure 5.36: Pesticide residue levels (µg/kg, dw) in weeds in Nandi-Lower Nyando in May

The pesticides concentrations detected in weeds showed strong positive bivariate Pearson correlation coefficients (P<0.05) in the range of 0.535-0.949 (Appendix 5.3, Table 5.36.1). The highest correlation value of 0.949 was obtained for sites 15 and 17, the lowest value of 0.532 was obtained for sites 23 and 25. The highest concentration was obtained for mechoxychlor (77.279 ±8.661 ug/kg) at site 26, this magnitude was followed by p,p'-DDT (38.025±1.959 µg/kg)

Generally dieldrin and endosulfan sulfate concentrations were above the WHO and Australian guidelines of daily intake for the drinking water in some sites in the two sub-catchment areas in May. The highest dieldrin and endosulfan concentrations in Kericho-Upper Nyando were both detected at site 9, while in the Nandi-Lower Nyando the highest dieldrin and endosulfan sulfate concentrations were detected at sites 25 and 26 respectively. For sediment samples, aldrin was detected in more samples from Kericho-Upper Nyando sub-catchment area (Table 5.32) than Nandi-Lower Nyando (Tables 5.35). Aldrin was highest at site 5 in Kericho-Upper Nyando area compared to site 30 in Nandi-Lower Nyando area. Residue levels of methoxychlor, lindane, aldrin and dieldrin had the highest frequencies of detection. There is potential risk of people, animals and macroinvertebrates drinking water contaminated with dieldrin in May with sites 9 (Tugunon at Bridge) and 25 (Chemwanabei) being highest risk areas while sites 9 and 26 (Kapngorium at Savanni Tea Estate) are highest risk areas for endosulfan sulfate. Sediment samples from sites 5 (Masaita at lambel farm) and 30 (Chebirirkut) are highly contaminated with aldrin.

5.1.3 Pesticides residues in water, sediments and weed samples in September

Pesticide residue levels detected in water samplesin September (Table 5.41 and 5.44) from the two sub-catchment areas in September (dry season), were slightly lower than the WHO guidelines except for dieldrin, endosulfan sulfate and heptachlor. In Kericho-Upper Nyando, the pesticides concentrations detected showed strong positive bivariate Pearson correlation coefficients ($P<0.05$) in the range of 0.608-0.996 (Appendix 5.3, Table 5.41.1). The highest correlation value of 0.996 was obtained for sites 4 and 6 and sites 4 and 14. the lowest value of 0.608 was obtained for sites 9 and 10.

Table 5.41: Pesticide residue levels (µg/L) in water from Kericho-Upper Nyando in September

Pesticide Residues	1	3	4	5	6	7	8	9	10	11	12	13	14
aldrin	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
dieldrin	BDL	BDL	BDL	BDL	BDL	0.109±0.001	BDL	BDL	BDL	0.150±0.002	0.179±0.007	0.109±0.001	BDL
endosulfan S	0.046±0.009	0.037±0.009	BDL	0.024±0.003	0.020±0.001	0.027±0.008	0.037±0.001	0.247±0.021	0.638±0.008	0.038±0.004	0.073±0.019	0.047±0.001	BDL
α-endosulfan	BDL	BDL	0.002±0.001	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
β-endosulfan	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.121±0.002	0.021±0.002	0.003±0.001	BDL	BDL
endrin	0.014±0.001	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.054±0.004	0.062±0.002	0.061±0.003	0.005±0.001	BDL
heptachlor	BDL	BDL	0.042±0.009	0.046±0.007	BDL	BDL	0.029±0.003	BDL	0.097±0.002	BDL	BDL	0.039±0.009	0.060±0.007
heptachlor-epoxide	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
lindane	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
methoxychlor	0.39±0.014	0.002±0.001	0.555±0.052	0.215±0.022	0.401±0.008	0.519±0.031	0.175±0.045	0.101±0.005	1.384±0.171	2.456±0.28	BDL	0.372±0.08	0.472±0.16
o,p'-DDT	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.103±0.025	BDL	BDL	BDL	BDL
p,p'-DDT	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.221±0.008	0.062±0.001	0.06±0.001	0.06±0.019	BDL
o,p'-DDD	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.119±0.006	0.032±0.004	0.172±0.009	0.034±0.001	BDL
p,p'-DDD	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.276±0.076	0.019±0.004	BDL	BDL	BDL
o,p'-DDE	0.034±0.003	BDL	BDL	BDL	BDL	BDL	BDL	0.049±0.001	0.055±0.003	0.018±0.002	BDL	BDL	0.035±0.001
p,p'-DDE	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.058±0.002	BDL	BDL	BDL	0.041±0.01	BDL

BDL = below detection limits n = 6, mean ± standard deviation

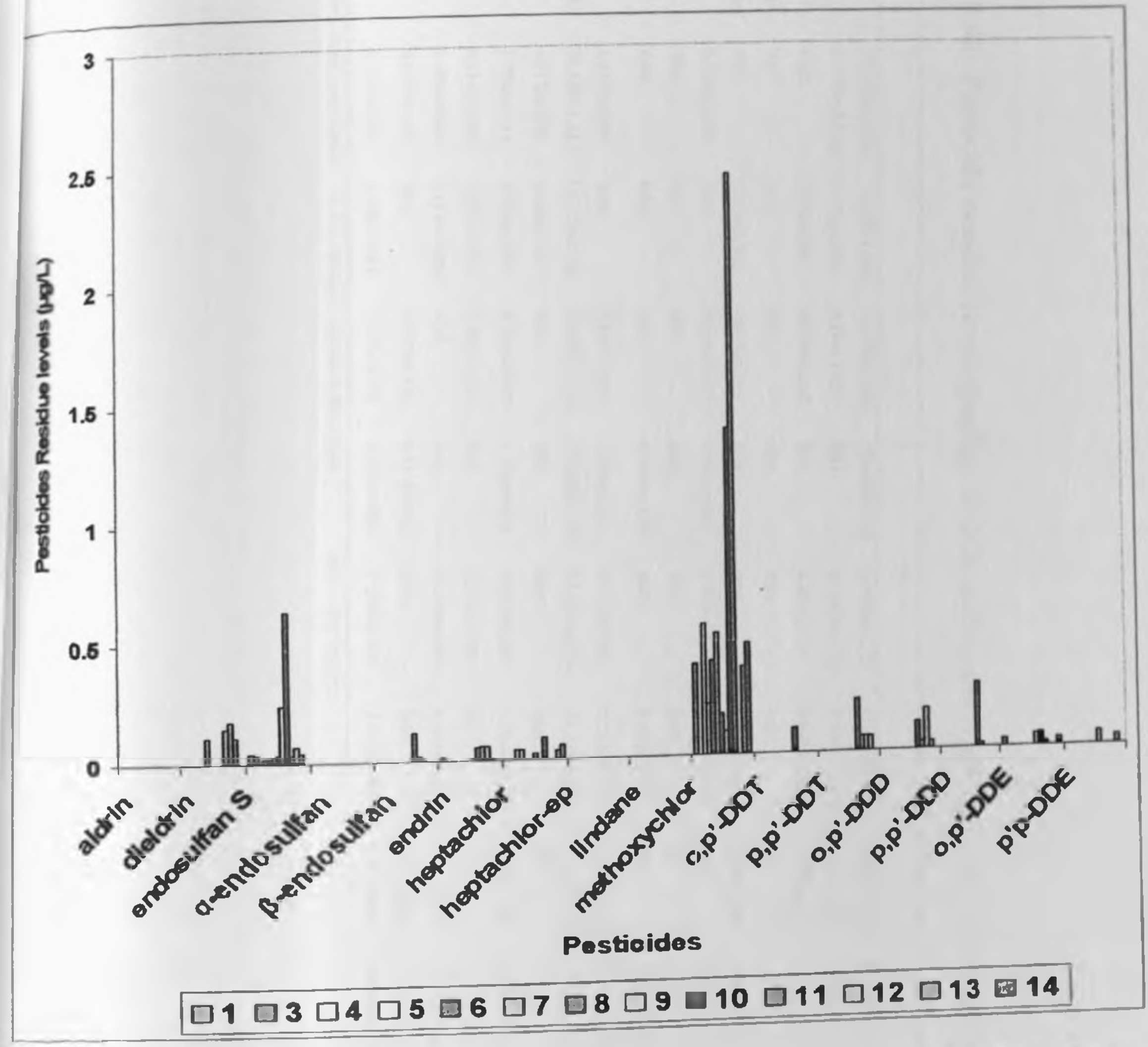

Figure 5.41: Pesticide residue levels in water from Kericho-Upper Nyando in September

The highest concentration of dieldrin was at sites 12 (0.179±0.007µg/L), endosulfan sulfate and heptachlor at site 10 (0.638±0.008 µg/L) and (0.097±0.002 µg/L) respectively in Kericho-Upper Nyando in water sampes. In sediment samples (Tables 5.42 and Figure 5.42) highest concentration of methoxychlor, aldrin, dieldrin and p,p'-DDE were recorded at sites 1 (79.330±2.287 µg/kg), 8 (29.866±3.961 µg/kg), 1 (11.587±2.246 µg/kg) and 14 (9.145±0.330 µg/kg), respectively.

Table 5.42: Pesticide residue levels (µg/kg, dw) in sediments from Kericho-Upper Nyando in September

Pesticides/ Sites	1	3	4	5	6	7	8	9	10	11	12	13	14
aldrin	13.839±0.873	12.672±1.334	13.455±1.209	12.669±0.628	14.900±2.275	12.471±2.104	29.866±3.961	11.712±1.082	12.956±1.441	12.979±1.246	4. 922±2.548	BDL	BDL
dieldrin	11.587±2.246	9.673±1.853	5.296±1.525	BDL	11.3075±1.753	8.804±1.783	3.554±0.569	0.351±0.071	6.769±0.967	8.011±1.373	0.128±0.026	0.135±0.049	9.236±1.434
endosulfan S	BDL	3.782±0.897	0.038±0.003	BDL	0.867±0.110	0.042±0.008	0.049±0.013	3.980±0.649	BDL	3.462±0.677	3.270±0.528	BDL	2.270±0.318
α-endosulfan	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
β-endosulfan	BDL	0.016±0.006	0.025±0.007	BDL	BDL	0.866±0.143	1.554±0.136	5.385±0.847	BDL	0.042±0.011	1.057±0.0509	BDL	BDL
endrin	0.544±0.153	BDL	0.016±0.007	0.932±0.082	0.880±0.136	0.045±0.015	BDL	BDL	1.86±0.105	4.054±0.094	1.522±0.217	BDL	0.662±0.139
heptachlor	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.056±0.016
Heptachlor -epoxide	BDL	BDL	BDL	0.764±0.155	BDL	1.114±0.022	BDL	1.387±0.408	0.539±0.167	0.997±0.016	BDL	0.022±0.014	1.788±0.155
lindane	1.272±0.195	BDL	7.401±1.933	3.851±1.166	8.741±0.424	7.765±1.025	16.339±1.130	6.343±0.581	3.726±0.999	3.864±0.046	7.154±0.176	0.923±0.040	6.971±0.104
methoxychlor	79.330±2.287	11.328±2.742	40.527±9.072	57.439±4.700	53.454±4.710	42.325±2.205	18.796±2.663	27.742±1.782	36.694±3.307	49.412±8.107	38.101±5.546	15.619±8.125	17.893±4.033
o,p'-DDT	1.612±0.529	0.24±0.119	BDL	BDL	BDL	BDL	BDL	BDL	0.839±0.078	0.557±0.148	BDL	BDL	1.453±0.471
p,p'-DDT	2.790±0.314	3.954±0.396	8.394±1.797	2.493±0.699	0.831±0.222	1.784±0.212	0.444±0.296	6.864±1.116	0.193±0.102	3.089±0.154	2.776±0.172	0.829±0.214	4.261±0.561
o,p'-DDD	0.616±0.099	0.892±0.026	2.081±0.134	BDL	0.600±0.024	BDL	BDL	1.516±0.211	0.696±0.025	0.326±0.067	1.129±0.203	BDL	1.361±0.106
p,p'-DDD	0.488±0.049	0.117±0.025	BDL	BDL	0.610±0.032	0.881±0.134	0.050±0.009	1.302±0.066	2.135±0.060	BDL	1.869±0.163	1.136±0.210	2.031±0.220
o,p'-DDE	0.837±0.182	BDL	1.567±0.152	0.137±0.012	BDL	BDL	0.904±0.039	2.764±0.188	1.564±0.488	BDL	3.885±0.140	BDL	1.586±0.552
p,p'-DDE	3.431±0.628	1.110±0.182	7.203±0.305	2.739±0.084	2.229±0.469	2.313±0.469	1.469±0.199	3.046±0.189	1.701±4.06	6.137±0.496	0.059±0.009	7.605±0.532	9.145±0.330

BDL = below detection limits   n = 6, mean ± standard deviation   dw = dry weight

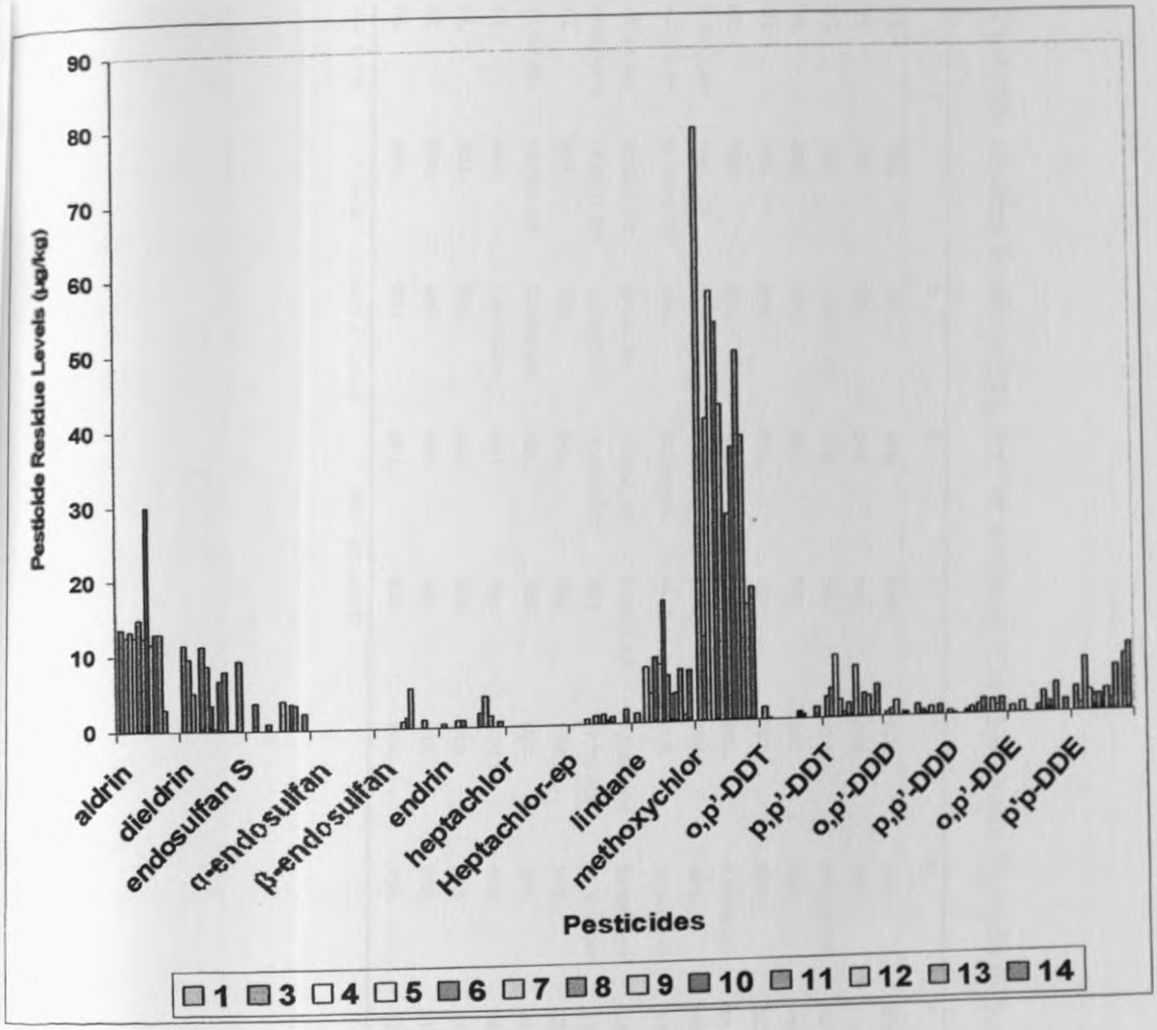

Figure 5.42: Pesticide residue levels in sediments from Kericho-Upper Nyando in September

In Kericho-Upper Nyando, the pesticides concentrations detected in sediments showed strong positive bivariate Pearson correlation coefficients ($P<0.05$) in the range of 0.933-0.997 (Appendix 5.3, Table 5.42.1). The highest correlation value of 0.997 was obtained for sites 6 and 11, the lowest value of 0.933 was obtained for sites 8 and 13. In weed samples (Tables 5.43 and Figure 5.43), methoxychlor, aldrin, dieldrin, heptachlor, heptachlor epoxide, lindane and endosulfan sulfate were detected at highest concentrations at various sites

Table 5.43: Pesticide residue levels (µg/kg, dw) in weeds in Kericho-Upper Nyando in September

Pesticides/ Sites	1	3	4	5	6	7	8	9	10	11	12	13	14
aldrin	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	17.498±1.159	6.713±0.423
dieldrin	BDL	BDL	BDL	BDL	BDL	BDL	BDL	17.635±2.939	6.070±010	10.825±0.570	2.541±0.953	5.375±0.469	7.156±0.428
endosulfan S	BDL	BDL	5.995±1.273	BDL	BDL	BDL	2.984±0.049	BDL	2.94±0.215	18.670±1.955	8.278±2.575	2.720±0.951	13.955±4.262
α-endosulfan	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
β-endosulfan	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
endrin	BDL	BDL	BDL	BDL	BDL	BDL	4.183±0.261	10.858±2.946	8.230±0.330	2.826±0.244	5.335±1.414	11.604±0.856	15.966±1.496
heptachlor	20.701±6.027	BDL	BDL	BDL	BDL	BDL	BDL	BDL	10.22±0.323	BDL	BDL	BDL	BDL
heptachlor-epoxide	41.252±4.195	61.449±8.591	BDL	81.936±6.56	14.054±1.300	BDL	4.483±0.686	4.639±0.801	17.959±0.403	4.567±0.859	17.627±2.481	2.903±0.054	4.216±1.36
lindane	8.487±3.366	3.703±0.278	5.91±0.407	10.10±1.290	2.082±0.385	2.730±1.365	9.248±0.354	6.327±1.169	7.080±1.453	2.877±0.378	5.111±0.665	3.459±1.227	6.342±1.104
methoxychlor	46.016±8.454	14.670±1.204	23.609±2.655	36.103±4.221	BDL	32.032±0.926	26.364±5.047	3.535±0.565	38.569±4.767	14.317±2.598	27.584±5.909	28.543±3.328	13.359±1.612
o,p'-DDT	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	2.089±0.128	BDL	1.883±0.534	BDL
p,p'-DDT	6.833±0.197	3.415±0.129	8.254±0.424	BDL	BDL	BDL	BDL	BDL	BDL	13.070±0.762	7.104±1.105	BDL	9.338±0.682
o,p'-DDD	BDL	BDL	3.847±0.234	BDL	BDL	BDL	BDL	BDL	BDL	4.774±0.579	7.471±1.250	BDL	7.968±0.061
p,p'-DDD	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	1.971±0.527	4.026±0.408	BDL	BDL
o,p'-DDE	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	7.083±1.049	BDL	BDL	BDL
p,p'-DDE	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	7.277±0.393	BDL	BDL	4.745±0.279

BDL = below detection limits n = 6, mean ± standard deviation dw = dry weight

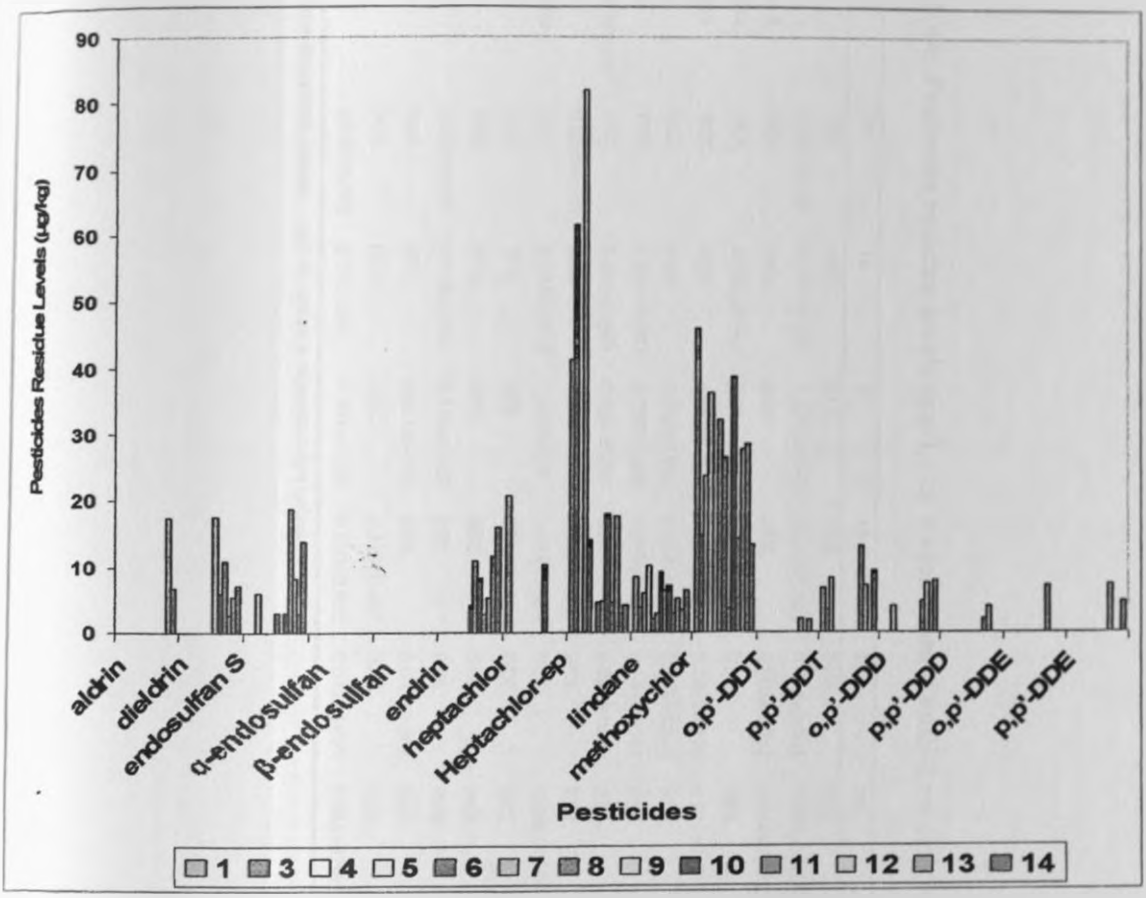

Table 5.43: Pesticide residue levels in weeds in Kericho-Upper Nyando in September

In Kericho-Upper Nyando, the pesticides concentrations detected in weed samples showed strong positive bivariate Pearson correlation coefficients ($P<0.05$) in the range of 0.517-0.945 (Appendix 5.3, Table 5.43.1). The highest correlation value of 0.945 was obtained for sites 7 and 8, the lowest value of 0.517 was obtained for sites 3 and 10. Heptachlor and heptachlor epoxide were detected at highest concentrations at sites 1 (8.701±1.027µg/kg) and 3 (6.449±1.591µg/kg) respectively and lindane at site 1 (8.487± 0.537µg/kg). The highest concentration of dieldrin in water samples was at sites 17 (1.156±0.042µg/L) in Nandi-Lower Nyando (Table 5.44 and Figure 5.44).

Table 5.44: Pesticide residue levels (μg/L) in water from Nandi-Lower Nyando in September

	15	16	17	18	19	21	22	23	25	26	27	30	33
aldrin	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
dieldrin	0.012±0.001	0.267±0.007	1.156±0.042	0.147±0.008	0.012±0.004	0.065±0.012	0.026±0.002	BDL	0.015±0.003	BDL	BDL	BDL	BDL
endosulfan S	BDL	BDL	BDL	BDL	0.905±0.011	0.841±0.028	BDL	BDL	BDL	BDL	0.027±0.001	BDL	0.033±0.004
α-endosulfan	BDL	0.004±0.001	BDL	0.019±0.003	BDL	BDL	BDL	BDL	0.007±0.001	BDL	BDL	BDL	BDL
β-endosulfan	BDL	BDL	0.059±0.015	0.027±0.003	0.226±0.016	0.013±0.001	BDL	BDL	BDL	0.004±0.001	BDL	BDL	BDL
endrin	BDL	BDL	0.012±0.001	0.024±0.001	0.129±0.008	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.030±0.003
heptachlor	BDL	0.074±0.007	0.508±0.080	0.059±0.010	0.144±0.043	BDL	BDL	0.034±0.006	0.034±0.004	BDL	BDL	BDL	BDL
heptachlor-epoxide	BDL	0.021±0.001	0.034±0.003	BDL	0.03±0.008	BDL	BDL	BDL	0.041±0.003	BDL	BDL	BDL	BDL
lindane	0.059±0.001	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.028±0.003
methoxychlor	BDL	0.335±0.019	2.919±0.39	3.984±0.354	BDL	0.806±0.009	1.800±0.036	1.325±0.205	0.924±0.010	0.061±0.001	0.345±0.050	0.356±0.008	0.025±0.001
o,p'-DDT	BDL	BDL	BDL	BDL	BDL	BDL	0.018±0.002	BDL	BDL	BDL	BDL	BDL	BDL
p,p'-DDT	BDL	BDL	BDL	BDL	BDL	BDL	0.071±0.003	BDL	BDL	0.064±0.001	0.047±0.003	BDL	BDL
o,p'-DDD	0.024±0.002	0.018±0.001	0.318±0.007	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
p,p'-DDD	BDL	BDL	0.011±0.002	BDL	0.035±0.003	BDL	BDL	BDL	0.034±0.002	BDL	BDL	BDL	BDL
o,p'-DDE	BDL	BDL	BDL	0.313±0.087	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.058±0.005
p,p'-DDE	0.034±0.005	0.021±004	0.594±0.120	0.150±0.052	0.031±0.007	0.066±0.005	BDL	BDL	BDL	BDL	BDL	BDL	0.098±0.012

BDL = below detection limits   n = 6, mean ± standard deviation

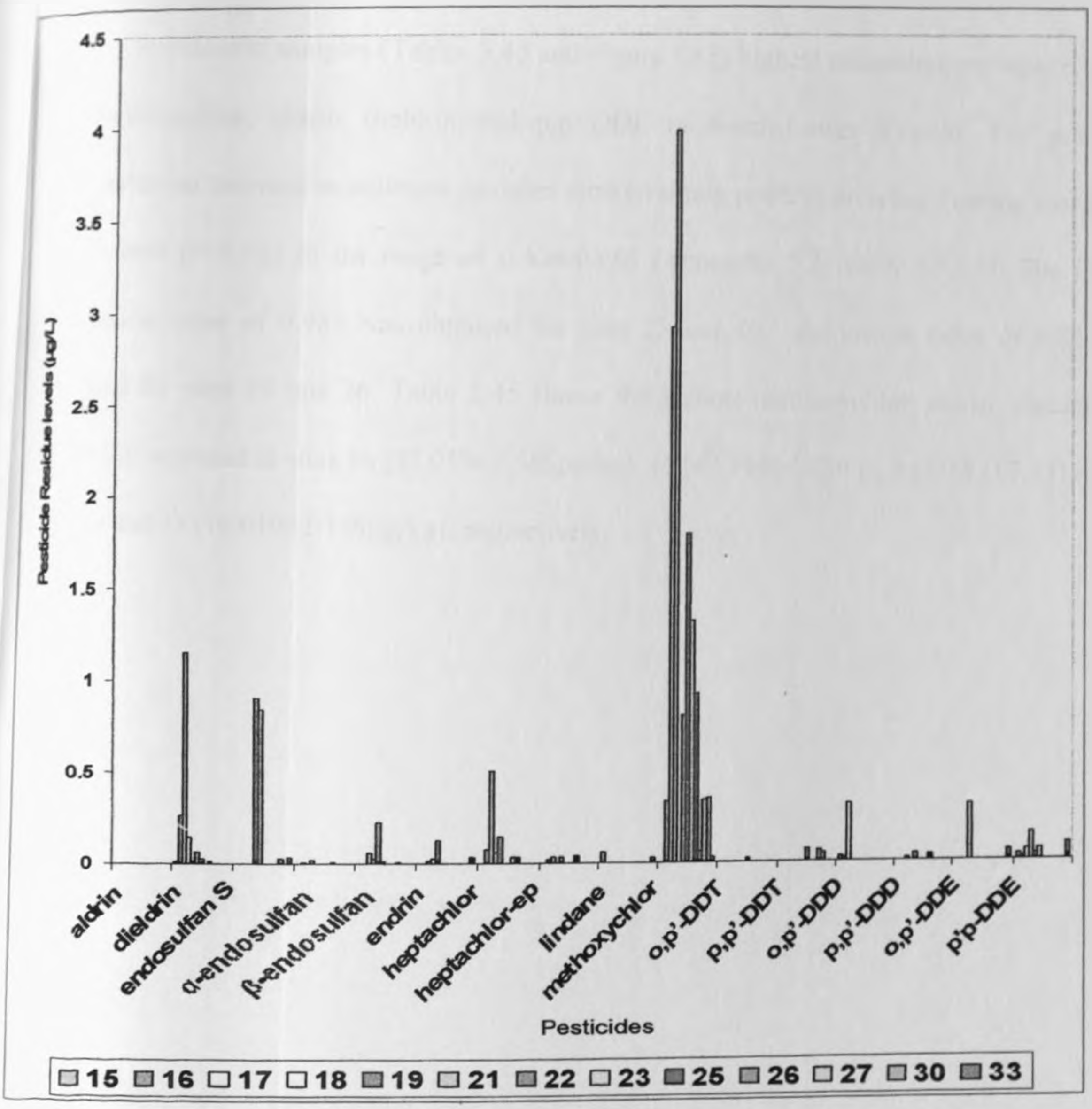

Figure 5.44: Pesticide residue levels in water from Nandi-Lower Nyando in September

Nandi-Lower Nyando, the pesticides concentrations detected in water samples showed strong positive bivariate Pearson correlation coefficients ($P<0.05$) in the range of 0.592-0.904 (Appendix 5.3, Table 5.44.1). The highest correlation value of 0.904 was obtained for sites 15 and 25, the lowest value of 0.592 was obtained for sites 15 and 17. The highest concentration of endosulfan sulfate and heptachlor were detected at sites 19 (0.905±0.011 μg/L) and 17 (0.508±0.08 μg/L), respectively.

In sediment samples (Tables 5.45 and Figure 5.45) highest concentrations were recorded for methoxychlor, aldrin, dieldrin and p,p'-DDE in Nandi-Lower Nyando. The pesticides concentrations detected in sediment samples showed strong positive bivariate Pearson correlation coefficients ($P<0.05$) in the range of 0.524-0.985 (Appendix 5.3, Table 5.45.1). The highest correlation value of 0.985 was obtained for sites 25 and 30. the lowest value of 0.524 was obtained for sites 19 and 26. Table 5.45 shows the highest methoxychlor, aldrin, dieldrin and p,p'-DDE recorded at sites 16 (91.019±2.585μg/kg), 16 (42.719±1.039 μg/kg), 15 (17.151±1.318 μg/kg) and 33 (10.019±1.158μg/kg), respectively.

Table 5.45: Pesticide residue levels (µg/kg, dw) in sediments from Nandi-Lower Nyando in September

Pesticides/ Sites	15	16	17	18	19	21	22	23	25	26	27	30	33
aldrin	BDL	42.719±1.039	25.047±1.571	10.628±1.064	12.611±1.325	BDL	BDL	BDL	34.127±2.276	12.292±1.314	BDL	BDL	14.043±0.535
dieldrin	17.151±1.318	3.153±0.035	9.814±0.519	0.845±0.188	8.233±1.28	BDL	17.124±0.323	8.579±1.780	0.932±0.073	0.457±0.062	0.368±0.069	6.757±0.475	10.824±0.690
endosulfan S	11.063±1.45	2.829±0.371	2.141±0.504	4.298±0.568	3.219±0.181	10.386±1.120	14.157±1.500	8.985±0.072	0.892±0.126	2.169±0.195	1.246±0.308	BDL	0.919±0.053
α-endosulfan	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
β-endosulfan	1.765±0.313	BDL	1.086±0.017	BDL	1.702±0.194	18.001±1.507	BDL	BDL	0.104±0.008	0.887±0.142	1.072±0.054	BDL	0.866±0.112
endrin	BDL	BDL	BDL	0.110±0.014	BDL	BDL	0.045±0.016	1.042±0.078	1.873±0.152	0.853±0.187	0.111±0.018	BDL	1.874±0.154
heptachlor	BDL	1.04±0.076	0.720±0.063	1.228±0.180	0.036±0.006	BDL	BDL	BDL	BDL	BDL	BDL	BDL	1.244±0.296
Heptachlor-epoxide	BDL	0.333±0.140	0.111±0.016	BDL	0.876±0.158	0.950±0.074	0.105±0.021	2.574±0.176	2.243±0.315	7.903±0.307	1.425±0.147	3.686±0.178	3.497±0.063
lindane	0.532±0.126	0.679±0.057	0.131±0.011	0.050±0.006	0.023±0.003	5.425±0.788	8.256±0.299	0.208±0.057	9.582±0.776	0.223±0.047	0.647±0.135	6.403±0.694	8.011±0.040
methoxychlor	26.827±1.721	91.019±2.585	56.695±4.724	72.264±4.470	6.127±2.947	63.791±3.893	19.688±0.995	52.084±4.305	2.424±0.650	27.975±5.553	16.996±5.589	6.477±2.091	12.108±2.925
o,p'-DDT	0.840±0.134	BDL	BDL	BDL	0.184±0.081	0.793±0.113	0.822±0.233	0.903±0.044	1.762±0.304	BDL	BDL	BDL	1.165±0.098
p,p'-DDT	6.097±1.257	9.378±0.544	5.008±0.262	2.997±302	0.777±0.297	5.060±1.002	2.956±0.236	4.424±0.619	6.188±0.456	6.633±0.756	6.101±1.018	8.357±1.748	4.927±1.329
o,p'-DDD	1.305±0.188	BDL	1.902±0.007	0.138±0.058	BDL	1.621±0.233	1.332±0.108	0.578±0.110	0.797±0.139	1.315±0.099	0.992±0.019	BDL	2.534±0.533
p,p'-DDD	0.199±0.028	1.571±0.117	1.158±0.240	1.564±0.154	0.633±0.128	0.884±0.040	1.899±0.031	0.878±0.155	1.936±0.059	0.017±0.007	0.139±0.006	BDL	4.062±0.086
o,p'-DDE	BDL	BDL	BDL	BDL	0.266±0.068	BDL	0.523±0.033	BDL	BDL	1.143±0.063	BDL	0.833±0.091	15.562±0.812
p,p'-DDE	9.145±0.330	1.418±0.107	BDL	1.361±0.179	0.855±0.155	0.773±0.291	1.535±0.163	BDL	0.909±0.106	2.973±0.055	BDL	5.134±0.344	10.019±1.158

BDL = below detection limits n = 6, mean ± standard deviation dw = dry weight

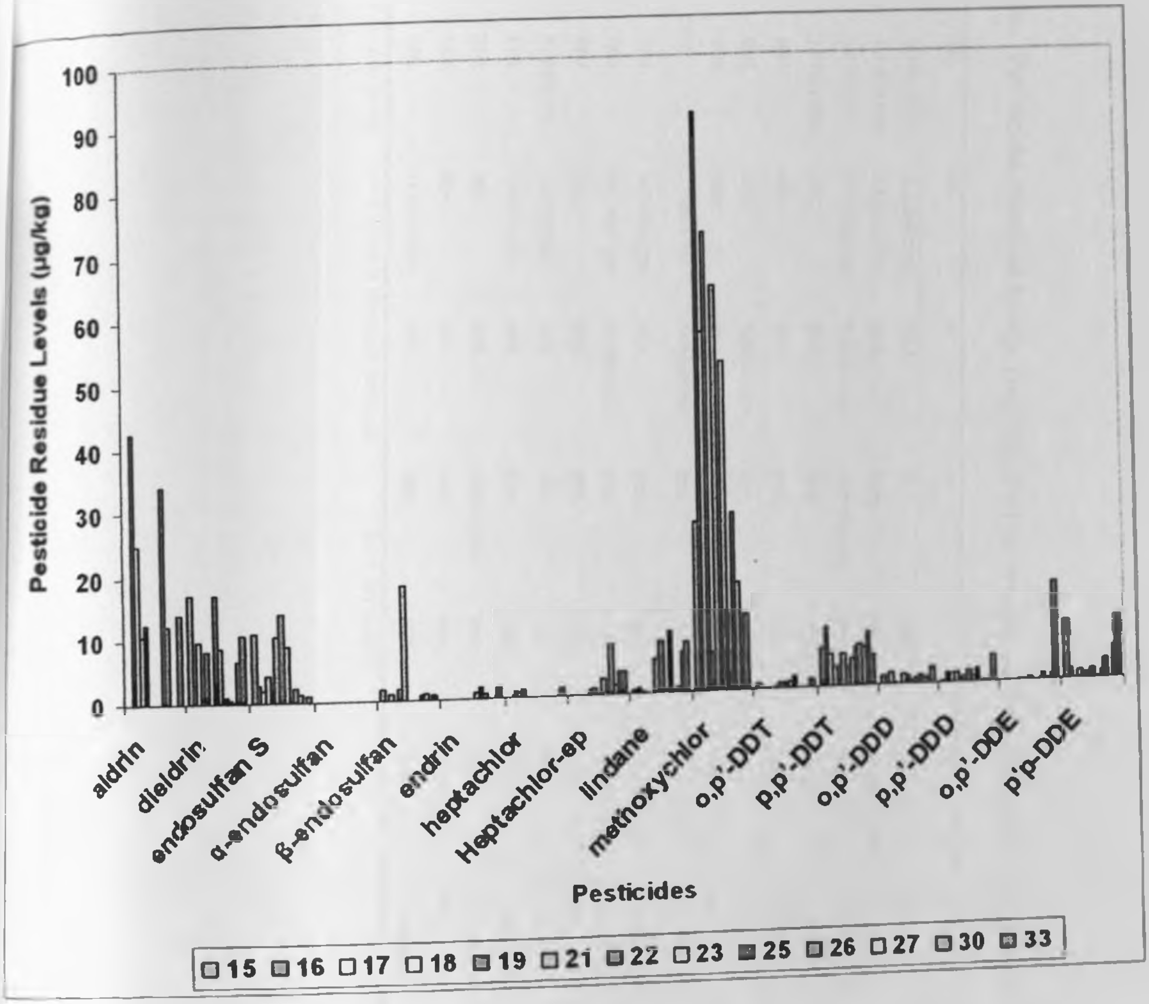

Figure 5.45: Pesticide residue levels in sediments from Nandi-Lower Nyando in September

In weed samples (Table 5.46 and Figure 5.46) methoxychlor, aldrin, dieldrin, heptachlor, heptachlor epoxide, lindane and endosulfan sulfate were detected at highest concentrations. The concentrations detected in weed samples showed strong positive bivariate Pearson correlation coefficients ($P<0.05$) in the range of 0.544-0.956 (Appendix 5.3, Table 5.46.1). The highest correlation value of 0.956 was obtained for sites 17 and 26, the lowest value of 0.544 was obtained for sites 18 and 23.

Table 5.46: Pesticide residue levels (µg/kg, dw) in weeds in Nandi-Lower Nyando in September

Pesticides/ sites	15	16	17	18	19	21	22	23	25	26	27	30	33
aldrin	0.749±0.006	4.265±0.736	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	13.135±0.296	BDL
dieldrin	2.378±0.295	9.233±0.335	BDL	BDL	BDL	30.037±2.928	BDL	BDL	39.295±7.100	BDL	BDL	BDL	9.511±0.865
endosulfan S	4.734±0.324	12.264±0.950	9.964±1.293	15.897±0.385	BDL	BDL	6.735±1.408	23.783±3.136	5.717±0.484	BDL	BDL	BDL	6.597±0.583
α-endosulfan	1.749±1.706	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
β-endosulfan	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
endrin	BDL	BDL	5.003±1.254	BDL	3.020±0.770	BDL	BDL	0.982±0.003	BDL	BDL	BDL	BDL	17.174±2.839
heptachlor	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
heptachlor-epoxide	BDL	7.749±2.706	4.966±0.245	BDL	BDL	19.469±1.914	20.155±1.865	8.095±1.257	7.972±0.635	9.241±0.418	7.117±0.620	27.332±1.243	5.129±2.214
lindane	BDL	20.378±2.295	BDL	BDL	BDL	15.966±2.703	4.966±0.841	13.757±3.252	16.470±0.856	BDL	15.877±1.349	6.790±1.107	13.108±2.954
methoxychlor	BDL	54.734±7.324	49.383±8.316	BDL	BDL	47.769±6.820	49.575±3.622	22.69±2.184	16.114±1.707	32.430±0.559	45.296±6.618	13.020±0.198	49.520±5.493
o,p'-DDT	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
p,p'-DDT	8.604±1.151	9.058±0.664	BDL	BDL	BDL	BDL	BDL	18.137±1.238	26.789±2.669	BDL	BDL	6.318±1.116	35.210±1.256
o,p'-DDD	BDL	7.462±0.655	BDL	BDL	BDL	BDL	4.360±0.781	BDL	BDL	BDL	BDL	BDL	BDL
p,p'-DDD	BDL	BDL	BDL	0.622±0.094	BDL	BDL	20.604±2.251	BDL	BDL	BDL	BDL	BDL	BDL
o,p'-DDE	BDL	BDL	BDL	BDL	BDL	7.424±0.788	BDL	BDL	BDL	BDL	BDL	BDL	BDL
p,p'-DDE	BDL	11.057±1.976	BDL	BDL	BDL	BDL	16.808±0.752	BDL	BDL	BDL	BDL	BDL	BDL

BDL = below detection limits n = 6, mean ± standard deviation dw = dry weight

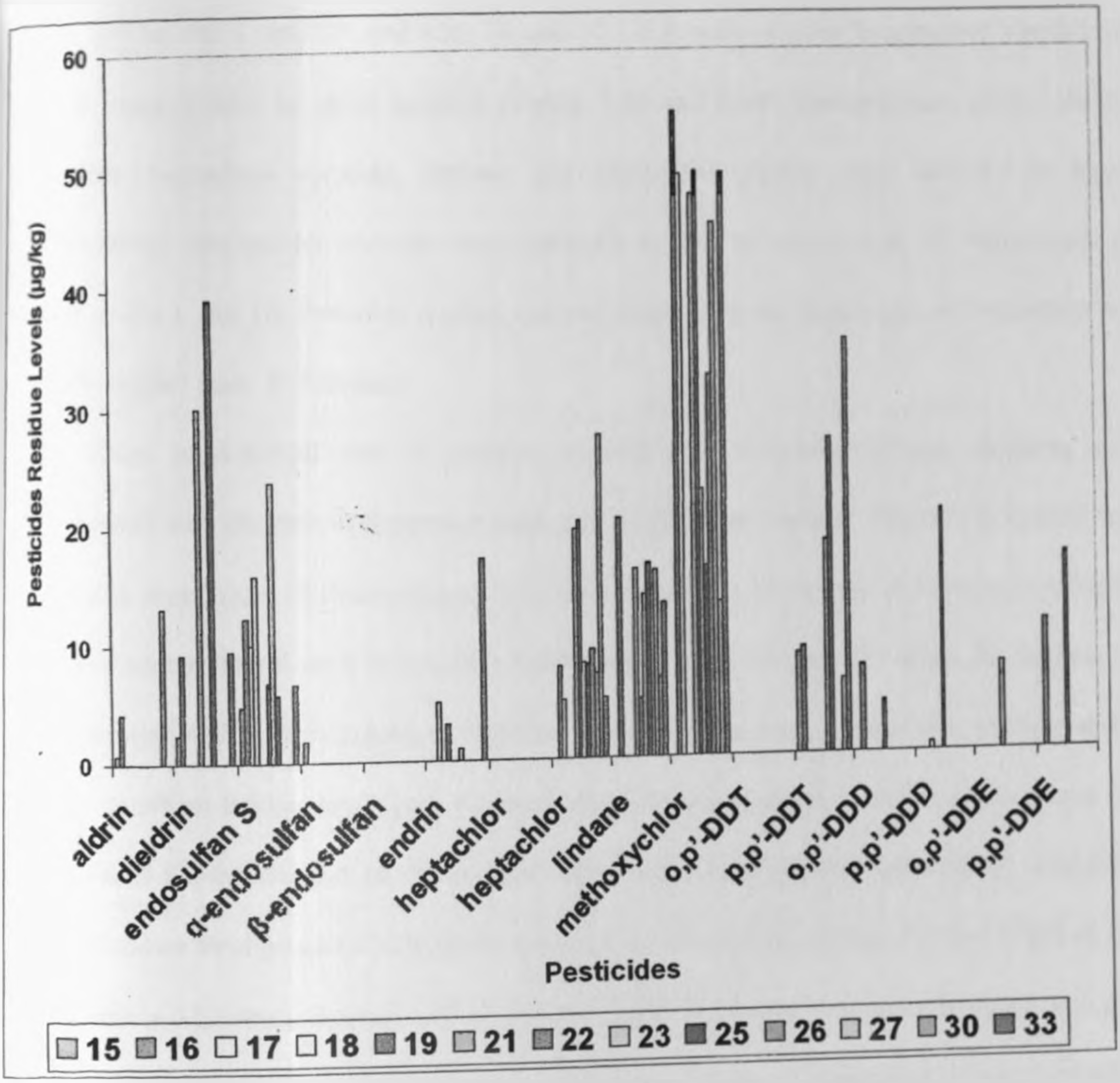

Figure 5.46: Pesticide residue levels in weeds in Nandi-Lower Nyando in September

Table 5.46 shows the highest methoxychlor, aldrin, dieldrin and p,p'-DDE recorded at sites 16 (91.019±2.585µg/kg), 16 (42.719±1.039 µg/kg), 15 (17.151±1.318 µg/kg) and 33 (10.019±1.158µg/kg), respectively.

Generally, in September the highest concentrations of dieldrin was at sites 12 and 17, endosulfan sulfate at sites 10 and 19 and heptachlor at sites 10 and in Kericho-Upper Nyando and Nandi-Lower Nyando in water samples, respectively. In sediment samples (Tables 5.42 and 5.45) highest concentration of methoxychlor, aldrin, p,p'-DDE were recorded at sites 1 and 16 sites 8 and 16, site 1 and 15 and sites 14 and 33 , in Kericho-Upper Nyando and Nandi-Lower Nyando, respectively. In weed samples (Tables 5.43 and 5.46) methoxychlor, aldrin, dieldrin, heptachlor, heptachlor epoxide, lindane and endosulfan sulfate were detected at highest concentrations. Heptachlor epoxide were detected highest at sites 3 and 30 respectively and lindane at site 1 and 16. Pesticide residue concentrations detected in samples in September were generally higher than in February.

There is potential risk of people, animals and macroinvertebrates drinking water contaminated with dieldrin in Sepember with sites 12 (Pararget) and 17 (Nyando at dykes) being highest risk areas, sites 10 (Namuting at Fort Ternna) and 19 (Ainamutua at Kibigori) are highest risk areas contaminated with endosulfan sulfate while sites 10 and 17 being the highest risk areas contaminated with heptachlor. Sediment samples from sites 1 (Kedowa bridge) and 16 (Nyando at Ahero bridge) are highly contaminated with methoxychlor, whereas those from sites 8 (Nyando at Kipkelion) and 16 (Nyando at Ahero bridge) are highly contaminated with aldrin, sites 1 (Kedowa Bridge) and 15 (Nyando at Ogilo) are contaminated with dieldrin where as sites 14 (Nyando at Muhoroni Bridge) and 33 (Ahero irrigation Channel) are contaminated with p,p'-DDE. In the case of the weed samples site 1 (Kedowa at bridge) is contaminated with heptachlor and lindane, site 3 (Masaita at Dam) is contaminated with heptachlor epoxide and site 16 (Nyando at Ahero bridge) is also contaminated with lindane.

5.1.4 Pesticides residues in water, sediment and weed samples in December

In December (short rainy season) Kericho-Upper Nyando sub-catchment area showed higher pesticide residue concentration in water (Table 5.51) than Nandi-Lower Nyando (Table 5.54). The concentrations detected in water samples from Kericho-Upper Nyando (Table 5.51 and Figure 5.51) showed strong positive bivariate Pearson correlation coefficients ($P<0.05$) in the range of 0.519-0.943 (Appendix 5.3. Table 5.55.1). The highest correlation value of 0.943 was obtained for sites 3 and 12, the lowest value of 0.519 was obtained for sites 1 and 10.

Sites 8 (1.667± 0.119μg/L) and 27 (1.438±0.463μg/L) recorded the highest methoxychlor levels. Dieldrin and endosulfan sulfate were above the WHO and Australian guidelines of daily intake for the drinking water in some sites in Kericho-Upper Nyando. Sites 12 (0.152±0.039 μg/L) and 7 (0.302± 0.017μg/L) recorded highest levels of dieldrin and endosulfan sulfate, respectively. The concentrations of heptachlor-epoxide and o,p'-DDT were below the detection limits in all the water samples from Kericho-Upper Nyando in December.

Table 5.55: Pesticide residue levels (µg/L) in water from Kericho-Upper Nyando in December

	1	3	4	5	6	7	8	9	10	11	12	13	14
aldrin	0.278±0.018	BDL	BDL	0.006±0.001	BDL	BDL	BDL	BDL	BDL	BDL	0.01±0.001	0.021±0.002	BDL
dieldrin	0.254±0.046	0.130±0.004		0.119±0.01	0.118±0.013	0.012±0.001	BDL	0.034±0.006	BDL	0.137±0.019	0.152±0.0389	0.096±0.019	0.029±0.001
endosulfan S	0.052±0.017	BDL	BDL	BDL	BDL	0.302±0.017	BDL	0.022±0.002	0.049±0.005	BDL	0.052±0.001	0.028±0.02	BDL
α-endosulfan	BDL	BDL	BDL	0.003±0.001	BDL	BDL	0.012±0.002	0.029±0.001	0.006±0.001	BDL	BDL	BDL	BDL
β-endosulfan	0.046±0.001	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.005±0.002	0.015±0.001	0.017±0.001	0.049±0.002	BDL
endrin	0.060±0.001	0.088±0.008	BDL	0.048±0.020	0.015±0.001	0.007±0.001	0.037±0.007	0.076±0.015	BDL	0.011±0.001	0.010±0.001	0.018±0.004	BDL
heptachlor	BDL	0.027±0.008	BDL	0.039±0.007	0.026±0.006	0.089±0.013	0.028±0.003	0.037±0.004	0.045±0.004	0.022±0.004	0.033±0.001	0.089±0.035	0.097±0.010
heptachlor-epoxide	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
lindane	0.065±0.001	0.035±0.005	BDL	0.062±0.008	0.013±0.003	0.005±0.003	0.024±0.002	0.017±0.003	0.034±0.006	0.014±0.004	0.013±0.005	0.016±0.004	0.032±0.004
methoxychlor	0.877±0.068	0.700±0.090	0.929±0.076	0.742±0.125	0.865±0.064	1.037±0.023	1.667±0.119	0.79±0.115	0.166±0.032	1.064±0.058	0.701±0.125	1.297±0.328	0.255±0.023
o,p'-DDT	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
p,p'-DDT	0.051±0.004	0.006±0.001	0.161±0.197	0.014±0.004	0.007±0.001	0.005±0.001	BDL	BDL	0.05±0.001	0.003±0.001	0.008±0.001	0.06±0.001	BDL
o,p'-DDD	0.08±0.019	BDL	BDL	0.044±0.004	BDL	0.044±0.002	BDL	BDL	BDL	BDL	BDL	BDL	BDL
p,p'-DDD	BDL	0.064±0.001	BDL	0.014±0.002	0.009±0.002	0.100±0.127	0.2±0.014	0.170±0.014	BDL	BDL	0.233±0.033	0.300±0.057	0.732±0.074
o,p'-DDE	BDL	0.049±0.011	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.037±0.004	0.022±0.001
p,p'-DDE	0.244±0.043	0.884±0.039	BDL	0.147±0.005	BDL	BDL	0.05±0.007	0.183±0.022	0.189±0.001	0.159±0.041	BDL	BDL	BDL

BDL = below detection limits   n = 6, mean ± standard deviation

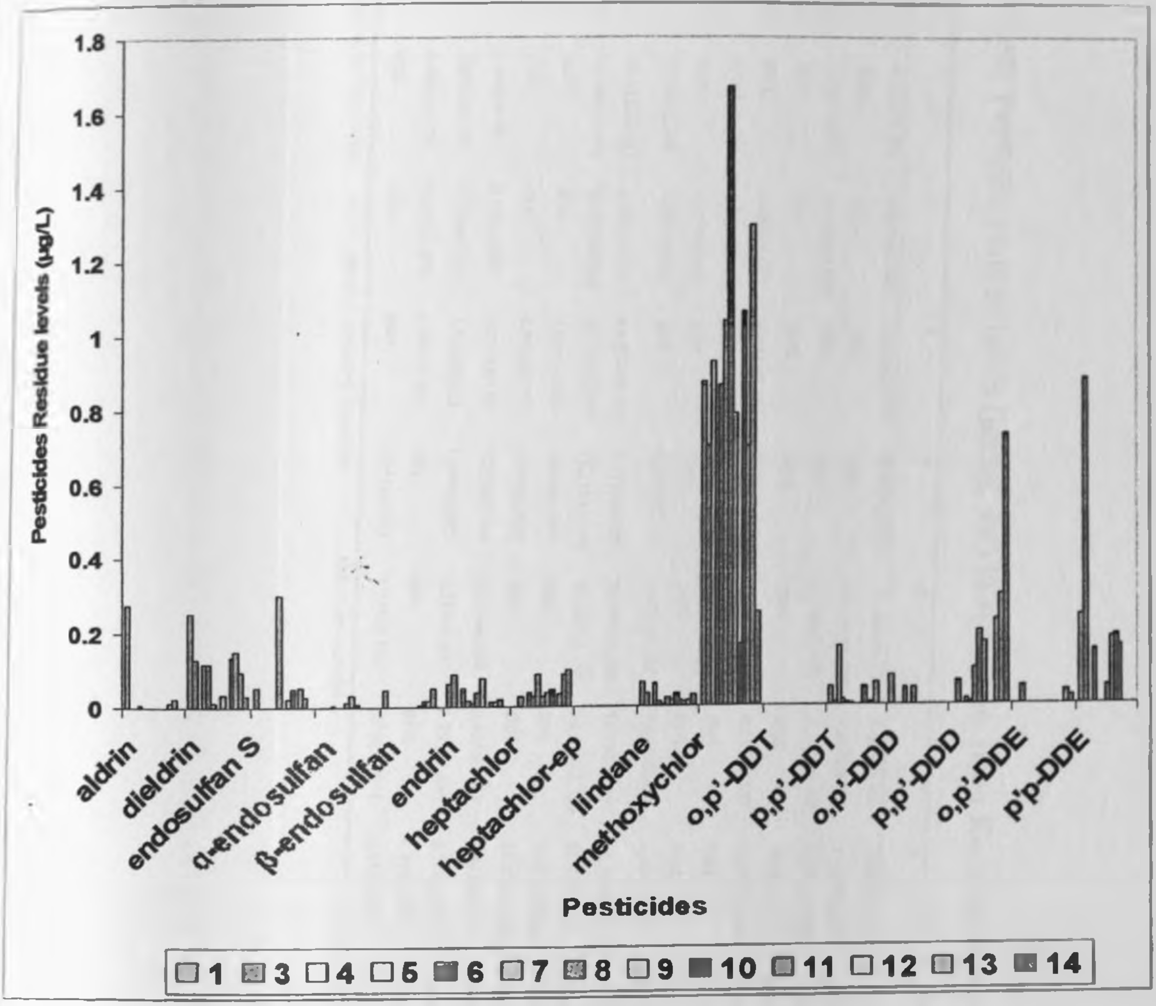

Figure 5.55: Pesticide residue levels in water from Kericho-Upper Nyando in December

For sediment samples, aldrin was detected in most samples in December (Table 5.52 and Figure 5.52) in the Kericho-Upper Nyando. Aldrin was highest at site 11 (26.676±0.981 µg/kg). The concentrations detected in sediment samples from Kericho-Upper Nyando (Table 5.52) showed strong positive bivariate Pearson correlation coefficients (P<0.05) in the range of 0.583-0.989 (Appendix 5.3, Table 5.52.1). The highest correlation value of 0.989 was obtained for sites 3 and 14, the lowest value of 0.583 was obtained for sites 7 and 10.

Table 5.52: Pesticide residue levels (μg/kg, dw) in sediments from Kericho-Upper Nyando in December

Pesticides/ Sites	1	3	4	5	6	7	8	9	10	11	12	13	14
aldrin	9.320±0.780	4.013±0.045	8.242±0.990	8.858±1.279	11.160±0.724	0.883±0.041	0.881±0.135	7.465±0.708	BDL.	26.676±0.981	10.931±1.343	14.550±1.113	5.223±1.276
dieldrin	BDL	BDL.	BDL.	BDL.	16.534±1.991	9.665±0.770	1.775±0.298	3.551±0.605	7.043±0.188	9.065±1.068	0.832±0.156	0.072±0.006	0.797±0.107
endosulfan S	6.362±0.997	10.687±4.618	BDL.	BDL.	2.569±0.369	5.105±0.490	2.094±0.966	2.931±1.474	1.391±0.492	3.677±1.805	2.800±1.394	BDL.	7.626±1.554
α-endosulfan	BDL.	BDL	BDL.	BDL.	BDL.	BDL.	BDL.	BDL.	BDL.	BDL.	BDL.	BDL.	BDL
β-endosulfan	BDL.	0.185±0.021	0.431±0.156	BDL.	0.113±0.023	0.534±0.157	1.255±0.233	5.296±0.530	BDL.	0.165±0.063	2.439±0.639	BDL.	0.047
endrin	1.742±2.464	1.780±2.517	BDL.	3.438±1.319	2.917±1.274	BDL.	BDL.	2.403±0.552	1.401±0.292	1.315±0.317	1.164±0.137	BDL.	BDL.
heptachlor	BDL.	0.717±0.092	BDL.	BDL.	BDL.	BDL.	BDL.	BDL.	BDL	BDL.	BDL.	BDL.	0.677±0.155
Heptachlor epoxide	8.234±1.348	3.224±0.363	BDL.	2.054±0.141	3.173±0.322	7.024±0.487	4.607±0.556	BDL.	BDL.	BDL.	BDL.	BDL.	BDL.
lindane	15.212±4.337	6.023±0.073	14.992±0.113	7.111±0.128	20.059±4.501	16.293±0.433	18.368±1.446	12.978±0.121	10.167±3.113	22.895±0.595	18.125±0.847	9.270±4.170	18.048±5.465
methoxychlor	34.548±3.472	23.007±2.865	33.380±3.477	25.223±1.854	40.807±1.155	84.699±3.920	82.948±1.204	3.464±0.657	80.586±2.125	21.739±2.462	33.868±0.203	25.649±2.444	9.603±1.126
o,p'-DDT	BDL.	BDL.	1.094±0.183	4.095±0.389	BDL.	BDL.	0.027±0.004	BDL.	BDL.	BDL.	BDL.	BDL.	0.875±0.155
p,p'-DDT	BDL.	BDL.	6.551±0.777	4.407±0.558	BDL.	BDL.	14.023±1.900	6.028±0.135	6.028±0.135	2.975±0.011	3.071±0.120	3.852±0.185	3.326±0.486
o,p'-DDD	1.942±0.064	0.145±0.031	3.210±0.116	0.210±0.116	0.377±0.050	0.525±0.163	0.803±0.211	0.803±0.211	0.095±0.107	0.827±0.054	1.534±0.160	BDL.	BDL.
p,p'-DDD	3.090±0.170	1.770±0.297	2.544±0.532	1.495±0.092	2.515±0.657	2.995±0.049	0.728±0.042	5.528±0.556	2.070±0.127	1.105±0.021	2.110±0.084	4.677±1.068	6.321±0.694
o,p'-DDE	0.858±0.175	0.437±0.490	1.401±0.189	BDL.	BDL.	BDL.	1.19±0.028	2.535±0.629	1.395±0.233	BDL.	3.425±0.474	BDL.	0.87±0.156
p,p'-DDE	BDL.	BDL.	BDL.	3.152±0.033	1.720±0.061	2.300±0.065	2.37±0.552	5.075±0.191	4.020±0.113	0.025±0.007	0.087±0.011	BDL.	3.109±0.027

BDL = below detection limits n = 6, mean ± standard deviation dw = dry weight

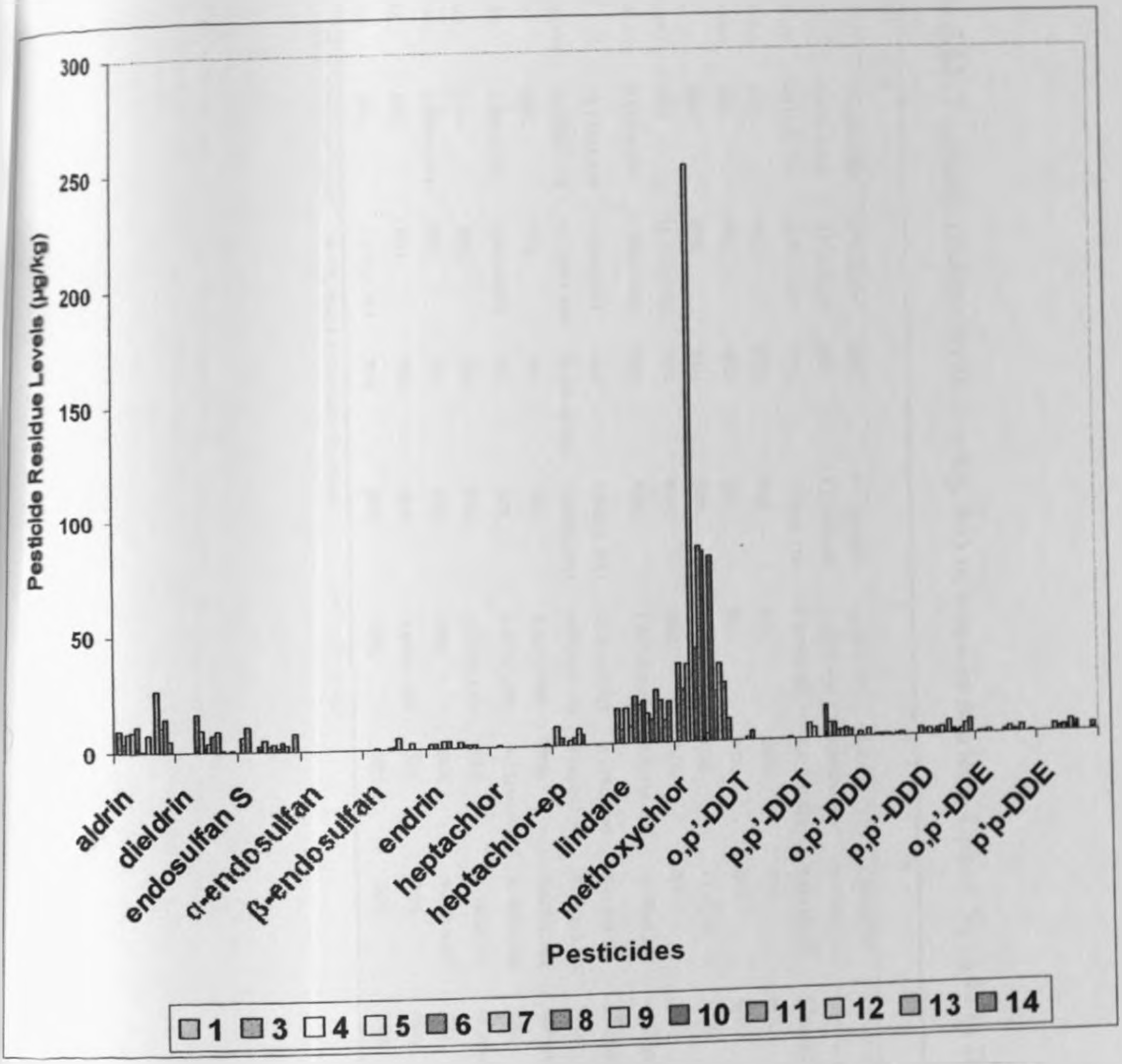

Figure 5.52: Pesticide residue levels in sediments from Kericho-Upper Nyando in December

Highest levels for methoxychlor (range 3.464±0.657-84.699±3.920 µg/kg) was recorded followed by lindane (6.023±0.073-22.895±0.595 µg/kg), aldrin (4.013±0.045-26.676±0.981 µg/kg) and dieldrin (BDL-16.534±1.991µg/kg) in sediment samples from Kericho-Upper Nyando in December. For weed samples (Table 5.53 and Figure 5.53) methoxychlor concentration was detected highest at site 4 (96.036±5.456 µg/kg).

Table 5.53: Pesticide residue levels (µg/kg, dw) in weed in Kericho-Upper Nyando in December

Pesticides/ Sites	1	3	4	5	6	7	8	9	10	11	12	13	14
aldrin	11.439±1.449	5.730±2.377	BDL	0.122±0.001	3.922±0.170	5.370±1.733	4.569±0.787	3.876±0.975	38.457±2.062	8.258±1.468	6.561±0.294	6.463±1.313	3.132±0.416
dieldrin	2.497±0.438	12.763±1.261	BDL	2.112±0.108	7.482±0.448	3.998±0.653	11.770±1.416	11.977±1.462	BDL	BDL	2.977±0.709	BDL	5.308±0.509
endosulfan S	6.946±0.711	21.502±0.890	BDL	1.120±0.118	5.467±0.982	2.017±0.069	7.411±0.447	5.204±0.824	BDL	BDL	18.210±1.948	BDL	12.397±2.618
α-endosulfan	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
β-endosulfan	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
endrin	BDL	BDL	BDL	BDL	BDL	BDL	11.417±3.152	BDL	BDL	BDL	BDL	BDL	BDL
heptachlor	BDL	11.963±0.982	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
heptachlor-epoxide	6.147±0.125	7.899±1.004	BDL	BDL	1.641±0.280	3.521±1.359	4.551±0.207	6.663±0.106	7.513±0.817	4.799±1.167	15.489±2.541	16.543±2.264	6.889±1.557
lindane	15.145±1.419	4.431±1.737	BDL	9.841±1.410	11.841±2.343	3.439±0.749	5.624±0.268	6.667±0.763	10.781±2.345	3.822±0.422	6.396±1.441	5.883±0.479	13.660±1.741
methoxychlor	86.246±1.168	51.754±3.540	96.036±5.456	23.904±1.512	59.904±3.478	13.613±2.495	51.861±2.266	74.649±3.935	95.244±8.539	69.874±3.633	49.634±3.633	8.465±0.830	22.814±0.643
o,p'-DDT	BDL	BDL	BDL	BDL	6.020±0.031	BDL	7.617±2.504	26.894±1.349	BDL	BDL	BDL	4.623±0.902	BDL
p,p'-DDT	6.891±0.284	9.315±0.899	BDL	BDL	5.874±0.360	6.121±0.074	8.708±0.289	BDL	BDL	BDL	BDL	8.364±0.675	8.364±0.675
o,p'-DDD	BDL	BDL	BDL	BDL	17.463±2.091	BDL	4.250±0.916	10.908±1.226	BDL	BDL	BDL	8.141±0.976	1.407±0.295
p,p'-DDD	1.355±0.504	BDL	BDL	BDL	BDL	BDL	3.439±0.258	BDL	BDL	BDL	BDL	BDL	BDL
o,p'-DDE	BDL	BDL	BDL	BDL	4.636±1.000	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
p,p'-DDE	BDL	9.156±1.765	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	2.822±0.230

BDL = below detection limits   n = 6, mean ± standard deviation   dw = dry weight

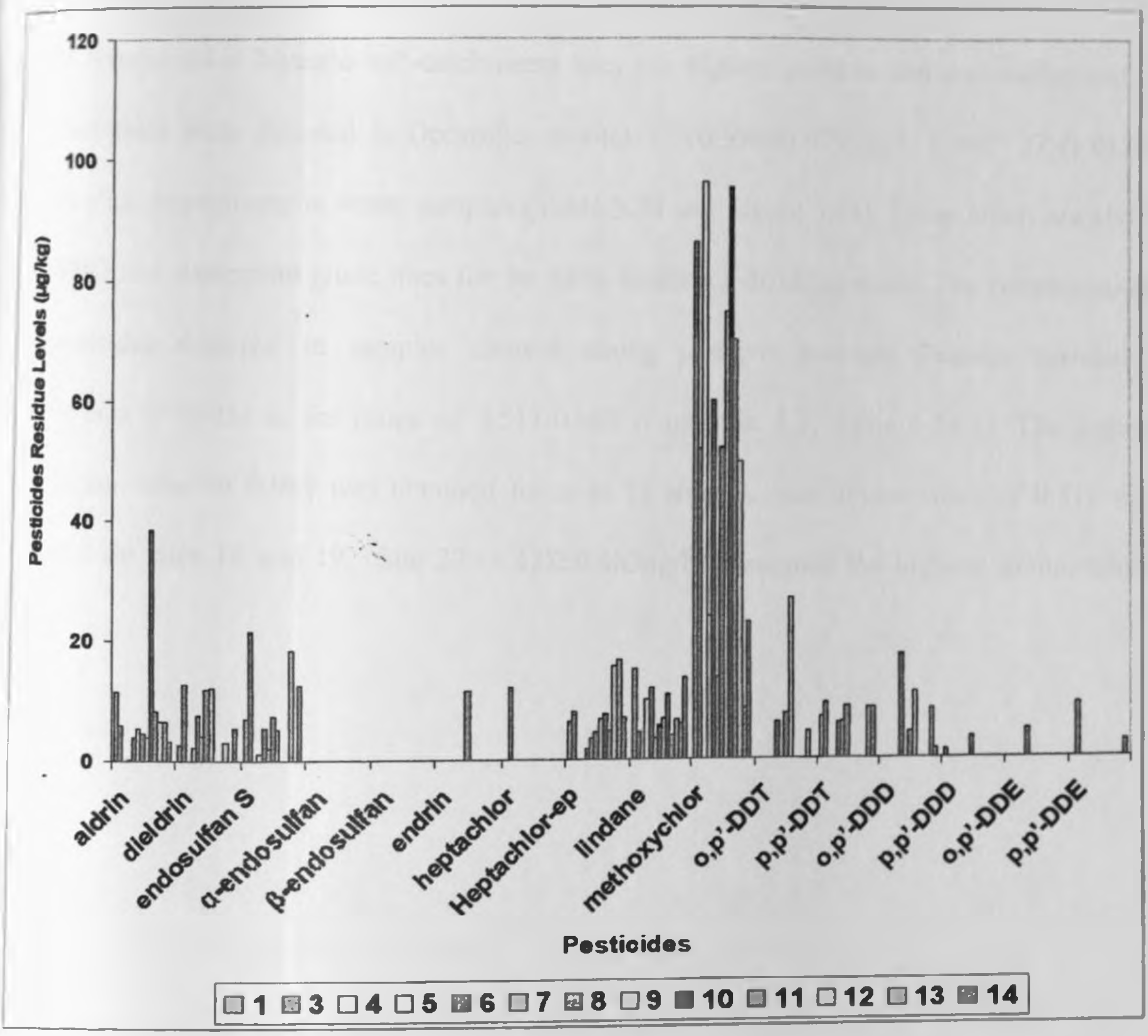

Figure 5.53: Pesticides residue levels in weed in Kericho-Upper Nyando in December

The concentrations of pesticides detected in weed samples showed strong positive bivariate Pearson correlation coefficients (P<0.05) in the range of 0.513-0.988 (Appendix 5.3, Table 5.53.1). The highest correlation value of 0.988 was obtained for sites 1 and 11, the lowest value of 0.513 was obtained for sites 7 and 13. Site 8 showed the highest number (11) of pesticide residues detected, this frequency was followed by that at site 6 which showed ten pesticide residues. Aldrin was highest at site 10 (38.457±2.062 µg/kg), dieldrin (12.763 ±1.261 µg/kg), lindane (15.145±1.419 μg/kg) and endosulfan sulfate (21.502±0.890 μg/kg) at sites 10 and 3 respectively.

In Nandi-Lower Nyando sub-catchments area the highest dieldrin and endosulfan sulfate concentrations were detected in December at sites 17 (0.596±0.079 μg/L) and 27 (1.013 ± 0.001μg/L), respectively in water samples (Table 5.54 and Figure 5.54). These levels are above the WHO and Australian giude lines for the daily intake for drinking water. The concentrations of pesticides detected in samples showed strong positive bivariate Pearson correlation coefficients ($P<0.05$) in the range of 0.511-0.989 (Appendix 5.3, Table 5.54.1). The highest correlation value of 0.989 was obtained for sites 23 and 33, the lowest value of 0.511 was obtained for sites 16 and 19. Site 27 (1.438±0.463μg/L) recorded the highest methoxychlor levels.

Table 5.54: Pesticides residue levels (µg/L) in water from Nandi-Lower Nyando in December

	15	16	17	18	19	21	22	23	25	26	27	30	33
aldrin	0.009±0.001	0.010±0.002	BDL	BDL	0.015±0.002	BDL	BDL	BDL	BDL	0.019±0.002	BDL	BDL	0.004±0.001
dieldrin	0.067±0.003	0.047±0.005	0.596±0.079	0.139±0.012	0.045±0.003	0.023±0.002	0.035±0.001	0.039±0.003	0.036±0.003	0.021±0.001	0.032±0.001	0.028±0.001	BDL
endosulfan S	0.031±0.002	BDL	0.022±0.003	BDL	0.019±0.001	0.201±0.002	BDL	BDL	0.011±0.001	BDL	1.013±0.001	0.055±0.001	0.042±0.002
α endosulfan	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.01±0.001	BDL	BDL	BDL
β endosulfan	0.021±0.001	0.030±0.002	BDL	BDL	0.031±0.002	BDL	BDL	BDL	BDL	0.034±0.002	BDL	BDL	0.031±0.002
endrin	0.034±0.005		0.059±0.004	0.029±0.008	0.032±0.004	0.014±0.004	0.021±0.002	0.011±0.001	BDL	0.010±0.001	0.025±0.003		0.116±0.009
heptachlor	0.02±0.002	0.034±0.005	BDL	BDL	BDL	0.032±0.006	0.071±0.004	0.026±0.004	BDL	0.095±0.012	BDL	0.059±0.002	0.021±0.006
heptachlor-epoxide	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
lindane	0.037±0.003	0.081±0.005	0.036±0.006		0.051±0.006	0.032±0.004	BDL	BDL	BDL	0.073±0.011	BDL	BDL	0.033±0.003
methoxychlor	1.161±0.165	0.328±0.076	0.061±0.001	0.498±0.130	0.620±0.008	0.263±0.007	0.645±0.008	1.234±0.114	0.635±0.072	3.184±0.277	1.438±0.463	0.169±0.018	0.983±0.031
o,p'-DDT	0.109±0.004	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.027±0.002	BDL	BDL	BDL
p,p'-DDT	0.029±0.008	0.498±0.059	0.032±0.004		0.167±0.612	0.039±0.004	0.038±0.007	0.073±0.008	0.046±0.008	0.045±0.005	0.035±0.005	0.064±0.004	0.048±0.004
o,p'-DDD	BDL	BDL	BDL	0.085±0.003	0.023±0.003	0.011±0.004	BDL	BDL	BDL	BDL	BDL	BDL	BDL
p,p'-DDD	0.979±0.012	0.640±0.014	0.069±0.006	0.016±0.004	0.091±0.006	0.275±0.064	0.14±0.028	0.035±0.007	BDL	BDL	BDL	BDL	0.084±0.008
o,p'-DDE	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.022±0.001
p,p'-DDE	0.038±0.005	0.017±0.001	0.026±0.004		0.035±0.001	0.042±0.004	0.255±0.064	BDL	0.009±0.001	BDL	BDL	BDL	0.076±0.003

BDL = below detection limits   n = 6, mean ± standard deviation

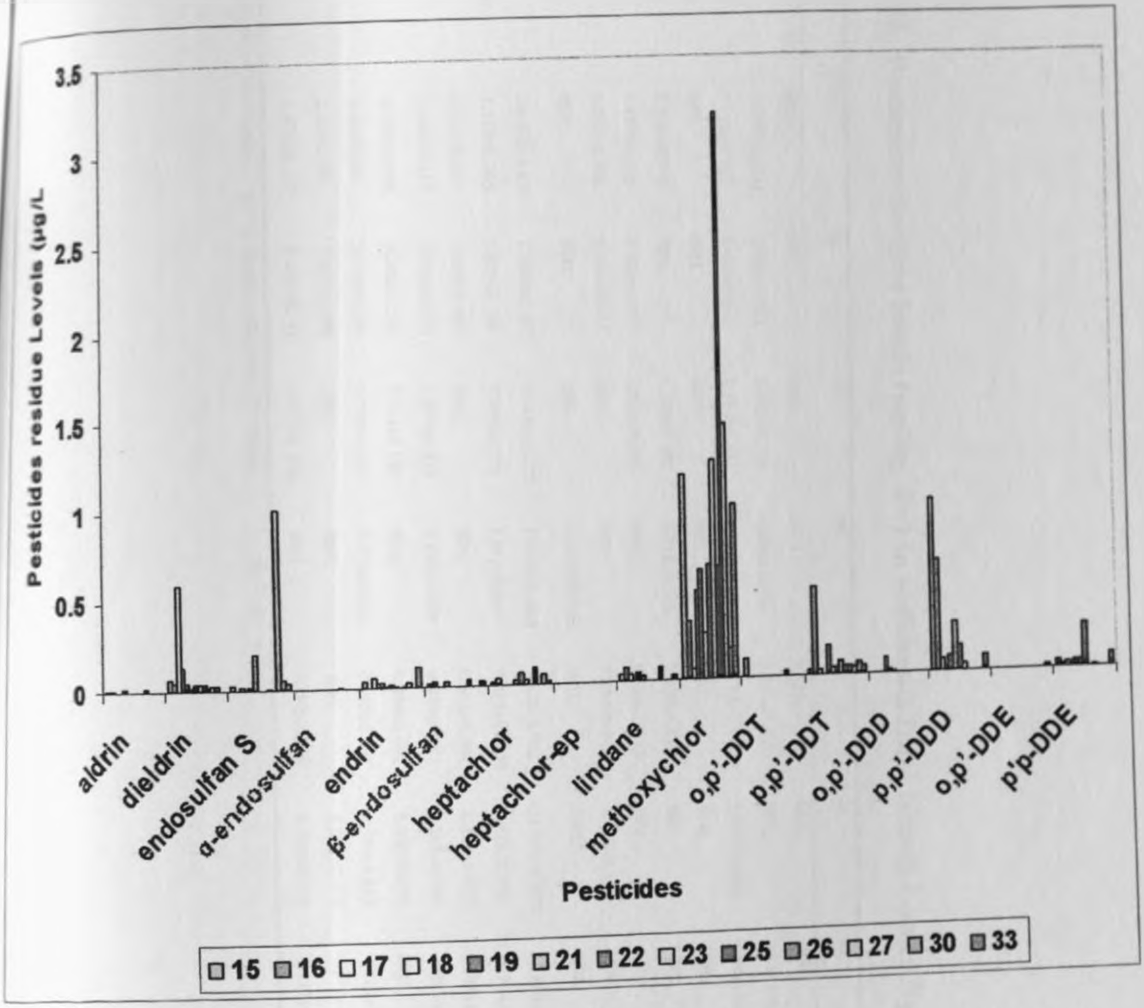

Figure 5.54: Pesticides residue levels in water from Nandi-Lower Nyando in December

For sediment samples, aldrin was detected in most samples (Table 5.55 and Figure 5.55). Aldrin was highest at site 30 (11.883±1.074 µg/kg) in Nandi-Lower Nyando. The concentrations of pesticides detected in sediment samples showed strong positive bivariate Pearson correlation coefficients ($P<0.05$) in the range of 0.536-0.984 (Appendix 5.3, Table 5.55.1). The highest correlation value of 0.984 was obtained for sites 17 and 27, the lowest value of 0.536 was obtained for sites 19 and 30.

Table 5.55: Pesticides residue levels (µg/kg, dw) in sediments from Nandi-Lower Nyando in December

Pesticides/ Sites	15	16	17	18	19	21	22	23	25	26	27	30	33
aldrin	BDL	BDL	BDL	BDL	3.027±0.183	BDL	BDL	0.913±0.087	BDL	0.964±0.032	BDL	11.883±11.074	8.968±0.046
dieldrin	18.297±0.531	5.968±0.221	3.041±0.178	0.892±0.028	7.367±0.643	BDL	18.625±0.685	8.733±0.547	0.817±0.079	0.184±0.024	0.071±0.029	6.88±0.339	9.635±0.658
endosulfan S	2.616±0.967	2.588±0.597	2.184±0.233	2.552±0.387	3.713±0.712	1.987±0.064	0.860±0.171	2.488±0.150	0.047±0.013	2.832±0.367	1.432±0.442	BDL	13.370±2.062
α-endosulfan	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
β-endosulfan	0.366±0.078	BDL	2.330±0.492	0.018±0.008	7.258±0.545	BDL	BDL	BDL	0.381±0.100	0.648±0.164	1.732±0.238	BDL	1.270±0.255
endrin	1.677±0.631	2.312±0.393	1.323±0.282	BDL	0.154±0.043	BDL	BDL	1.073±0.152	BDL	0.181±0.069	BDL	BDL	2.237±0.302
heptachlor	2.299±0.406	0.168±0.064	BDL	BDL	0.294±0.069	2.029±0.104	BDL	BDL	BDL	1.041±0.123	BDL	BDL	3.027±0.085
Heptachlor-epoxide	BDL	BDL	BDL	14.540±0.916	BDL	BDL	BDL	8.965±1.195	BDL	BDL	BDL	0.830±0.222	2.654±0.462
lindane	16.442±3.670	27.888±1.053	19.436±2.257	17.386±1.064	7.578±1.722	21.596±0.870	22.489±0.816	33.917±2.360	26.677±2.199	8.303±1.668	15.030±1.537	6.017±0.014	21.050±6.925
methoxychlor	2.513±0.265	5.629±0.588	7.499±0.772	3.371±0.507	7.517±11.479	2.526±0.690	17.604±2.250	36.871±4.189	3.310±0.621	9.484±0.184	6.169±1.057	46.093±4.243	45.629±2.769
o,p'-DDT	0.116±0.010	1.885±0.064	BDL	BDL	0.893±0.089	0.316±0.037	0.105±0.021	BDL	BDL	BDL	BDL	BDL	1.168±0.104
p,p'-DDT	3.980±0.011	3.192±0.370	1.827±0.038	2.470±0.693	0.876±0.157	6.283±0.709	4.397±0.707	2.913±0.095	1.235±0.148	0.887±0.142	0.287±0.078	3.278±0.218	2.697±0.284
o,p'-DDD	0.028±0.006	0.308±0.343	0.111±0.140	BDL	0.499±0.091	0.930±0.076	BDL	BDL	4.390±0.575	0.402±0.008	BDL	BDL	0.900±0.029
p,p'-DDD	3.32±0.283	3.725±0.276	1.735±0.247	0.702±0.072	0.865±0.104	3.354±0.803	3.023±0.134	1.101±0.016	0.817±0.204	1.640±0.463	0.070±0.004	1.112±0.209	5.363±0.777
o,p'-DDE	2.31±0.198	2.310±0.198	BDL	BDL	BDL	1.605±0.474	0.816±0.038	BDL	BDL	1.040±0.071	BDL	0.830±0.069	9.221±0.918
p,p'-DDE	0.876±0.127	1.330±0.141	0.850±0.156	BDL	0.082±0.008	1.078±0.016	0.942±0.064	BDL	BDL	0.685±0.092	BDL	0.285±0.078	13.554±0.801

BDL = below detection limits   n = 6, mean ± standard deviation   dw = dry weight

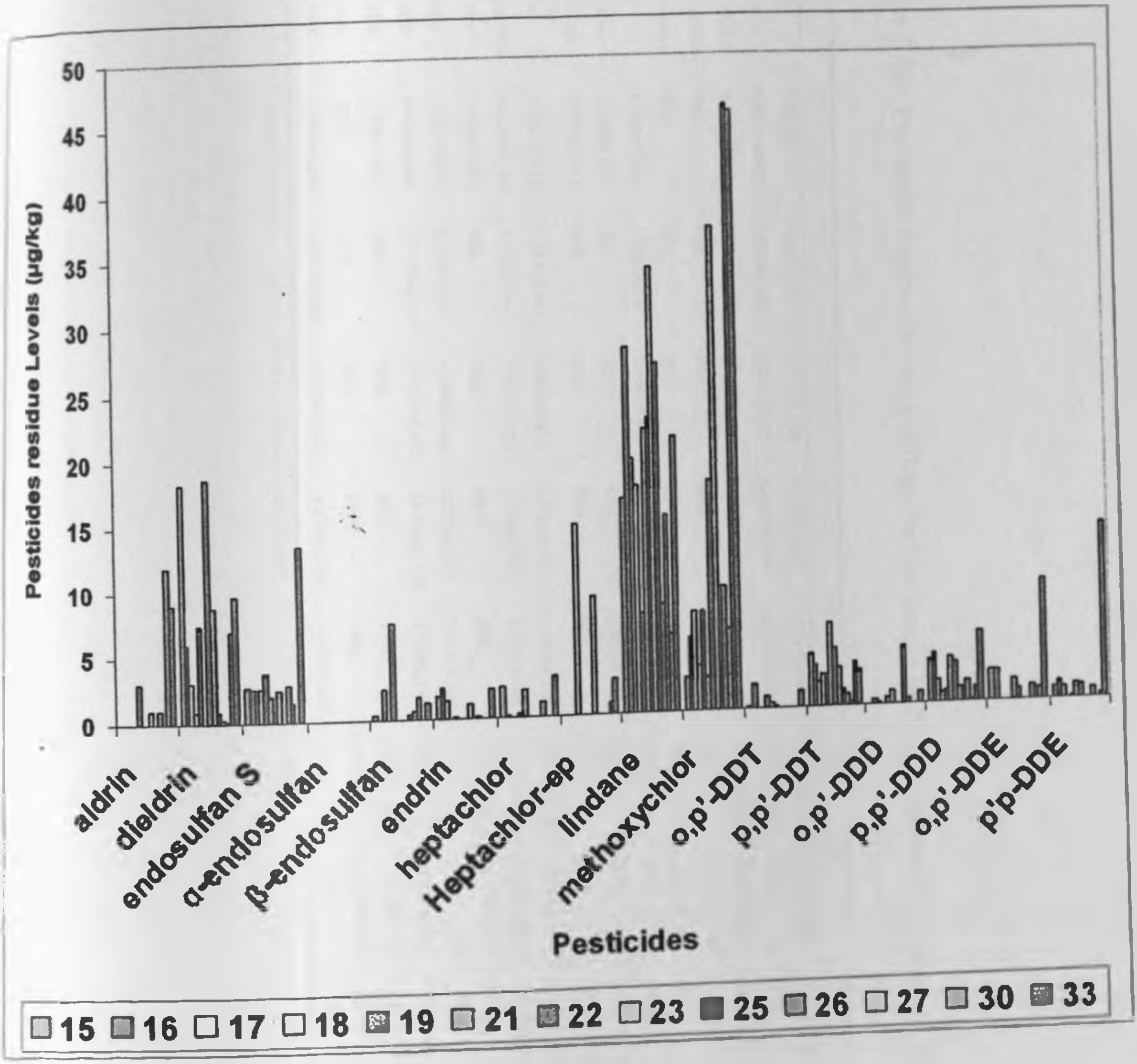

Figure 5.55: Pesticides residue levels in sediments from Nandi-Lower Nyando in December

In sediment samples, highest levels for methoxychlor (range 2.513±0.265-46.093±4.243µg/L) was recorded followed by lindane (6.017±0.014-33.917±2.360 µg/kg), aldrin (BDL-11.883±1.074 µg/kg) and dieldrin (BDL-18.625±0.685 µg/kg). In the case of weed samples (Table 5.56 and Figure 5.56) the highest frequency (81.25%) of pesticide residues was obtained at site 15.

Table 5.56: Pesticide residue levels (µg/kg, dw) in weeds in Nandi-Lower Nyando in December

	15	16	17	18	19	21	22	23	25	26	27	30	33
aldrin	3.067±0.014	2.140±0.417	1.996±0.145	4.276±0.020	2.116±0.148	3.067±0.014	7.917±1.409	7.095±1.237	BDL	4.936±3.875	3.333±0.190	BDL	7.135±0.269
dieldrin	6.114±1.911	3.093±0.194	7.102±0.072	4.116±0.315	3.009±0.104	6.178±1.201	BDL	BDL	4.630±0.357	BDL	15.052±0.528	BDL	BDL
endosulfan S	4.970±0.412	BDL	BDL	BDL	BDL	1.970±0.112	1.567±0.314	8.140±0.417	4.996±0.453	6.276±0.920	2.516±0.348	10.018±1.407	BDL
α-endosulfan	BDL	BDL	BDL	BDL	BDL	BDL	66.149±1.589	17.793±2.947	27.029±5.972	54.116±7.315	37.389±3.848	BDL	BDL
β-endosulfan	BDL	BDL	BDL	BDL	BDL	BDL	4.970±0.412	BDL	BDL	BDL	BDL	BDL	BDL
endrin	1.567±0.314	3.940±0.141	1.906±0.410	5.127±0.192	3.151±0.134	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
heptachlor	1.290±0.089	BDL	BDL	BDL	0.389±0.048	BDL	BDL	6.105±0.170	7.066±0.227	BDL	BDL	BDL	BDL
Heptachlor -epoxide	4.970±0.412	BDL	BDL	BDL	BDL	BDL	BDL	37.664±6.635	15.090±2.193	7.153±1.773	13.095±0.934	BDL	7.779±0.481
lindane	3.356±0.131	1.314±0.141	4.996±0.453	6.276±0.920	2.516±0.348	1.067±0.014	1.567±0.314	8.140±0.417	4.996±0.453	6.276±0.920	2.516±0.348	3.821±0.384	31.539±2.313
methoxychlor	42.219±1.309	7.793±2.947	7.029±1..972	5.116±0.015	3.039±0.848	6.614±1.689	6.149±1.589	17.793±2.947	27.029±5.972	54.116±7.315	37.389±3.848	31.384±1.317	44.908±1 502
o,p'-DDT	0.970±0.014	BDL	BDL	BDL	BDL	4.970±0.412	4.970±0.412	BDL	BDL	BDL	BDL	3.084±0.141	BDL
p,p'-DDT	3.987±0.835	8.140±0.417	4.996±0.453	6.276±0.920	2.516±0.348	BDL	BDL	BDL	17.069±0.117	BDL	16.454±0.791	3.714±0.879	BDL
o,p'-DDD	0.049±0.005	17.793±2.947	27.029±5.972	54.116±7.315	37.389±3.848	BDL	1.567±0.314	8.140±0.417	4.996±0.453	6.276±0.920	2.516±0.348	5.467±1 697	BDL
p,p'-DDD	2.13±0.196	BDL	BDL	BDL	BDL	BDL	66.149±1.589	17.793±2.947	27.029±5.972	54.116±7.315	37.389±3.848	BDL	BDL
o,p'-DDE	BDL	BDL	BDL	BDL	BDL	BDL	4.970±0.412	BDL	BDL	BDL	BDL	BDL	BDL
p,p'-DDE	3.743±0.210	1.414±0.042	2.106±0.103	1.276±0.192	1.351±0.238	BDL	BDL	BDL	BDL	BDL	BDL	BDL	8.244±0.348

BDL = below detection limits   n = 6. mean ± standard deviation   dw = dry weight

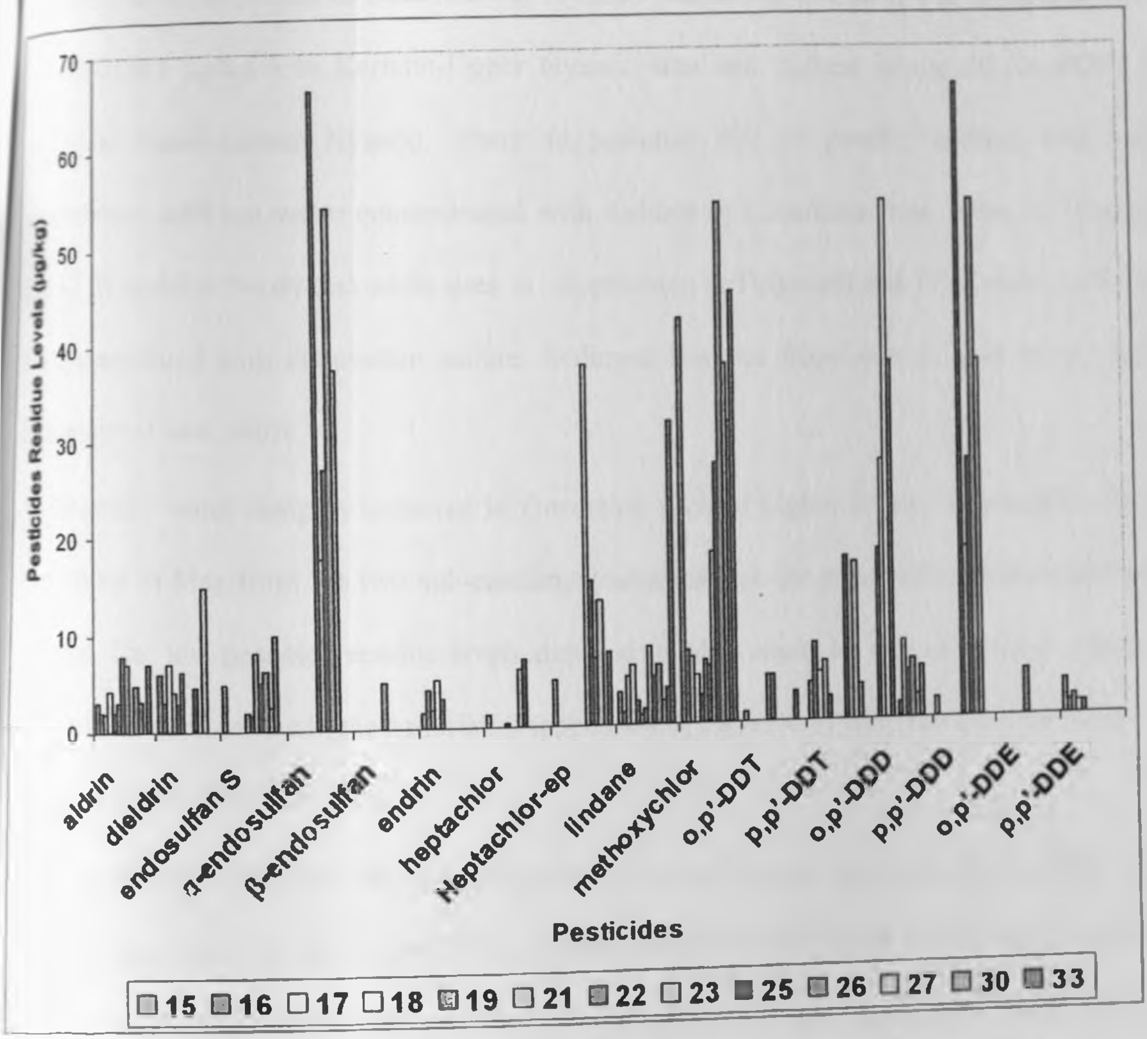

Figure 5.56: Pesticide residue levels in weeds in Nandi-Lower Nyando in December

The concentrations of pesticides detected in the weed samples in December showed strong positive bivariate Pearson correlation coefficients ($P<0.05$) in the range of 0.566-0.997 (Appendix 5.3, Table 5.56.1). The highest correlation value of 0.997 was obtained for sites 18 and 19, the lowest value of 0.566 was obtained for sites 21 and 30. The highest concentration in Nandi-Lower Nyando in December was obtained for methoxychlor (44.908±1.502 µg/kg) at site 33, this magnitude was followed by dieldrin (15.052±0.528 µg/kg) at site 27.

For sediment samples, aldrin was detected in more samples in December in the Kericho-Upper Nyando (Table 5.52) than in Nandi-Lower Nyando (Table 5.55). Aldrin was highest at site 11 (26.676±0.981 μg/kg) in Kericho-Upper Nyando area and highest at site 30 (11.883±1.074 μg/kg) in Nandi-Lower Nyando. There is potential risk of people, animals and macro invertebrates drinking water contaminated with dieldrin in December from sites 12 (Pararget) and 17 (Nyando at the dykes) while sites 6 (Kipchorian at Tuiyobei) and 27 (Kundos at Bridge) are contaminated with endosulfan sulfate. Sediment samples from sites 11 and 30 are highly contaminated with aldrin

Generally water samples collected in December showed higher levels of pesticide residues than those in May from the two sub-catchment areas as was the case with sediment and weed samples. The low pesticide residue levels detected in May could be due to dilution effects on pollutants in rivers, since highest rainfall (Appendix 4.0, Figure 4.5) were recorded for the month of May in 2004, 2005 and 2006.

The pooled results show that various environs of River Nyando are contaminated with the 16 different organochlorine pesticides (OCP) including their metabolites but at different distribution levels. Besides, the analyses showed that OC pesticides and their metabolites were generally found in sediment, weeds and soil than in water. Organochlorine pesticides with their high hydrophobic chemical properties occur as contaminants in water systems partitioned between water, living and dead materials with the greatest affinity for the high carbon solids. The River Nyando and its tributaries are increasingly becoming contaminated with methoxychlor, dieldrin and endosulfan sulfate from the agricultural activities. Pesticides concentrations detected in soil samples from the agricultural areas (section 4.1.1) were generally higher than those in water. Dieldrin, β-endosulfan, endosulfan sulfate, lindane and methoxyhlor were found at higher levels in soil samples. Meythoxychlor, dieldrin, aldrin, lindane, endosulfan sulfate, are the major predominant pollutants in all matrices analysed. This study reveals that these compounds although banned by the Kenya Government and have not been legally imported since 1986 (PCPB, 1992) find their way into the River Nyando drainage basin. The results of analysis of samples from the different locations within the two sub-catchment areas, show that the occurance and concentrations of organochlorines varied among seasons and sites. In December the concentrations of the OC in water samples were generally higher than other sampling periods (February, May and September) in both years especially for dieldrin, methoxychlor, endosulfan sulfate, lindane and heptachlor. Site 16 showed the highest lindane concentration (0.081±0.005 µg/L) and dieldrin at site 17 (0.596±0.079 µg/L) in December, heptachlor was highest at site 17 (0.508±0.080 µg/L) and endosulfan sulfate at site 26 (1.558±0.166 µg/L) in September. This shows that the river does not have effective self cleaning capacity downstream at sites 16 and 17.

In this study it was established that aldrin had higher concentrations than its converted product, dieldrin in sediment samples. The residue levels of methoxychlor, dieldrin and endosulfan sulfate seem to be in very high proportions. This result could suggest a recent use of OC pesticides in the study area plus other environmental factors such as temperatures atmospheric deposition which may come onto play. In sediment samples p,p'-DDE was found at higher concentrations than p,p'-DDT and p,p'-DDD. Lindane was observed mostly in water samples collected in December and February but not afterwards. Most pesticide residue levels were below the WHO, USA-EPA, Australian guidelines for drinking water except for dieldrin, endosulfan sulfate, lindane and heptachlor in some instances. This confirms the fact that these compounds may be in use in vegetables, coffee and tea farms in December. Even if the other compounds are present only in very low concentrations in water, they are hazardous because some species of aquatic life are known to concentrate them 1000-folds or more (Murly 1985). The OC pesticides in water and sediment samples from various sites were generally lower than those detected in other rivers studied in Kenya (Madadi 2005, Wandiga *et al.*, 1999), though the sites under study are located in wide agricultural areas along the Nyando drainage basin. This may be due to stringent measure on the international residue limits requirements in food, drinking water supplies as well as export products such as fish, fruits and horticultural produce and the recent ban and restrictions impossed on these pesticides by the Kenyan authority after being party to the stockholm convention on 24th September, 2004.

Pesticide residues were detected at all studied sites. They were found in streams where no agricultural activites or human settlements are present upstream from the sampling sites (reference site 30), indicating that some pesticides are deposited along the drainage basin after aerial transport. The possible sources are the Nandi and Kericho highlands and the Kano plains where agricultural activities are intensive and are close to the tributatries of River Nyando where relatively large tea, sugar cane, coffee, maize, vegetables and rice farms are located. However local use of pesticides in subsistence agriculture and for control of vector borne diseases in small villages should not be disregarded.

CHAPTER SIX

6.0 Benthic macroinvertebrate of River Nyando

6.1 Benthic Macroinvertebrates as an Indicator of Pollution

Microinvertebrates or Zooplanktons are microscopic organisms up to 2 mm-body length. The group also includes the protozoan. Macroinvertebrates are that part of the invertebrates group, which are retained by a mesh size of between 200 µm and 500 µm (Rosenberg and Resh, 1993). There are at least 28 different phyla of invertebrates, six of which are found in stream and rivers (Quigley, 1977). These are porifera, Coelenterata, Platyhelminthes, Annelida, Anthropoda and Mollusca. Porifera and Coelenterata are poorly represented in fresh water compared to the other groups. Most texa are associated with bottom substrate (sediments, debris, logs, macrophytes, and filamentous algae) of fresh water habitats for at least part of their life cycle and are mainly referred to as benthic macroinvertebrates (Rosenberg and Resh, 1993). Others are either associated with vegetation along the shores and littoral zones (Macro-littoral invertebrates) or are free swimming in littoral or off shore (macro-pelagic invertebrates). Some texa of medium size are also referred to as macroinvertebrates (small metazoans, nematodes, rotifers and small crustaceans). In streams and rivers, benthic macroinvertebrates are dominated by insects (Paayne, 1986; Welch, 1992)

Benthic macroinvertabrates are linked in the aquatic food chain. In most aquatic environments the energy stored by plants is available to animal life either in the form of leaves that fall in the water or in the form of algae that grow at the bottom. The algae and leaves are eaten by macroinvertabrates. The macroinvertabrates are sources of energy for the larger animals such as fish which in turn are a source of energy for birds, water snakes and even man. The benthic macroinvertabrates differ in their sensitivity to water pollution. Some cannot survive in polluted water while others can thrive in polluted water. In a healthy aquatic environment the benthic community will include a variety of pollution-sensitive macroinvertebrates while only a few types of non sensitive may be present in unhealthy environment. Benthic macroinvertabrates can therefore provide information about the quality of the water body over a long period of time. It may be difficult to identify pollution with water analysis, which can only provide information for the time of sampling. Even the presence of fish may not provide information about pollution problem because fish can move away to avoid polluted water and then return when conditions improve. However most benthic macroinvertebrates cannot move to avoid pollution. Macroinvertebrates samples may thus provide information about pollution that is not present at the time of sample collection (Kruegar *et al.*, 2003).

Mwangi (2000) noted that the fauna of most East African streams have been scarcely studied and little published literature exists on their composition, distribution and diversity. This is particularly true for polluted streams. Kinyua and Pacini (1991) reported the presence of only a few numbers of oligochates and chironmids in the anoxic section of Nairobi River in Kenya. Trichoptera and Simuliidae were present at the upper reaches of the river. Barnard and Biggs (1988) studied the macroinvertebrates in Lake Naivasha Catchment streams and found ten (10) Orders with the dominant ones being Ephemeroptera, Trichoptera and Diptera.

6.1.1 Biological Monitoring

The response of biological communities or of the individual organism's artificial change can be monitored in a variety of ways to indicate the effects on the ecosystem (Champman, 1992). In water quality assessment, knowledge of the relative tolerance of organisms present is usually combined with a numerical expression of community structure or indicator organism

Welch, 1992). For instance large numbers of *Tubifex* indicate gross organic pollution (Welch, 1992). Mason (1991) pointed out that the absence of a particular species or group from a river may be indicative of pollution because not all reaches are suitable for them. The degree of change in community structure may be used to assess the intensity of environmental stress (Ellis, 1989). The Shannon-Weiner Diversity Index (Shannon, 1948) is widely used in biological monitoring. It combines data on species or texa richness with data on individual abundance (Bartram and Balance, 1996). The number of species or texa indicates diversity of the ecosystem while the distribution of individual organisms between sites indicates evenness. The general assumption in the use of diversity indices is that as pollution increases diversity decreases (UNEP, 1992). However, this is true in certain cases but is not universal.

Macroinvertebrates are good indicators of watershed health because they live in water for all or most of their lives and differ in their tolerance to amount and types of pollution/habitat alteration. The presence and numbers of different types of benthic macroinvertebrates provides accurate information about the health of a stream and watershed. It is the objective of the Environmental Management and Water Acts-to "restore and maintain the chemical, physical and biological integrity of the Nation's waters". Biological integrity of any ecosystem is commonly defined as "the ability to support and maintain a balanced, integrated, and adaptive community of organisms having a species composition, diversity and functional organization camparable to those of natural habitats within a region" (Karr J.R and D.R. Dudley, 1981). The purpose of this study was to provide bioassessment of the benthic macroinvertebrate assemblage for the River Nyando reaches for a period of two years which would be used as an indicator of biological integrity and the river environmental health and by extension may be adopted for other riverine tropical ecosystems.

To study the influence of abiotic environmental variables on the biotic composition of ecosystem, multivariate analytical techniques have been used for many years in ecology (Legendre and Legendre, 1998). Community composition differences between sampled sites are analysed in relation to measured or observed variables such as altitude, river discharge, turbidity, pH, habitat quality and dissolved oxygen. In particular ordination has proved to be useful technique for this purpose because it results in a diagram (biplot or triple plot) displaying both the sites and the species and if measured, the environmental variables in reduced space (Ter Braak, 1995). It therefore enables one to evaluate differences in species composition between sites and to identify the environmental variables responsible for these differences in a single analysis. This property of ordination is the main advantage over other multivariate techniques such as, for instance, clustering and similarity analyses. Ordination techniques are capable of summarising very complex responses because they are not restricted to a single dimension. When an ordination technique is combined with Monte Carlo permutation testing not only graphical summary of the structure present in the data set is obtained, but also the statistical significance of the hypothesised difference (Ter Braak & Šmilauer, 2002). Samples and species are represented in a diagram by points (or arrows) plotted at the scores (values) they have. Samples with nearly identical species composition lie close together in the diagram, while samples that lie far apart have very different species composition. In biplots arrows (for species or environmental variables) point in the direction of higher values.

Recently the Lake Victoria has been experiencing progressive decline in fish catch and loss of biodiversity. The decline could be associated with a number of reasons one of them being eutrophication arising from nutrient enrichment through increased inflow from the rivers draining into the lake phosphorus and nitrogen that has resulted into algal growth (ICRAF, 2000;

LVEM, 2003). The organic pollution causes deoxygenation of much of the lake's bottom threatening the survival of fish species and the invertebrate organisms. Assessment of the current occurrence and distribution of macroinvertebrates in River Nyando which is one of the major drainage to Lake Victoria could be important for assessing the pollution status of the Nyando Basin. The studies of invertebrates' occurrence in the Kenya side of Lake Victoria and its waterways have not been done despite their ecological importance with respect to energy flow and fish production.

6.2. Data Analysis

Macroinvertebrate counts collected from the sediments were analyzed to obtain average number of organisms per square meter (m^2) and the percentage composition of each taxonomic group in the two sub-catchment areas. The mean values of the measured physical and chemical parameters were calculated and correlated with the occurrence, abundance and distribution of the benthic macroinvertabrates for the two years. The data were presented in terms of differences in faunal occurrence (order and species) and the required information on composition, diversity, densities and distribution of species in the sub-catchment areas were obtained. Part of the data on macro invertebrates collected were analysed at Alterra, Centre for Water and Climate, Wageningen University, Netherlands, using statistical program CANOCO for Windows Version 4.5 (Ter Braak & Šmilauer, 2002). Correlation tests were performed to determine the relationship between independent variables (pH, DO, water temperature, TSS, altitude, discharge, areas and widths of the rivers, pesticide residues, TP and TN concentrations) and the dependant variables (total number of individual macro invertebrate organisms).

6.3 Results and Discussion

The species collected were identified into four phyla namely Arthropoda, Mullusca, Platyhelminthes and Annelida. The Arthropoda (insects) dominated the catch and were mainly larvae, nymphs and pupae of insects which include mayflies (*Baetis spp* and Caenidae), stoneflies, caddisflies (Limnephilidae), damselflies (Zygoptera), dragonflies (Anisoptera), mosquitoes (Culicid*a*e), water snipe fly (*Atherix spp.*), water bug (Corixidae), water penny (*Pseupharus spp.*) and riffle beetles (Hydrophilda). These were again classified into seven orders i.e. Ephemeriptera (mayflies), Plecopetera (stoneflies), Trichoptera (caddisflies), Odonata (dragonflies and damselflies), Coleoptera (water beetles and water penny), Diptera (Mosquitoes and water snipeflies), Hemiptera (water bug), Neuroptera (spongillaflies). For the phylum Mollusca was presented by the order Bivalves (clams), the Annelida were represented by the aquatic worms (oligochaetes) and Hirudinae (leeches). Acariformes (water mites) were also present.

6.3.1 Diversity/Abundance and Distribution

Tables 6.11, 6.12, 6.21 and 6.22 show the number of macroinvertebrates taxonomic grouping (diversity and order) found in Nyando catchment area. A diversity of sixteen (16) families was recorded from each of the two sub-catchment area in 2005 and 2006. The families identified belong to the orders Ephemeroptera which had two (2) families, Odonata (2), Diptera (2), Cleoptera (2) and Trichoptera, Hirudinae, Oligochaeta, Bivalve, Hemiptera, Plecoptera, Acariform, and Neuroptera had one each. The number of macroinvertebrate orders found in this study was higher than that found in other rivers which have been studied in Kenya. A total of ven orders were identified as compared to ten previously found by Barnard and Biggs (1988) in Lake Naivasha catchment streams and eight in Sagana River by Mwangi (2000). Two families in the order Diptera were found in this study as compared to six and three reported in River atharaini (Ndaruga, 1998) and Lake Naivasha catchment streams (Barnard and Biggs, 1988) espectively.

Tables 6.11 and 6.12 show the family diversity in Kericho-Upper Nyando catchment area in 2005 and 2006 respectively. Sites 1 (Kedowa at Bridge) and 14 (Nyando at Muhoroni Bridge) had the highest number (13) of species diversity followed by sites 6 (Kipchorian at Tuiyobei) and 12 (Pararget) which had a diversity of 12 species each. Sites 4 (Masaita at Londiani), 7 (Kimoson) and 8 (Nyando at Kipkelion) had the lowest diversity (7). This may be attributed to pollution at those sites. Site 4 receives raw domestic sewage directly from Londiani Township while sites 7 and 8 receive rain run off laden with agrochemicals from maize, cabbage, kales and potatoes farms in Kipkelion Division.

In Nandi-Lower Nyando area (Tables 6.21 and 6.22), sites 27 (Kundos at Bridge) shows the highest diversity (13) followed by sites 23 (Ainopngetuny) and 25 (Chemwanabei) with diversity of 12 families each. These three sites are at the upper reaches of the Nandi-Lower Nyando sub-catchment area. Sites 16 (Nyando at Ahero Bridge), 17 (Nyando at Dykes), 18 (Awach Kano at Bridge) and 33 (Ahero Irrigation Channel) which are at the lower reaches of River Nyando had the lowest diversities (i.e. 0, 0, 4 and 4) in 2005 and (2, 0, 4 and 4) in 2006. Sites 16 and 17 receive raw domestic sewage from Ahero Town while sites 18 and 33 are served with water from rice growing areas where agrochemicals are intensively used. Kericho-Upper Nyando sub-catchment area shows more species diversity than the Nandi-Lower Nyando as the species diversities show decreasing trend downstream with the last station (site 17) having no macroinvertabrate species in 2005 and 2006. Most macroinvertebrates disappeared downstream site 15 (Nyando at Ogilo bridge). Oligochaetes and leeches were the main invertebrates found beyond this sampling site.

6.3.2 Density and Distribution

Tables 6.31, 6.32, 6.41 and 6.42 show the density and the distribution of macro invertabrate species in the two sub-catchment areas in 2005 and 2006. In Kericho-Upper Nyando sub-catchment area (Tables 6.31 and 6.32), site 1 had the highest density of macro invertebrates (478/m^2 and 499/m^2) in 2005 and 2006 respectively. This was followed by site 6 with 447/m^2 and 431/m^2 respectively. In site 1, the order Ephemeroptera had the highest density followed by Plecoptera. These were mainly nymphs of mayflies (Baetidae, 188/m^2, 195/m^2 and Caenidae, 49/m^2, 30/m^2) and stoneflies (63/m^2, 59/m^2,) in 2005 and 2006 respectively. Site 4 was the only station which did not have the nymphs of mayflies. This could be attributed to direct discharge of raw domestic sewage from Londiani Township into the river at site 4.

In Nandi-Lower Nyando sub-catchment area (Tables 6.41 and 6.42), site 25 had the highest density (494/m^2 and 316/m^2) of macroinvertebrate species in 2005 and 2006 followed by site 33 which had densities of 331/m^2 and 309/m^2 respectively. At these two sites, the dominant orders were Ephemeroptera (Baetidae, 99/m^2 and 90/m^2) and Hirudinae (leeches, 159/m^2 and158/m^2) respectively. Clam (*Corbicule sp.*, 1/m^2) and oligochaeta (7/m^2) were the only macroinvertebrate species found at site 16 in 2005 but the same organisms were completely absent in 2006. Oligochaeta are invertebrates that are tolerant to pollution. There were no macroinvertebrate species collected from sampling site 17 (Nyando at the Dykes, 5km downstream Ahero Town) in 2005 and 2006. The Kericho-Upper Nyando had the highest density of macroinvertebrate species than the Nandi-Lower Nyando sub-catchment area. In River Nyando no single family of the macroinvertebrate organisms was represented in all the sampled sites in 2005 and 2006.

In Kericho-Upper Nyando sub-catchment area, the orders Hemiptera (Corixidae), Coleoptera (Hydrophilidae) and Acariform (water mite) were present in all the sampling sites but were absent in some sites in Nandi-Lower Nyando sub-catchment area. All pollution sensitive macroinvertebrates disappeared downstream site 15 (Nyando at Ogilo bridge). The orders Ephemeroptera (Baetidea and Caenidae), Hemiptera (Corixidae), Plecoptera (Stone flies) and Tricoptera (Limnephilidae) were mostly found in the upper site of the River Nyando. The Oligochaeta were found in both the upper and the middle sections of the river while the Hirudinae (Leeches) were mainly restricted to rice growing areas, sites 18 and 33 which are at the lower reaches of the river.

6.3.3 Taxonomic Composition

Percentage taxonomic compositions (Tables 6.51, 6.52, 6.61 and 6.62) by number of benthic macroinvertebrates collected were obtained from Tables 6.31, 6.32, 6.41 and 6.42. These datas are summarized in Figures 6.11, 6.12, 6.21 and 6.22 respectively. From Figures 6.11 and 6.12, the order Ephemeroptera (nymphs of mayflies) was dominant and contributed 74 % and 70 % of total macroinvertebrates found at site 10 in 2005 and 2006 respectively followed by Tricoptera (20 % and 25 %) at site 8 and Plecoptera (16.2 % and 18 %) at site 9 respectively. The order Hirudinae (leeches) was the only macroinvertebrate organisms not found in Kericho-Upper Nyando area. The order Neuroptera was only found at site 5 (Masaita at Lambel farm) and contributed 2.6% and 2.3% of the total macroinvertabrates organisms in that site in 2005 and 2006 respectively.

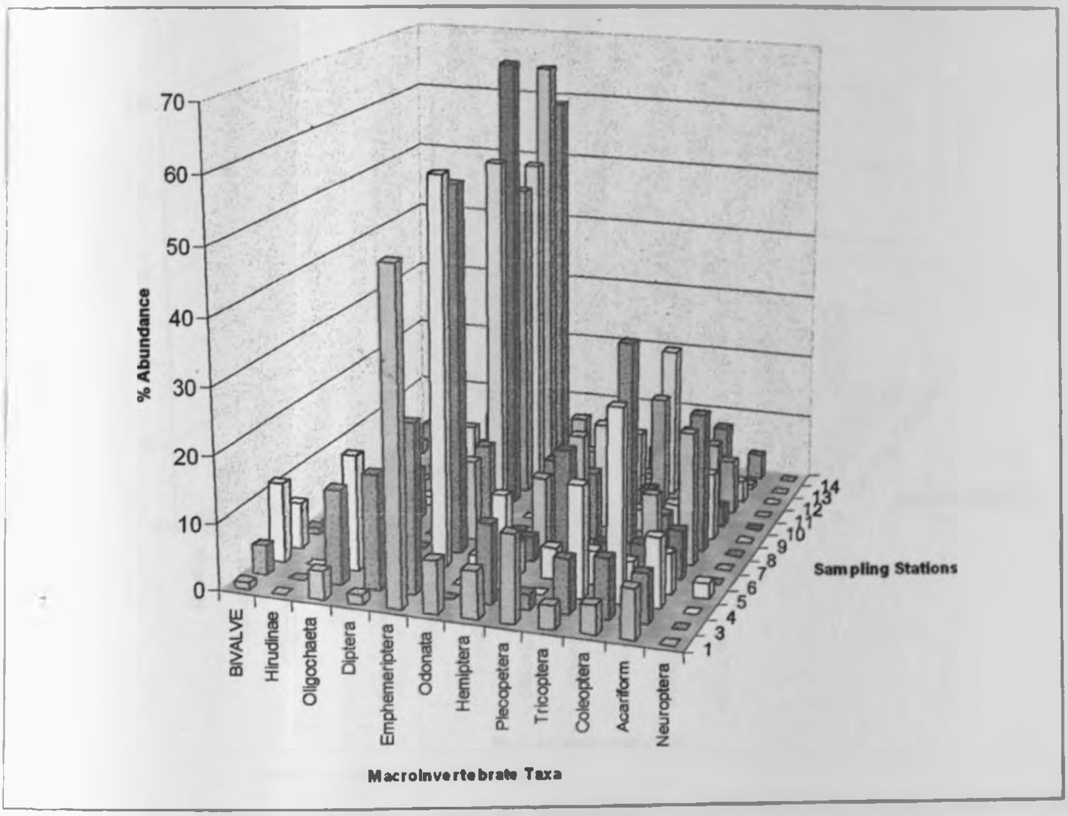

Figure 6.11: Macro invertebrate taxonomic grouping in Kericho-Upper Nyando in 2005

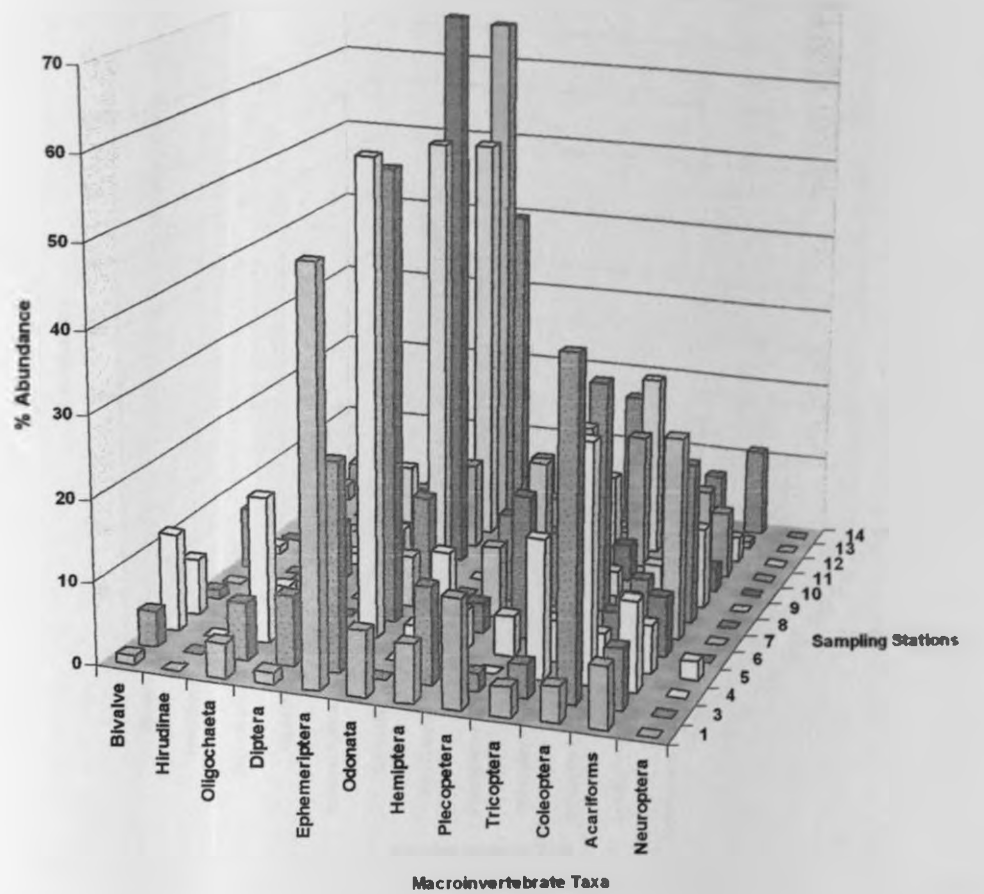

Figure 6.12: Macro invertebrate taxonomic grouping in Kericho-Upper Nyando in 2006

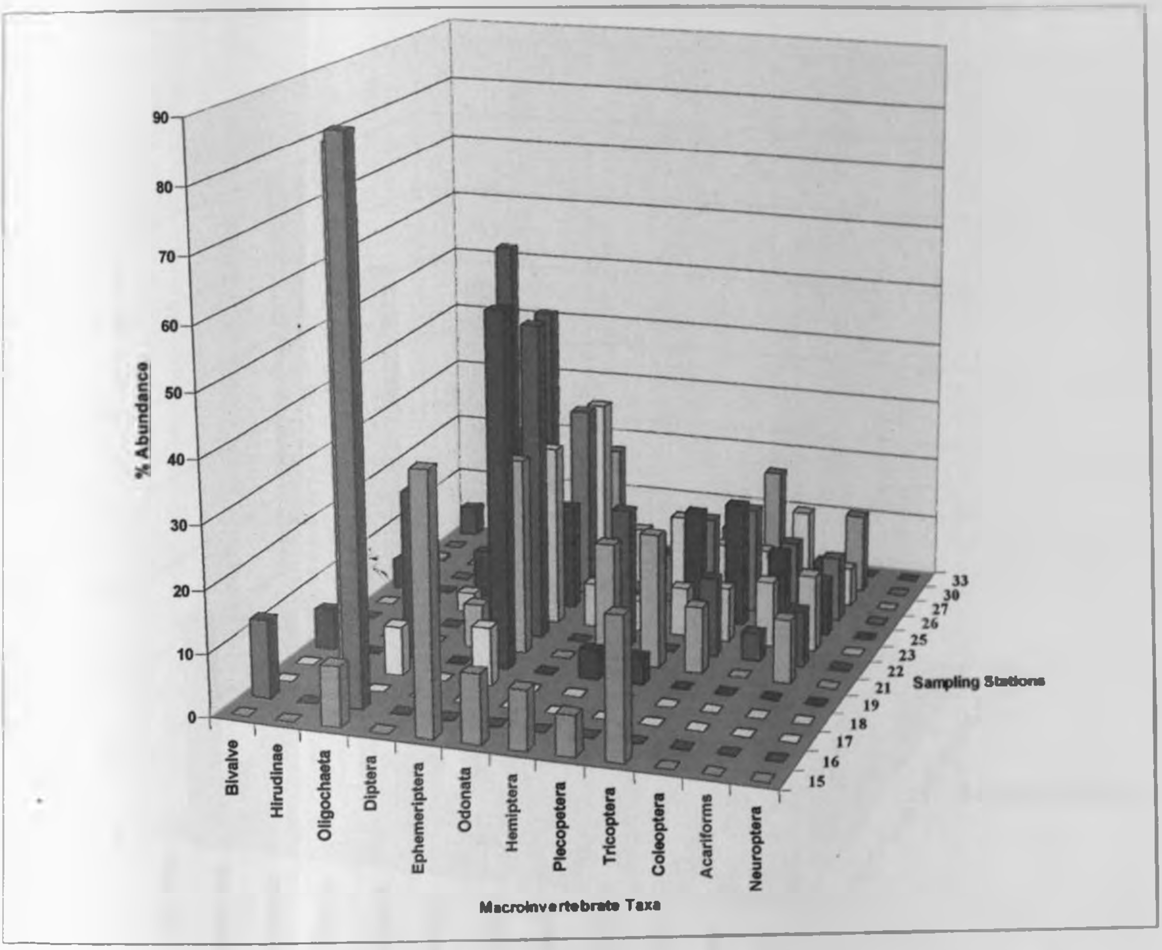

Figure 6.21: Macro invertebrate taxonomic grouping in Nandi-Lower Nyando in 2005

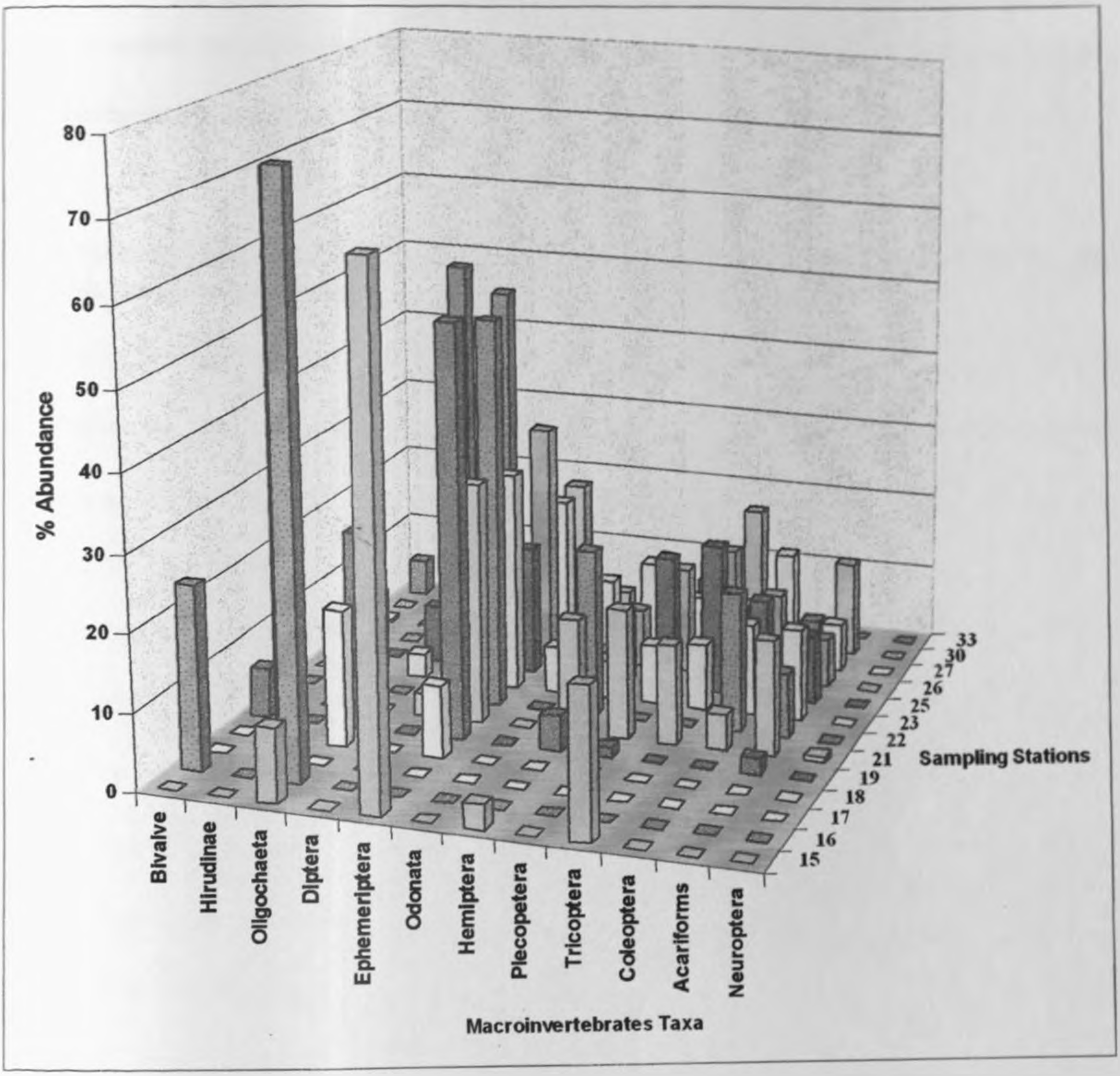

Figure 6.22: Macro invertebrate taxonomic grouping in Nandi-Lower Nyando in 2006

In the Nandi-Lower Nyando sub-catchment area (Figure 6.21 and 6.22), the order Ephemeroptera also dominated the total number collected with the highest abundance (71 % and 68 %) at sites 15. There were no species in the order Ephemeroptera collected at sites 16, 17 and 33. Site 18 had the highest number of Hirudinae, contributing to 82.7% and 73% in 2005 and 2006, respectively, while the numbers of Olingochaeta (earthworm) were highest at sites 16

(87.5% and 76%). The order Neuroptera was only found at site 21 contributing 0.3% and 0.7% of the total organisms in that site in the two years. Ephemeriptera (nymps of mayflies are the dominant benthic macroinvertebrates in the upper reaches of the drainage basin while leeches and oligochaeta are found in the lower.

6.4 Correlating physico-chemical parameters and organochlorine pesticides with diversity of benthic macroinvertebrates.

Redundancy Analysis (RDA) and Canonical Correspondence Analysis (CCA) were performed on the data to determine the statistical significance of the relationships by Monte Carlo permutation test and the results are as shown in Figures 6.30, 6.31, 6.32, 6.41 and 6.42. In Figure 6.30 pesticide concentrations play the role of species while physical parameters. TP and TN concentrations play the role of environmental variables. In Figures 6.31, 6.32, 6.41 and 6.42 the macro invertebrates play the role of species while pesticide residues levels, physical parameters, TP and TN concentrations play the role of environmental variables. Since the differences between sampling periods were not of interest, four nominal variables denoting the four sampling dates were introduced as covariables, i.e., the part of the variance captured by these variables were excluded from analysis. For interpretation of data twenty six nominal variables denoting sampling sites were also included in the data set.

From Figure 6.30, the most important physical parameters that influenced the levels of pesticide residues in water in 2005 were pH, temperature, turbidity, and conductivity respectively. The pH was highest at sampling sites 21, 4, 30, 8 and 10, respectively. Residue levels of heptachlor epoxide were highest at sampling site 7 at values that were negatively correlated the water temperatures. Water temperatures were higher at sampling sites 16 and 9 than at sites 22 and 26. Residue levels of p. p'-DDD were highest at sites 26 and 16 as compared to levels at 22 and 9.

Temperatures of water are highly significant in terms of distribution, behavour and activities of biota and pesticide residues. Pesticide degradation rates and persistence are markedly affected by temperatures with higher temperatures increasing the degradation rates and lowering the persistence (Kruegar *et al*., 2003); hence lower the concentrations of pesticides residues. Turbidity was highest at sampling sites 3 and 12. At these two stations residue levels of aldrin were highest followed by, β-endosulfan and p,p'-DDE respectively. Suspended inorganic and organic matters can affect the availability of pesticides in water. Many pesticides bind quite strongly to suspended particulate matter and will be removed downstream of a contaminated area fairly quickly. Turbid rivers give high degree of protection to local fauna and dilution downstream may mitigate some of the toxic effects (Kruegar *et al*., 2003). Conductivity was higher at sampling station 15, 33 and 25 respectively. At these sites levels of lindane, p. p'-DDT and dieldrin were detected in significant amounts. Conductivity of water is a parameter that does not vary greatly under natural conditions, with the exceptions of estuarine conditions and where saline intrusion into lakes occur (Kruegar *et al*., 2003).

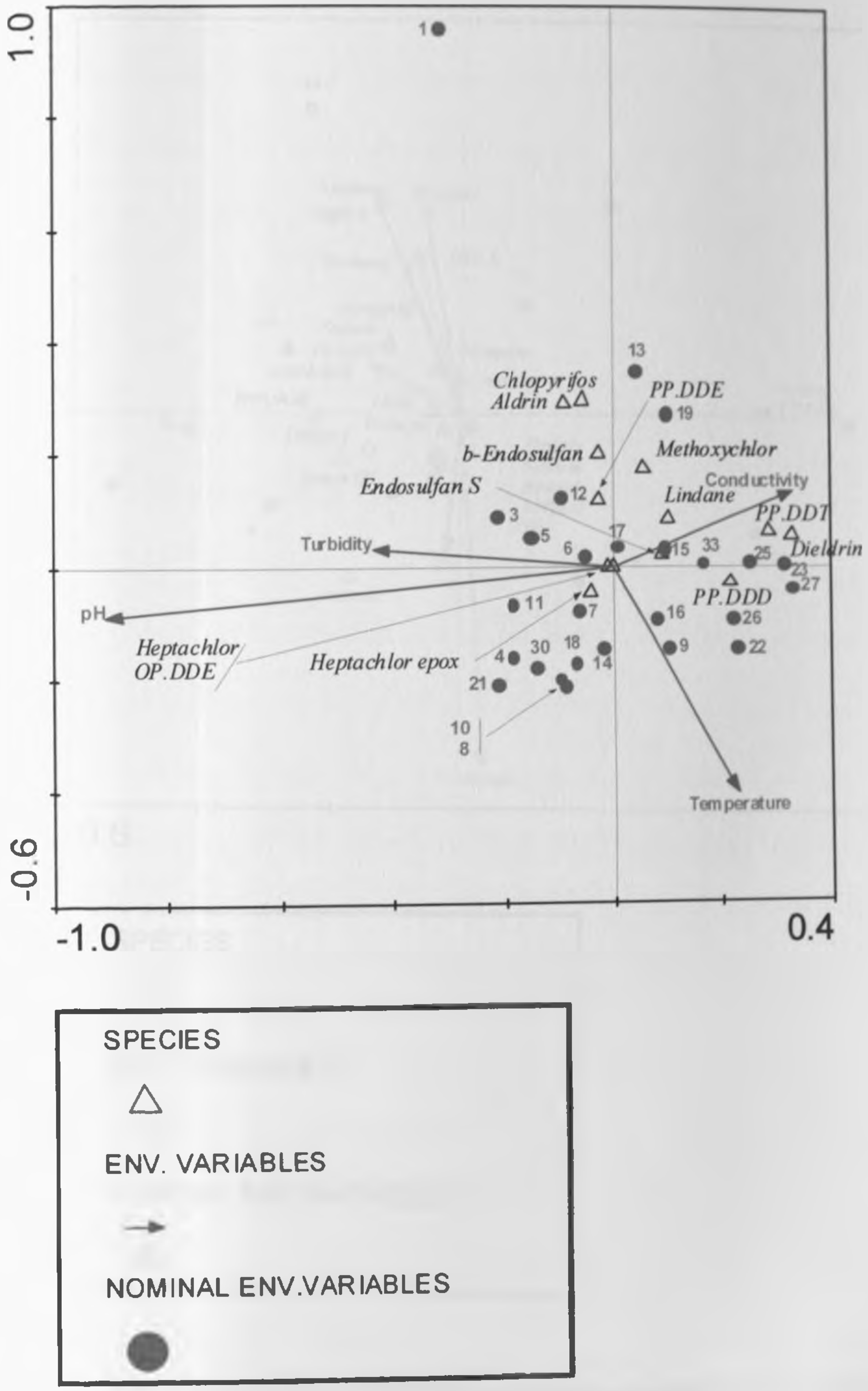

Figure 6.30: Effect of physical parameters on Pesticides Levels in River Nyando in 2005

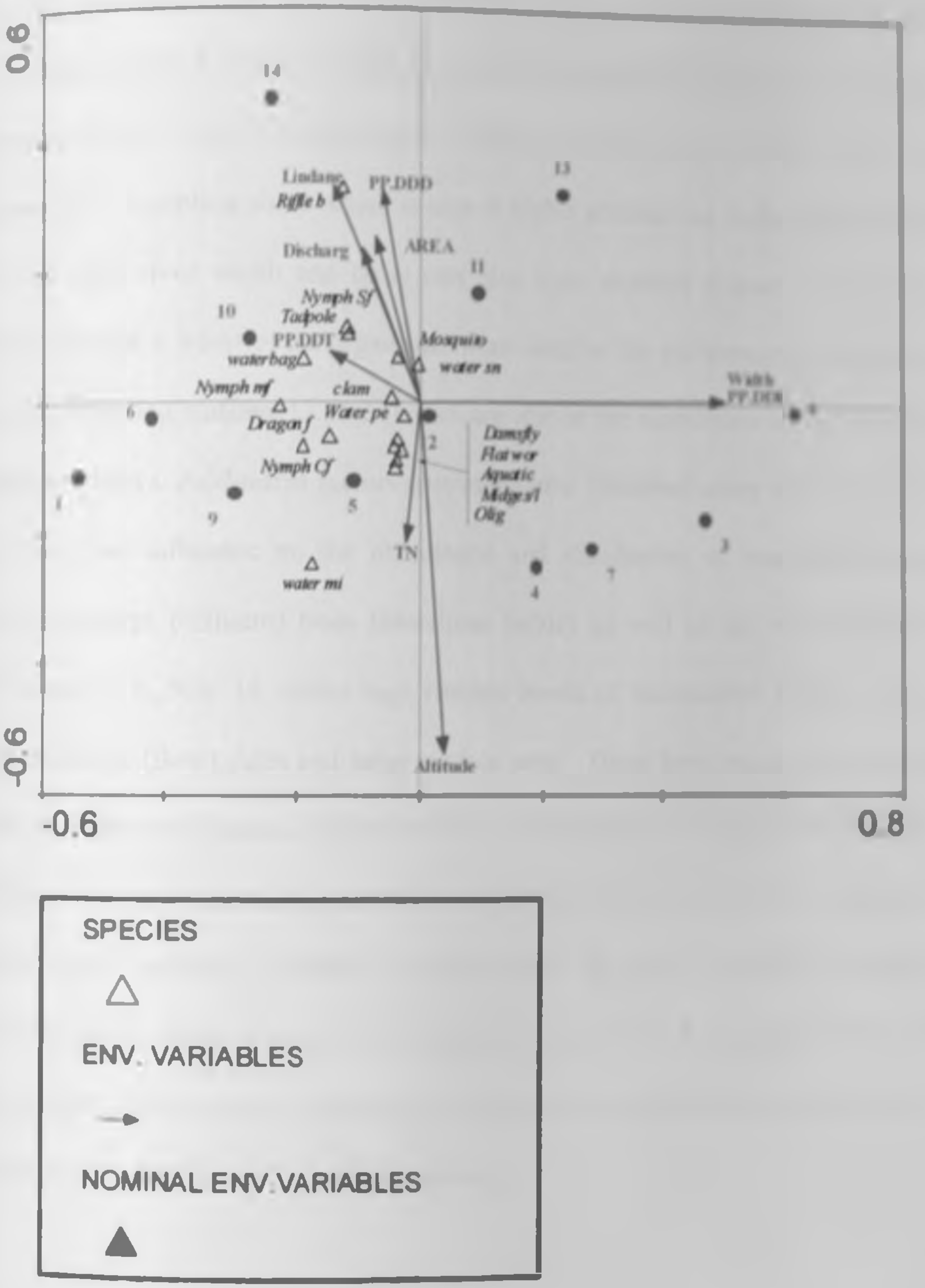

Figure 6.31: Correlating effects of pesticides and physico-chemical parameters on macro invertebrate in Kericho-Upper Nyando in 2005

The physical factors (Figure 6.31) that had influence on the abundance and distribution of macroinvertebrate species in Kericho-Upper Nyando sub-catchment area in 2005 were altitude. the widths. discharge (flow rate) and the areas of the rivers. Altitude is the most significant factor as is evident in sites 3, 4 and 7 which are at the upper reaches of the river and had few benthic macroinvertebrate. Very low pesticide residues concentrations were detected from these sampling sites. Sampling site 8 which is also at higher altitude had higher residue levels of p. p'-DDE and large river width and these can also have negative impact on the survival of the macroinvertebrates. Most of the organisms were found at the midstream of the river at sites 5. 6. 9 and 10. Sampling stations 13 and 14 that are also at the midstream of the river had very few macroinvertebrates. Additional factors (environmental variables) other than those in Figure 6.31 could have had influence on the abundance and distribution of macroinvertebrate. Site 13 receives discharge (effluent) from Homalime factory as well as and run-off from sugar cane farms closer to it. Site 14 shows high residue levels of insecticides lindane and p. p'-DDD. higher discharge (flow) rates and large surface area. These have negative correlation with the species of macroinvetebrates. Water velocity (discharge) has a profound effect on physico-chemistry. the composition of a riverbed (sand. silt) and the ability of the invertebrates to keep a foothold, respire and feed. Variable flow can have a far greater impact on benthic population than low level pesticide contamination (Kruegar *et al*., 2003). It is apparent that in this part of River Nyando catchment. pH, turbidity and conductivity did not have any significant effects on the population distribution of macroinvertebrates.

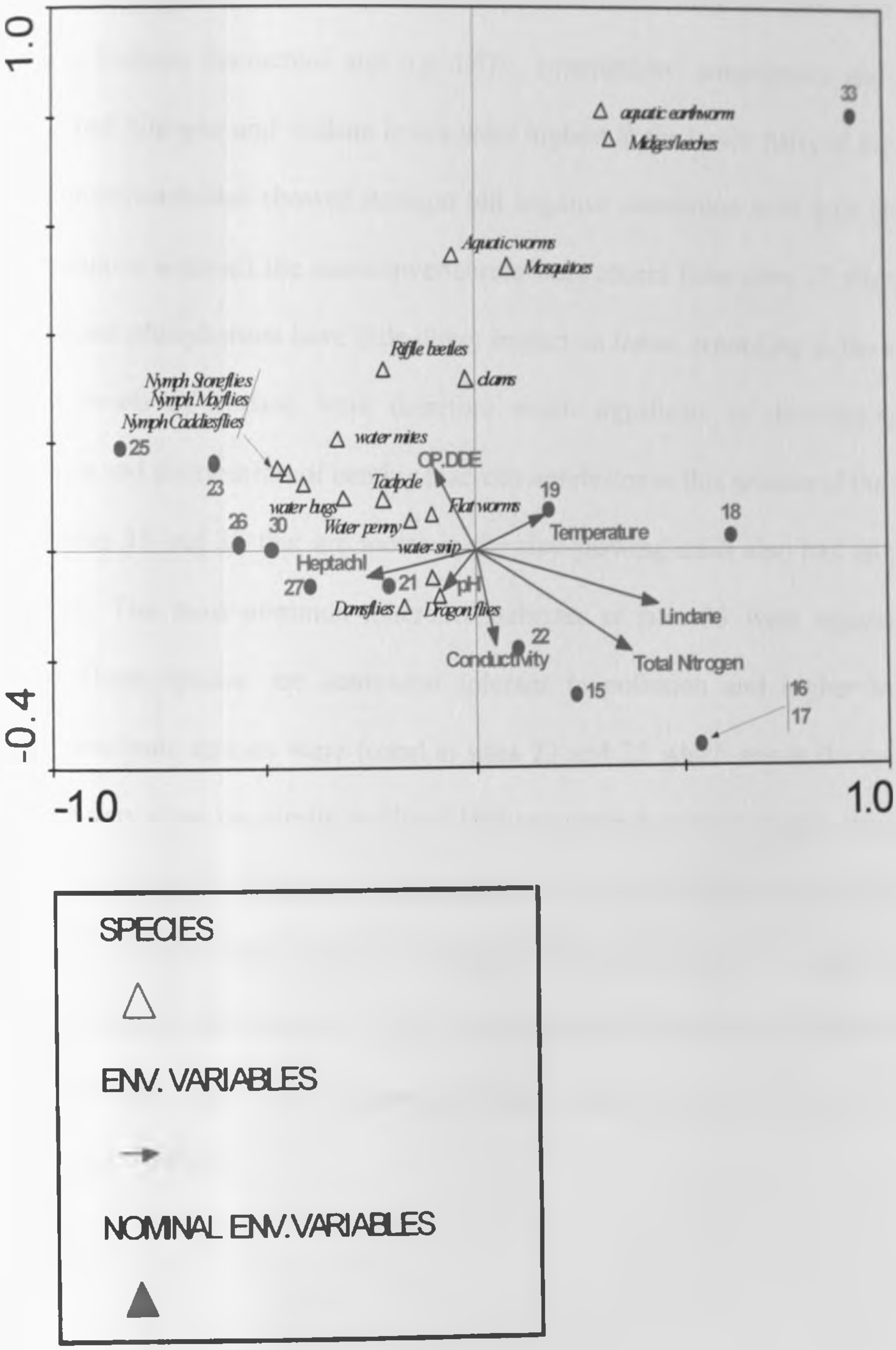

Figure 6.32: Correlating effects of pesticide and physico-chemical parameters on macro invertebrates in Nandi-Lower Nyando in 2005

From Figure 6.32, the parameters that had effects on the distribution and abundance of benthic macroinvertebrates in Nandi-Lower Nyando catchment area in 2005 were levels of total nitrogen, lindane, heptachlor and o,p'-DDE, conductivity, temperature and pH values in that order. Total nitrogen and lindane levels were highest at the lower parts of the river, sites 16 and 17. Macroinvertebrates showed stronger but negative correlation with total nitrogen and lindane concentrations since all the macroinvertebrate were absent from sites 17. Plant nutrients such as nitrogen and phosphorous have little direct impact on fauna, according to Ian and Collins (2002). Residue levels of lindane were therefore much significant in determining the occurrence, abundance and distribution of benthic macroinvertebrates in this section of the river in 2005.

Sites 18 and 33 that are locate in the rice-growing areas also had no pollution sensitive organisms. The most common macroinvertebrates at sites 33 were aquatic earthworms and leeches. These species are somewhat tolerant to pollution and higher temperatures. Most macroinvertebrate species were found at sites 23 and 25 which are at the upper reaches of the river with very close proximity to Nandi Hill areas which receives heavy rainfall throughout the year. Temperatures in these areas are usually low (Figure 6.32). These factors may be favoring the survival of the benthic macroinvertebrates in these two sites. Low water temperatures favor indirect increase in the amount of dissolved oxygen and this indirectly promotes the survival of macroinvertebrate organisms. Oxygen solubility is higher in colder water than in warmer water (Kruegar *et al.*, 2003).

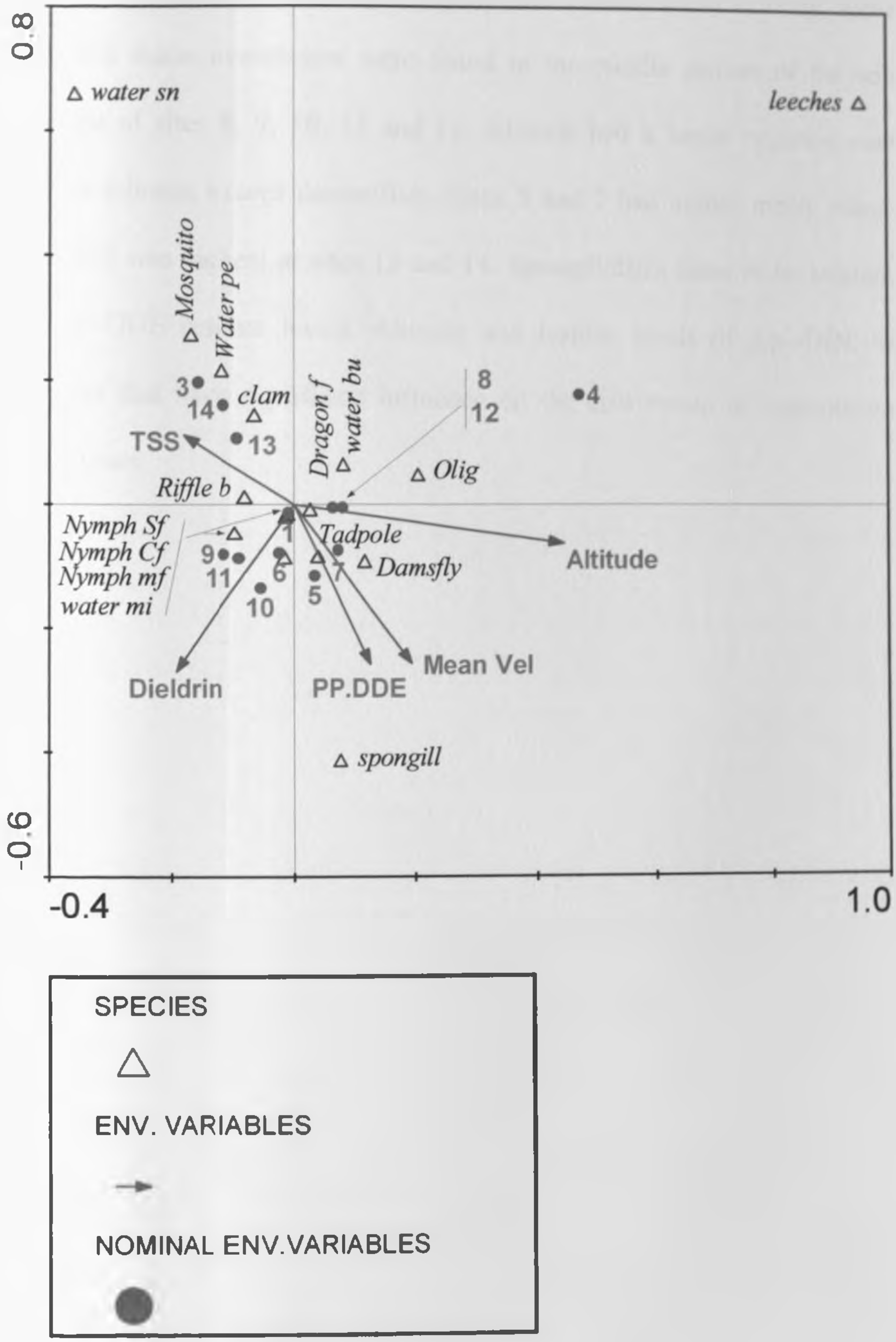

Figure 6.41: Effects of pesticides and physico-chemical parameters on benthic macro invertebrates in Kericho-Upper Nyando in 2006.

In Kericho-Upper Nyando area (Figure 6.41) the environmental factors that influenced the distribution of macroinvertebrates in 2006 were altitude. mean velocity. dieldrin. p.p'-DDE and TSS. Most macroinvetebrates were found in the middle section of the sub-catchment which comprised of sites 8. 9. 10. 11 and 12. Altitude had a larger negative correlation with most macroinvetebrates except damselflies. Sites 5 and 7 had higher mean velocity and p. p'-DDE levels. TSS was highest at sites 13 and 14. Spongillaflies seem to be tolerant to mean velocity and p. p'-DDE residue levels. Altitude and residue levels of p.p'-DDE were the only two parameters that have significant influence on the distribution of macroinvetebrates species in both the years.

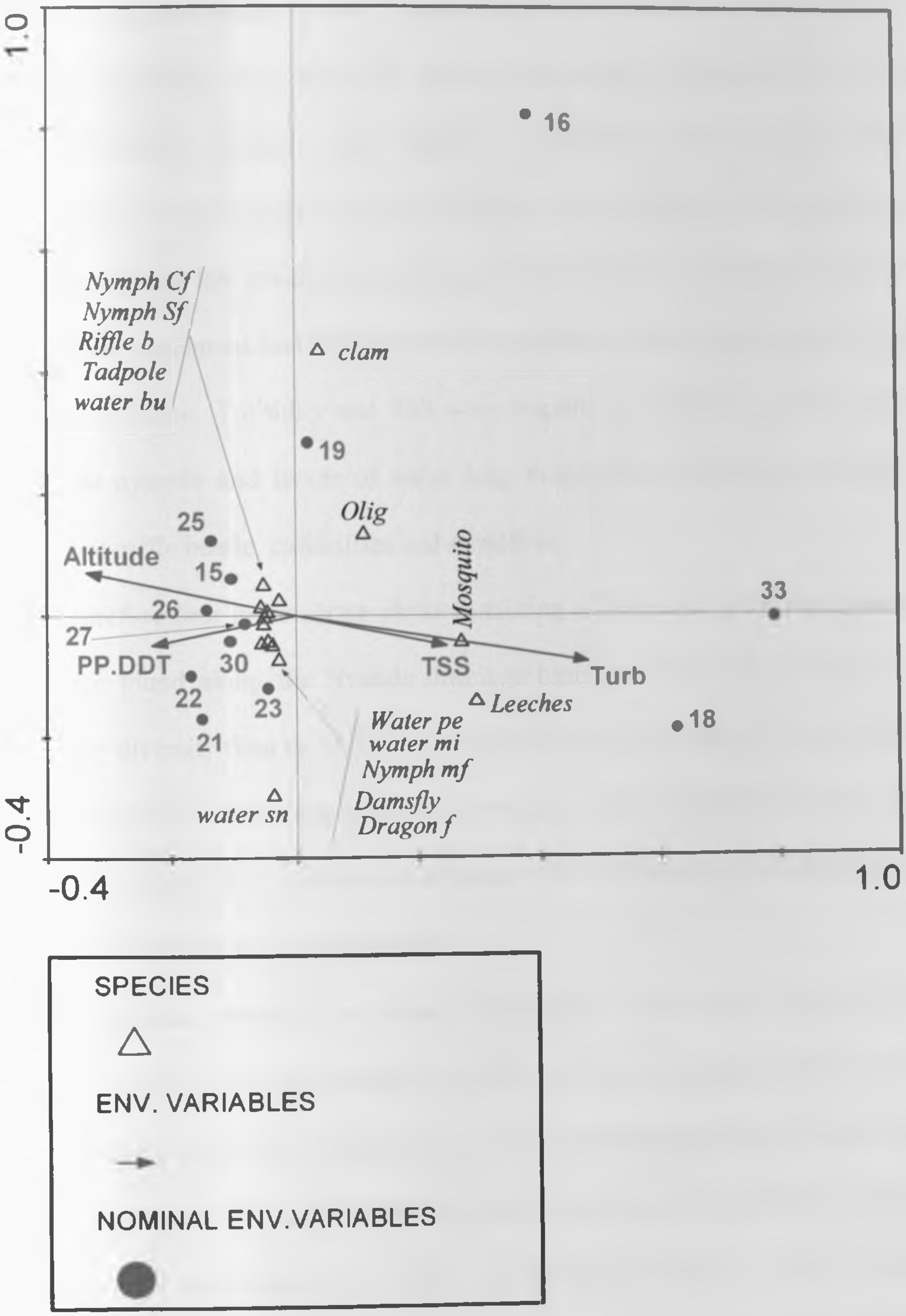

Figure 6.42: Correlating effects of pesticides and physico-chemical parameters on macro invertebrates in Nandi -Lower Nyando in 2006

From Figure 6.42, the most important physical parameters that influenced the occurrence of macroinvertebrate in Nandi-Lower Nyando area in 2006 were found to be altitude, turbidity and TSS while o,p'-DDE was the only chemical parameter that influenced the occurrence of macroinvertebrates. Altitude had negative correlation with the occurrence of macro invertebrates; most pollution sensitive organisms were reported in the upper sites 27 and 30 which however had low residue levels of p,p'-DDT. Sites 16, 18, 19 and 33 that are at the lower reaches of the catchment had predominantly oligochaete, leeches and mosquito larvae which are tolerant to pollution. Turbidity and TSS were negatively correlated to most macroinvertebrates that include nymphs and larvae of water bug, dragonflies, damselflies, mayflies, water mites, water penny, riffle beetle, caddisflies and stoneflies.

Therefore four invertebrate phyla consisting of a diversity of sixteen families and eleven orders were found along the Nyando drainage basin with the Kericho-Upper Nyando having more family diversity than the Nandi-Lower Nyando sub-catchment. The order Ephemeroptera is the most abundant in the upper sections of the river, while Hirudinae (leaches) and Oligochaeta in the lower. Much of the pollution problems of River Nyando are downstream from sampling site 15 as the river drains into Winam Gulf.

Multivariate analytical technique, Redundancy Analysis and Canonical Correspondence Analysis have been used to correlate the effects of environmental variable on the occurrence, abundance and distribution of benthic macro invertebrates along River Nyando drainage basin. It has been established that higher altitudes, water temperature, pH, turbidity, and rate of discharge (river flow rate) and levels of p,p'-DDE, o,p'-DDE, p,p'-DDD, p,p'-DDT, lindane, heptachlor and dieldrin have negative impact on the occurrence, abundance and distribution of benthic macro invertebrates along the drainage basin and that in 2005, River Nyando discharged significant amounts of insecticide lindane and total nitrogen (TN) into Lake Victoria and this could have had significant negative influence on the occurrence and distribution of benthic macroinvertebrates in sites 16 and 17 while rice farms (sites 18 and 33) that are at a relatively close proximity to the Lake Victoria could be posing larger pollution problem than the tea (sites 25. 26. 27 and 30), coffee (site 23) and sugar cane farms (sites 10. 11,12,13,14. 21 and 22) that also use agrochemicals but are at the upper and middle reaches of the Nyando drainage basin.

CHAPTER SEVEN

7.0 Integrating discussion and way forward

Monitoring the concentrations of the pesticides residues in soil, water, sediments, aquatic weeds along the Nyando basin and correlating the effects of these residue levels to benthic macroinvetebrstes indicate a greater concern for preservation of aquatic fauna. It also gives signal to the fact that rehabilitation, restoration and management of the lake reservior is not achievable unless the river pollution is eliminated.

The results indicate that the current agricultural practices regarding pesticide use along the Nyando drainage basin may have had profound effects on important ecosystem service such as honey bees, predatory insects, Red-Billed Oxpecker among others and on the occurance, abundance and distribution of benthic macroinvertebrates along the River Nyando basin.

The study reveals that much of the pollution problems of River Nyando are from sampling site 15 (Nyando at Ogilo Bridge) to the lower section as the river drains into Winam Gulf since pollution sensitive macroinvertebrates diseappeared downstram site 15. In 2005, River Nyando discharged significant amounts of insecticide lindane and total nitrogen into Lake Victoria and these could have had significant impact on the occurrence and distribution of macroinvertebrate species in sites 16 and 17 which were selected further down stream to assess the self cleaning capacity of the river. The rice farms that are relatively in close proximity to the Lake Victoria pose significant pollution problem than the maize, sugarcane, coffee and tea farms that also use pesticides and fertilizers and are in the middle and upper reaches of the Nyando drainage basin.

7.1 Recommendations

1. There is no detailed research on contamination and its ecotoxicological effects of pesticides on fish and other species of aquatic life along the Nyando drainage basin. Detailed research on the effects of pesticide residue concentrations are recommended to corroborate the results presented here.

2. There is need for well targeted comprehensive analyses of pesticide residue levels and their effects for other drainages to Lake Victoria and the lake itself.

7.2 Suggested management strategies for River Nyando and Lake Victoria ecosystem

1. Possible changes in agricultural practices especially on farms which are adjacent to river ecosystem include crop rotation, resistant host-plant, biological control and use of genetically modified crops. Integrated Pest Management strategies apply a combination of these control tools.
2. Applications of soil conservation, afforestation efforts and policies to control clearing of forests are some of good land management approaches which can strength the catchments area of river and that of the lake in order to reduce the nutrient and pesticides loading to the lake.
3. Introduction of economic incentives by government can also be aimed at waste reduction in the industrial sector. These may include incentives to use biodegradable pesticides and fertilizers, production-tax rebates to encourage clean technologies and environmentally friendly activities, introduction of the "polluter pays" principle to the communities living in the Lake Victoria catchments and attachment of the values to the rivers and lake itself.

4. One of the most worth taking approaches is human-capacity development and management of the water resources. Mass mobilization in form of education and training programs on the safe use of agrochemicals and importance of the rivers and Lake Victoria pollution control efforts need to be established and those which are existing need to be strengthened.

5. The potential of wetland to filter incoming pollutants should be appreciated by maintaining their filtering efficiency by avoiding the prevailing habits of indigenous people to cultivate the wetlands and use of pesticides and fertilizers which have negatively impacted on the health of River Nyando.

6. Reduction of effluent pollutants from point sources (industrial and domestic pollution) such as pollution eminating from Homalime, Muhoroni and Chemelil factories, Londiani township and Ahero town may be realized through improvement of the existing production processes, introduction of recycling of waste streams and strengthening application of the end of pipe technology such as treatment of effluents streams before discharging them into aquatic environment.

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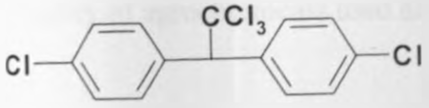
Appendix 1.0: Structures of pesticides studied



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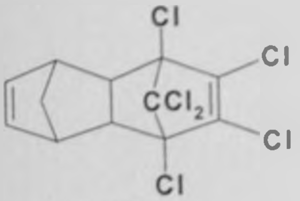

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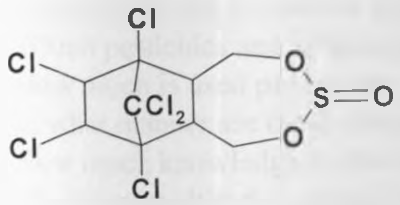

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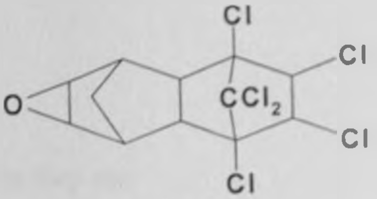

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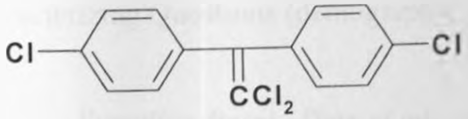

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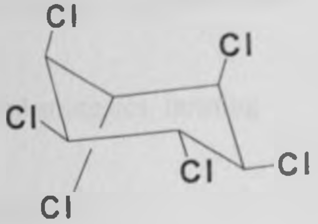
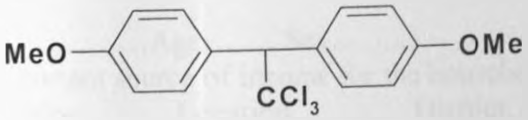


6 LINDANE



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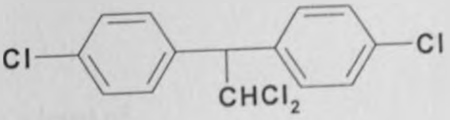

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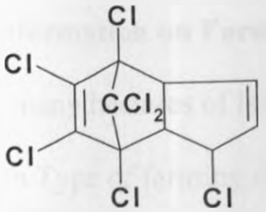

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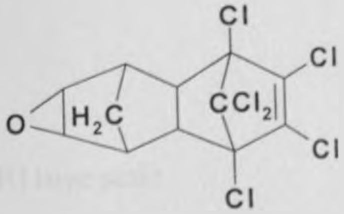

10 ENDRIN

Appendix 2.0: Questionnaire for the Farmers in River Nyando area

Survey of agrochemicals used along River Nyando catchment area

Agriculture and Land use

Main Objectives were to determine:

- Whether there are pesticides or fertilizers used in farming
- What types of crops are grown
- What part of the population use pesticides or fertilizers
- Which pesticides and fertilizers are used for which crops
- How much is used per hectare
- In what manner are these chemicals used or applied to fields
- How much knowledge do the farmers have about the pesticides they use
- The farmers altitudes towards pesticides used
- Whether the farmers have observed any negative ecological effects of these pesticides
- Whether the farmers have experienced any health problems associated with pesticides use.

2.1 Characterizing Questions (demographic, language/education. livelihood strategies. farming system)

At……………Sampling Point Date of interview………… Questionnaire Number……
Topography of the region………………

(A) Farmer's Particulars

Name……………Age……. Sex……..
Most important source of income for the household
Sub-Location………Location…………District…………farmer's level of education……………. Number of adult…….. and children……..living in the farmer's house hold
Languages spoken in the household------------

(B) Information on Farming activities

(i) How many hectares of land do you have? ……….. ha

(ii) Which Type of farming do you practice? [A] Subsistence farming [B] large scale Farming

(iii) Which crops do you grow?
How much land have you devoted for each?
For how long have you been using this piece of land for this crop(s)?
(iv) Do you practice any crop rotation? [Yes] [No]

If No, Why?
If [Yes], for which crops?

(v) When do you plant your crops and why?
How many times do you plant this type of crop(s) in a year?
When do you harvest the crop(s)?
What problems have you experienced with the crop(s)?
Is it a common problem, how do you solve it?

(vi) Use of fertilizers in farming
Do you use any fertilizer on your crop(s)? [Yes], [No]
If [No], why?
If [Yes], which one(s) and why?

(vii) How much of each do use per hectare and what is the yield?
How and when do you apply the fertilizers?
Where do you get the fertilizers(s) from?
What is the cost per unit?
How long have you been using the fertilizer on the farm(s)?

(C) Use of pesticides in farming
Do you use any pesticides for your crop(s)? [Yes], [No]
If [No], why?
If [yes], which one(s)?
How much of each pesticide(s) do use per hectare and what is the yield?
How and when do you apply the pesticides?
Where do you get Pesticide(s) from?
What is the cost per unit?
How long have you been using the pesticide(s) on the farm(s)?
Do you know of any banned or restricted pesticides in Kenya?
If [yes], which one(s)?

(D) Use of pesticides on Livestock Farming and human health
(i) Do you keep any farm animals? [Yes], [No]
If [No], why?
If [Yes], which one(s) and how many?
How much land have you devoted for these animals?
How long have you been keeping the animal(s) on the farm?
What problem(s)/diseases do you experience with the animal(s)?
How do you solve the problem(s)?

(ii) Use of acaricides on livestock
Do you use any acaricides on your animal(s)? [Yes], [No]
If [no], why? ....
If [yes], which ones and how much per animal?

(iii) What method of application do you employ?
When do you apply the acaricide(s) and how often?
Where do you get the acaricide(s) from?
What is the unit cost per acaricides?
For how long have you been handling the acaricide(s)?

(E) Health problems associate with use of pesticides

(i) Have you experienced any health problem suspected/or due to exposure to the acaricide(s)? [Yes], [no]

If [yes], when? How was it treated?
If [no], have you gone for any medical check-up?
Do you have any or had any health problem apart from the one(s) above.

Appendix 3.0: Agrochemicals used in River Nyando

Table 3.12: The pesticides used in River Nyando basin and their recommended rates

Pesticides used	crops	Recommended rates and remarks
Karate	Tomatoes, kales, cotton	750-1,000 litres per ha
Milraz	Tomatoes	30-50 g/20 litres
Dithane M45/Mancozeb	Tomatoes	30-50 g/20 litres
Actellic	cereals-maize and sorghum	100 g per 90 kg bag on storage pests
Dimethoate	vegetables, fruits, trees and tobacco	25-50 ml/20 litres, 0.75-1.5 litres per ha, in a number of trade names
Ridomil	Tomatoes	180 g per 20 litres, 500-1,000 g per ha.
Milthane	Tomatoes	180 g per 20 litres, 500-1,000 g per ha.
Furdan 5G	rice and horticulture nursery beds	1-1.5 kg per ha.
Diazinon	Tea, coffee	1kg per ha.
Kocide	coffee	2-2.5 kg per ha
Dipterex	maize and sorghum	1 kg per ha.
Linulon	sugarcane	Herbicides up to 5 kg per ha.
Round Up	sugarcane	Herbicides 3-5 litres per ha.
Fenthion	coffee	2.5 kg per ha.
Fenitrothion	Tea, coffee	250 g per ha.

Source: NYD/SUP/VOL.1/-District Agriculture Officer-Nyando (2008)

Table 3.13: Fertilizers used in River Nyando catchment and their recommended rates

Fertilizer	crops	Recommended rates and instruction
Urea	sugarcane and occasionally rice	50-100 kg per top dressing used in splits
CAN	all crops	50-120 kg per top dressing used in splits
DAP and NAP	all crops	75-150 kg per ha. basal application

Source: NYD/SUP/VOL.1/-District Agriculture Officer-Nyando (2008)

Table 3.14: Pesticides used in River Nyando Catchment Area

Crops/ Livestock	Insecticide	Fungicide	Herbicides
Rice	Furadan. carbofuran		
Tea	Fenintrothion. Diazinon, Dimethoate. Karate	copper zinc spray. Dithane M45 (mancozeb).Marshal. Milraz. Ridomil	Round Up. Touch Down. Gramoxone. (paraquat). Afalon. 2-4-D Amine (72 %)
Sugarcane			Round UP. Diuron. Nata. Kombi
Coffee	Diazinon, Dasis. Fenitrothion. Fenthion	copper nordo. Kocide 101. Dithane. Antracol. copper-oxychloride	
Horticultural crops	Diazinon. Abush. Doom Powder. Karate. Dimethoate	Dithane super. milruz. Ridomyl. Mithane Super. Acrobat. Antracol. Sancozeb. Samcozide	Round Up
Cattle	**Acaricides** Triatix, Delnav, Steladone, Almatrix		

Sources: Farmers, District agricultural and Livestock Extension Officers: Nandi, Kericho and Nyando Districts (2004). *Note:* The above pesticides have been identified with their trade names other than chemical names.

Table 3.15: Fertilizers used in River Nyando Catchment area

Type of crop	Fertilizer
maize	CAN. DAP. NP. UREA (nitrate based)
Rice	DAP. CAN
Tea	CAN. ASN. NPK 25:5:5. NPK 20:20:0. NPK 26:6:12. UREA
Sugarcane	NPK. CAN. UREA
Coffee	NAP 20:20:0. NAP17:17:0
Horticultural crops	DAP

Sources: Farmers. District agricultural and Livestock Extension Officers: Nandi. Kericho and Nyando Districts (2004)

Key: DAP = Diammonium Phosphate $(NH_4)_2HPO_4$
NPK = Nitrogen Phosphate Potassium
ASN = Ammonium Sulphate Nitrate
NP = Nitrogen Phosphate
CAN = Calcium Ammonium Nitrate

Table 3.16: Status of major agricultural enterprises in Kericho District

Crops	Hectares	Agro-chemicals used
Main cash crops		
Tea (KTDA)	7000	-Round Up (herbicide) -NPK 23:23:5S (fertilizer)
Tea Estates	9000	-Round Up (herbicide) -NPK 23:23:5S (fertilizer)
Coffee	2850	-Round Up (herbicide) -Copper-Zinc spray (Fungicide)
Sugar cane	4000	-Round Up. Diuron –Nata. Kombi (herbicides)-CAN. NPK. Urea (Fertilizers)
Pyrethrum	600	-DAP. NPK
Main Food Crops		
Maize	36000	-DAP. NPK. CAN and UREA
Beans	13900	-DAP. NPK. CAN and UREA
Sorghum	700	
Other food crops		
Finger Millet	1540	-DAP (fertilizer). DithaneM45 Ridomil. Milthane super (Fungicides)
Irish Potatoes	230	-DithaneM45 - Ridomil -Milthane super (Fungicides)
Kales	690	-DithaneM45 -Ridomil - Milthane super Kombi. karate (Fungicides)
Tomatoes	1500	-DithaneM45 -Ridomil -Milthane Super. Kombi. karate (Fungicides)
Cabbages	3000	-DithaneM45 -Ridomil -Milthane Super. Kombi. karate (Fungicides)
Livestock	6000	-Triatix -Delnav -Stelladone. Almatix

Sources: Farmers. District agricultural and Livestock Extension Officers. Nandi. Kericho and Nyando Districts (2004)

Table 3.17: **Status of the major agricultural enterprises in Nandi District**

Crops	Hectares
Main Cash Crops Sugarcane, Tea and Coffee	25,000
Main Food Crops Maize	65,000
Other Food Crops Beans, Irish Potato, Sorghum and Cassava	15,000
Major Horticultural Crops Kales, Cabbages, Tomatoes, Beans, Pineapples, French Beans and Passion Fruits	2,000
Major Livestock Dairy cattle, Poultry, Sheep and Goats	127,000
Total	**234,000**

Sources: Farmers, District agricultural and Livestock Extension Officers, Nandi, Kericho and Nyando Districts (2004)

Table 3.18: Status of the major agricultural enterprise in Nyando District

Crops	Hectares	
Main Food Crops		
Maize	15.000	
Sorghum	6.000	
Rice	5,500	
Beans	4,400	
Cowpeas	2,000	
Green grams	300	
Ground nuts	500	
Sim Sim	150	
Kales	150	
Tomatoes	100	
Onions	50	
Traditional vegetables	500	
Total		**34,650**
Main Fruits/Tree Crops		
Mangoes	380	
Avocados	360	
Pineapples	260	
Bananas	160	
Citrus	150	
Paw Paw	260	
Total		**1,570**
Main Cash Crops		
Coffee	3000	
Sugarcane	20.000	
Cotton	4.000	
Tobacco	14	
Total		**27,014**

Source: NYD/SUP/VOL.1/-District Agriculture and Livestock Extension Officer- Nyando (2007)

Table 3.19: Sugarcane Coverage by Factory Zone

Factory	Potential Hectares Nucleus	Out-Growers (ha)	Planted (ha)		
			Nucleus	Out Growers	Total (ha)
Chemelil	2,260	9,535	1,958.00	6,567	8,525.00
Muhoroni	1,538	8,647	1,395.22	5,476.09	6,871.31
Miwani	3,200	330	1,529.89	2,226.21	3,756.1
Total	**7,098**	**20,096**	**4,883.11**	**14,269.30**	**19,152.41**

Source: NYD/SUP/VOL.1/-District Agriculture Officer-Nyando (2007)

Table 3.20: General levels of Pesticides usage in Nandi District

Enterprise	% Level of adoption	Area (ha)	Annual pesticides usage (kg)			
			Fungicides	Insecticides/Acaricides	Herbicides	Total
Maize		64,500	-	60,000	10,000	70,000
Beans	5	12,560	1,300	-	-	1,300
Brassicas	50	1,200	2,400	9,600	-	12,000
Sugarcane	80	9,500	-	-	30,000	30,000
Coffee	80	1,100	3,300	5,300	5,300	13,900
Floriculture	80	5	400	300	10	710
French Beans	80	70	500	500	-	1,000
Irish Potatoes	60	300	2,200	-	-	2,300
Passion Fruits	80	10	200	100	-	300
Tea	80	25,000	-	-	96,000	200,000
Tomatoes	70	360	6,000	3,000	-	9,000
Livestock		-	-	120,000	-	120,000
Total		114,605	16,300	198,800	141,310	356,410

Sources: District Agricultural and Livestock Extension Officers (2007): Nandi District.

Table 3.21: Pesticides used in Nyando Catchment area and their toxicity to bees

Active ingredient	Toxicity towards insects (bees)
Chlorpyrifos	Toxic to bees, LD_{50} (oral), 0.36µg/bee LD_{50} (contact) 0.07µg/bee
Fenitrothion	NR
Mancozeb	LC_{50} 193µg/bee
Diazinon	NR
Carbofuran	NR
Cypermethrin	NR
Endosulfan	NR
Lambacyhalothrin	Highly toxic to bees, (oral) 0.038 µg /bee, LD_{50} (contact)0.9 µg /bee
Chlorfenviphos	LD_{50} (24h, oral) 0.55 µg /bee, (topical) 4.1 µg /bee
Amitraz	Low toxicity to bees LD_{50} (contact) 50 µg /bee

Source: The Extension Toxicology Network, 2006 and Tomil, the Pesticide Manual, British Crop Protection Council, 1997, NR = Not Rated

Table 3.22: Pesticides used in Nyando Catchment area and their toxicity to birds

Active ingredient	Toxicity towards birds
Amitraz	LD_{50} Bobwhite quail 788mg/kg, LC_{50} (8d) Mallard ducks 7000mg/kg, Japanese quail 1800mg/kg
Endosulfan	Acute oral Mallard ducks 205-245mg/kg, Ring-necked pheasant 620-1000mg/kg
Chlorfenviphos	Acute oral LC_{50} pheasant 107mg/kg, pigeons 16mg/kg
Chlorpyrifos	Acute oral LC_{50} Mallard ducks 490mg/kg, House sparrow 122mg/kg, chickens 32-102mg/kg. Dietary LC_{50} (8d) Bobwhite quail 423mg/kg

Source: The Extension Toxicology Network, 2006 and Tomil, the Pesticide Manual, British Crop Protection Council, 1997

Table 3.23: Quantities of imported pesticides into Kenya (quantity in tones)

Year	Insecticides & Acaricides	Herbicides	Fungicides	Others	Total
2007	2,887	2,289	2,651	1,330	9,157
2006	2,475	1,859	3,190	1,225	8,749
2005	2,844	1,311	2,361	1,192	7,708
2004	2,881	1,538	2,031	597	7,047
2003	2,665	1,396	1,687	723	6,441
2002	2,747	1,506	2,139	434	6,826
2001	2,320	1,398	1,779	154	5,651
2000	1,762	633.4	1,665.90	1,116	4,431 90
1999	2,186	593	2,284	370 6	6,179
1998	1,814 40	1,407.80	4,225.40	159	7,606 40
1997	2,077.80	703.1	2,391	655 6	5,827 50
1996	1,876 20	997.9	3,469 80	602 5	6,946 40
1995	1,413.30	870 6	2,323	501 9	5,108 80
1994	1,049.90	747.4	1,671.80	563 3	4,032 10
1993	839	882	1,503	309	3,533
1992	1,670	1,122	2,634	1,164	6,590
1991	1,072	844	1,568	570	4,051
1990	1,572	1,134	1,330	857	4,893
1989	1,571	1,148	4,327	665	7,711
1988	1,089	2,108	4,259	801	8,257
1987	1,206	1,311	715	697	3,929
1986	1,076	112	654	808	2,650
Total	**22,274.60**	**14,604.20**	**45,020.90**	**9,839.70**	**81,749.40**

Source: Pest Control Products Board (PCPB, 2007)

Appendix 4.0: Rainfall data for the Nyando Catchment Area

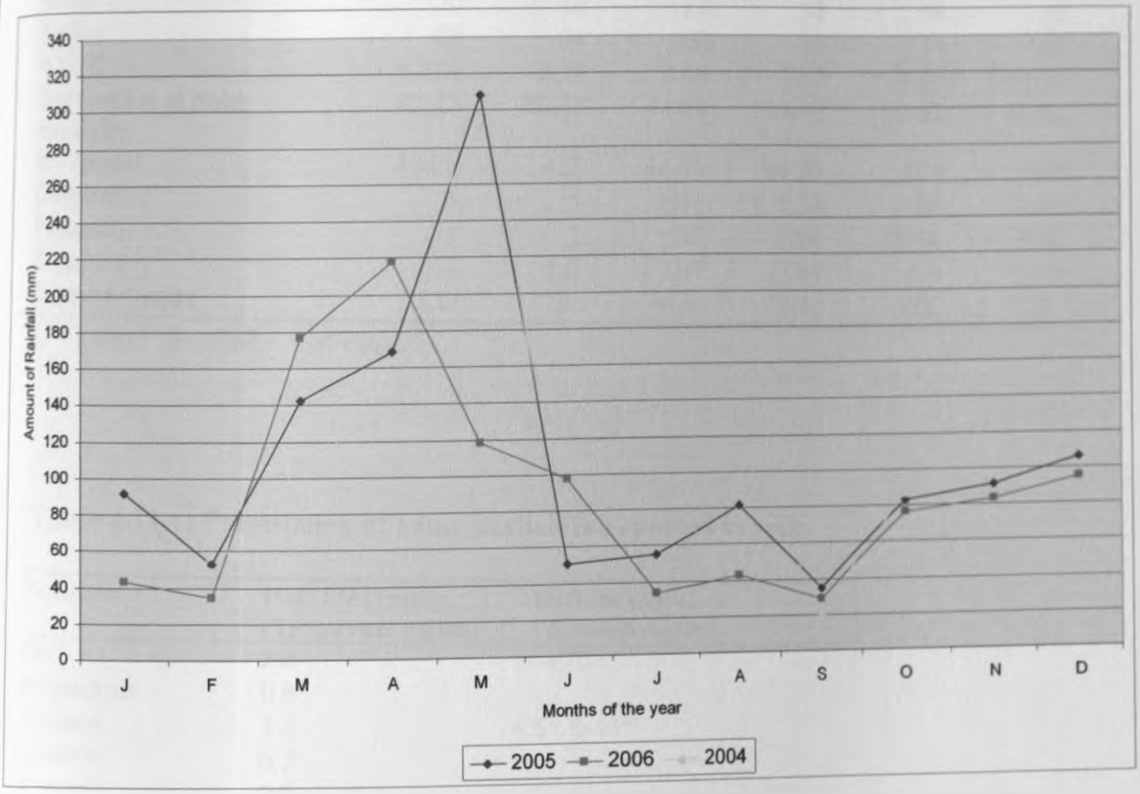

Figure 4.5: Rainfall Pattern in the River Nyando catchment Area
Source: (LVEMP, 2004- 2006 Weather reports, Metrology Department at Uiniversity of Nairobi)

Appendix 4.1 Soil texture, pesticide persistence in soil and banned pesticides

Table 4.11: Soil texture and properties at various sites

	1	4	22	23	26	33
pH	6.72	6.32	6.83	6.45	6.72	7.47
%Sand	12	18	24	14	12	8
%Silt	20	18	26	28	14	10
%Clay	68	64	50	58	74	82
%TOC	1.731	3.12	2.48	2.53	0.93	1.72
%Moisture at field capacity	47.27	50.07	44.63	68.49	86.32	52.35
Mn (ppm)	454.5	437	14.16	69.96	129	168
Cu(ppm)	1	1	1.41	1.53	1.96	1.95
Fe(ppm)	1	1	12	1.92	13.74	5.92
Zn(ppm)	1	2.6	1.09	0.64	4.5	0.78
Texture Grade	LS	SL	SCL	SCL	SL	SL

L = loam, S=sand C= clay

Table 4.11.1: Persistence of some pesticides reported in soils

Pesticides	Half-life (years) (Temperate region)	Half-life (days) (Tropical region)
DDT	2.8	64-270
Heptachlor	0.8	-
Lindane	1.2	4.5*; 6-48**
Dieldrin	0.3	-
Endrin	2.2	-

Source: Wandiga, 2001 (* 1st phase; ** 2nd phase)

Table 4.11.2: Banned and Restricted pesticides in Kenya

Common name	Former use
Dibromochloropropane (DBCP)	soil fumigant
Ethylene dibromide (EDB)	soil fumigant
2,4,5-T phenoxy herbicide	herbicide
Chlordimeform	Acaricide/insecticide
All isomers of HCH	Insecticide
Chlordane	Insecticide
Captafol	Fungicide
Heptachlor	Insecticide
Toxaphene (Camphechlor)	Acaricide
Endrin	Insecticide
Parathion (methyl and ethyl)	Insecticide
Restricted pesticide	**Permitted use**
lindane	Termite in building industry
Aldrin, dieldrin	Termite in building industry
DDT	Public health only

Appendix 5.1: Guidelines for Pesticides Residue levels in drinking water

Table 5.12: Drinking water pesticide guidelines for some organizations in µg/L

Pesticides	WHO	EPA	Australia
Aldrin	0.03	NC	0.01
Dieldrin	0.03	NC	NC
DDT	2	0.2	0.06
Lindane	2	0.2	0.05
Methoxychlor	20	40	0.02
Endrin	NC	2	NC
Heptachlor	0.03	0.4	0.05
Heptachlor-epoxide	0.03	0.2	0.05
Endosulfan	NC	NC	0.05

Source: (IUPAC, 2003). NC= Not classified

Appendix 5.2: Correlation tables of pesticides in water, sediments and weeds

Table 5.21.1: Correlation coefficients for pesticide in water from Kericho-Upper Nyando in February

Correlations

		1	3	4	5	6	7	8	9	10	11	12	13	14
1	Pearson Corre	1 000	912*	261	625*	560*	618*	777*	374	143	054	389	328	542*
	Sig (2-tailed)		000	329	010	024	011	000	153	597	843	137	215	030
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
3	Pearson Corre	912*	1 000	.274	471	527*	661*	823*	527*	256	171	366	395	663*
	Sig (2-tailed)	000		305	066	036	005	000	036	338	528	163	130	005
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
4	Pearson Corre	261	274	1 000	295	149	295	126	170	- 106	- 149	- 078	- 070	- 100
	Sig (2-tailed)	329	305		267	581	268	641	530	696	581	775	797	712
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
5	Pearson Corre	625*	471	295	1 000	615*	584*	617*	330	114	- 048	712*	377	476
	Sig (2-tailed)	010	066	267		011	017	011	212	674	861	002	150	062
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
6	Pearson Corre	560*	527*	149	.615*	1 000	711*	387	721*	636*	511*	494	629*	570*
	Sig. (2-tailed)	024	036	581	011		002	139	002	008	043	052	009	021
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
7	Pearson Corre	618*	661*	295	584*	711*	1 000	784*	758*	640*	385	658*	764*	787*
	Sig. (2-tailed)	011	005	268	017	002		000	001	008	141	006	001	000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
8	Pearson Corre	777*	823*	126	617*	387	784*	1 000	517*	294	121	685*	557*	820*
	Sig. (2-tailed)	000	000	641	011	139	000		040	270	655	003	025	000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
9	Pearson Corre	374	527*	170	330	721*	758*	517*	1 000	881*	814*	478	810*	770*
	Sig. (2-tailed)	153	036	530	212	002	001	040		000	000	061	000	000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
10	Pearson Corre	143	256	- 106	114	636*	640*	294	881*	1 000	848*	468	899*	708**
	Sig. (2-tailed)	597	338	696	674	008	008	270	000		000	068	000	002
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
11	Pearson Corre	054	171	- 149	-.048	511*	385	121	814*	848*	1 000	184	639*	468
	Sig. (2-tailed)	843	528	581	861	043	141	655	000	000		495	008	067
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
12	Pearson Corre	389	366	-.078	712*	494	658*	685*	478	468	184	1 000	785*	822**
	Sig. (2-tailed)	137	163	.775	002	052	006	003	061	068	495		000	000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
13	Pearson Corre	328	395	-.070	377	629*	764*	557*	810*	899*	639*	785*	1 000	886**
	Sig. (2-tailed)	215	130	.797	150	009	001	025	000	000	008	000		000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
14	Pearson Corre	542*	663*	- 100	476	570*	787*	820*	770*	708*	468	822*	886**	1 000
	Sig. (2-tailed)	.030	005	712	062	021	000	000	000	002	067	000	000	
	N	16	16	16	16	16	16	16	16	16	16	16	16	16

**Correlation is significant at the 0 01 level (2-tailed)

*Correlation is significant at the 0 05 level (2-tailed)

Table 5.22.1: Correlation coefficients for pesticide in sediments from Kericho-Upper Nyando in February

Correlations

		1	3	4	5	6	7	8	9	10	11	12	13	14
1	Pearson Corre	1 000	975*	910*	682*	711*	601*	676*	576*	652*	631*	630*	598*	589*
	Sig. (2-tailed)		000	.000	004	002	014	004	019	006	009	009	014	016
	N	16	16	15	16	16	16	16	16	16	16	16	16	16
3	Pearson Corre	975*	1.000	.970*	.680*	686*	592*	662*	577*	623*	619*	620*	594*	577*
	Sig. (2-tailed)	000		.000	.004	003	016	005	019	010	011	010	015	019
	N	16	16	15	16	16	16	16	16	16	16	16	16	16
4	Pearson Corre	910*	970*	1.000	994*	989*	997*	989*	984*	973*	991*	998*	987*	996*
	Sig. (2-tailed)	.000	000		.000	.000	000	000	000	000	000	000	000	000
	N	15	15	15	15	15	15	15	15	15	15	15	15	15
5	Pearson Corre	682*	.680*	.994*	1.000	.992*	992*	988*	982*	983*	993*	994*	992*	990*
	Sig. (2-tailed)	004	004	.000		000	000	000	000	000	000	000	000	000
	N	16	16	15	16	16	16	16	16	16	16	16	16	16
6	Pearson Corre	.711*	.686*	.989*	992*	1.000	986*	990*	975*	984*	990*	988*	979*	985*
	Sig. (2-tailed)	002	.003	.000	.000		000	.000	000	000	000	000	.000	000
	N	16	16	15	16	16	16	16	16	16	16	16	16	16
7	Pearson Corre	.601*	.592*	.997*	992*	986*	1 000	.984*	991*	981*	996*	998*	994*	999*
	Sig. (2-tailed)	.014	016	.000	000	000		000	000	000	000	000	000	000
	N	16	16	15	16	16	16	16	16	16	16	16	16	16
8	Pearson Corre	.676*	662*	989*	988*	990*	984*	1 000	975*	978*	983*	987*	979*	983*
	Sig. (2-tailed)	.004	.005	.000	000	000	000		000	000	000	000	000	000
	N	16	16	15	16	16	16	16	16	16	16	16	16	16
9	Pearson Corre	.576*	.577*	.984*	982*	.975*	991*	975*	1 000	.971*	993*	988*	988*	991*
	Sig. (2-tailed)	.019	.019	.000	.000	000	000	000		000	000	000	000	000
	N	16	16	15	16	16	16	16	16	16	16	16	16	16
10	Pearson Corre	.652*	.623*	.973*	983*	984*	981*	978*	971*	1 000	983*	976*	989*	983*
	Sig. (2-tailed)	.006	.010	.000	.000	.000	.000	.000	000		.000	000	000	000
	N	16	16	15	16	16	16	16	16	16	16	16	16	16
11	Pearson Corre	.631*	.619*	.991*	.993*	990*	996*	.983*	993*	983*	1 000	995*	992*	996*
	Sig. (2-tailed)	.009	.011	.000	.000	.000	000	.000	000	.000		000	000	.000
	N	16	16	15	16	16	16	16	16	16	16	16	16	16
12	Pearson Corre	.630*	.620*	.998*	994*	988*	998*	987*	988*	976*	995*	1 000	990*	996*
	Sig. (2-tailed)	.009	.010	.000	000	000	000	000	.000	000	000		.000	.000
	N	16	16	15	16	16	16	16	16	16	16	16	16	16
13	Pearson Corre	.598*	.594*	.987*	992*	.979*	994*	.979*	988*	989*	992*	.990*	1.000	995*
	Sig. (2-tailed)	.014	.015	000	000	000	000	.000	000	000	000	000		000
	N	16	16	15	16	16	16	16	16	16	16	16	16	16
14	Pearson Corre	589*	.577*	.996*	990*	.985*	.999*	983*	991*	983*	996*	996*	995*	1 000
	Sig. (2-tailed)	.016	.019	.000	000	000	000	000	000	000	.000	000	000	
	N	16	16	15	16	16	16	16	16	16	16	16	16	16

**Correlation is significant at the 0.01 level (2-tailed).

*Correlation is significant at the 0 05 level (2-tailed)

Table 5.23.1: Correlation coefficients for pesticide in weeds from Kericho-Upper Nyando in February

Correlations

		1	3	4	5	6	7	8	9	10	11	12	13	14
1	Pearson Corre	1.000	.820*	.456	.964*	.638*	.789*	.810*	.918*	.225	a	.697*	a	.778*
	Sig. (2-tailed)		.000	.076	.000	.008	.000	.000	.000	.402		.003		.000
	N	16	16	16	15	16	16	16	16	16	16	16	16	16
3	Pearson Corre	.820*	1.000	.811*	.921*	.937*	.965*	.947*	.956*	.491	a	.865*	a	.963*
	Sig. (2-tailed)	.000	.	.000	.000	.000	.000	.000	.000	.053		.000		.000
	N	16	16	16	15	16	16	16	16	16	16	16	16	16
4	Pearson Corre	.456	.811*	1.000	.548*	.914*	.772*	.659*	.625*	.431	a	.581*	a	.746*
	Sig. (2-tailed)	.076	.000		.034	.000	.000	.005	.010	.095		.018		.001
	N	16	16	16	15	16	16	16	16	16	16	16	16	16
5	Pearson Corre	.964*	.921*	.548*	1.000	.760*	.905*	.942*	.985*	.422	a	.814*	a	.923*
	Sig. (2-tailed)	.000	.000	.034		.001	.000	.000	.000	.117		.000		.000
	N	15	15	15	15	15	15	15	15	15	15	15	15	15
6	Pearson Corre	.638*	.937*	.914*	.760*	1.000	.894*	.834*	.820*	.486	a	.778*	a	.903*
	Sig. (2-tailed)	.008	.000	.000	.001		.000	.000	.000	.056		.000		.000
	N	16	16	16	15	16	16	16	16	16	16	16	16	16
7	Pearson Corre	.789*	.965*	.772*	.905*	.894*	1.000	.948*	.928*	.591*	a	.906*	a	.961*
	Sig. (2-tailed)	.000	.000	.000	.000	.000		.000	.000	.016		.000		.000
	N	16	16	16	15	16	16	16	16	16	16	16	16	16
8	Pearson Corre	.810*	.947*	.659*	.942*	.834*	.948*	1.000	.943*	.662*	a	.899*	a	.943*
	Sig. (2-tailed)	.000	.000	.005	.000	.000	.000		.000	.005		.000		.000
	N	16	16	16	15	16	16	16	16	16	16	16	16	16
9	Pearson Corre	.918*	.956*	.625*	.985*	.820*	.928*	.943*	1.000	.401	a	.838*	a	.933*
	Sig. (2-tailed)	.000	.000	.010	.000	.000	.000	.000		.124		.000		.000
	N	16	16	16	15	16	16	16	16	16	16	16	16	16
10	Pearson Corre	.225	.491	.431	.422	.486	.591*	.662*	.401	1.000	a	.662*	a	.566*
	Sig. (2-tailed)	.402	.053	.095	.117	.056	.016	.005	.124			.005		.022
	N	16	16	16	15	16	16	16	16	16	16	16	16	16
11	Pearson Corre	a	a	a	a	a	a	a	a	a	a	a	a	a
	Sig. (2-tailed)													
	N	16	16	16	15	16	16	16	16	16	16	16	16	16
12	Pearson Corre	.697*	.865*	.581*	.814*	.778*	.906*	.899*	.838*	.662*	a	1.000	a	.879*
	Sig. (2-tailed)	.003	.000	.018	.000	.000	.000	.000	.000	.005				.000
	N	16	16	16	15	16	16	16	16	16	16	16	16	16
13	Pearson Corre	a	a	a	a	a	a	a	a	a	a	a	a	a
	Sig. (2-tailed)													
	N	16	16	16	15	16	16	16	16	16	16	16	16	16
14	Pearson Corre	.778*	.963*	.746*	.923*	.903*	.961*	.943*	.933*	.566*	a	.879*	a	1.000
	Sig. (2-tailed)	.000	.000	.001	.000	.000	.000	.000	.000	.022		.000		
	N	16	16	16	15	16	16	16	16	16	16	16	16	16

**Correlation is significant at the 0.01 level (2-tailed)

*Correlation is significant at the 0.05 level (2-tailed).

a Cannot be computed because at least one of the variables is constant

Table 5.24.1: Correlation coefficients for pesticide in water from Nandi-Lower Nyando in February

Correlations

		15	16	17	18	19	21	22	23	25	26	27	30	33
15	Pearson Correl	1 000	973*	993*	888*	670*	525*	723*	844*	615*	942**	952*	a	760*
	Sig (2-tailed)		000	000	000	005	037	002	000	011	000	000		001
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
16	Pearson Correl	973*	1 000	969*	902*	650*	550*	729*	817*	675*	917*	922*	a	757*
	Sig (2-tailed)	000		000	000	006	027	001	000	004	000	000		001
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
17	Pearson Correl	993*	969*	1 000	919*	740*	564*	757*	866*	641*	967*	970*	a	800*
	Sig (2-tailed)	000	000		000	001	023	001	000	007	000	000		000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
18	Pearson Correl	888*	902*	919*	1 000	744*	608*	795*	893*	647*	957*	945*	a	877*
	Sig (2-tailed)	000	000	000		001	013	000	000	007	000	000		000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
19	Pearson Correl	670*	650*	740*	744*	1 000	604*	726*	702*	487	771*	730*	a	636*
	Sig (2-tailed)	005	006	001	001		013	001	002	055	000	001		008
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
21	Pearson Correl	525*	550*	564*	608*	604*	1 000	922*	832*	370	611*	615*	a	626*
	Sig (2-tailed)	037	027	023	013	013		000	000	158	012	011		009
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
22	Pearson Correl	723*	729*	757*	795*	726*	922*	1 000	950*	490	803*	813*	a	758*
	Sig (2-tailed)	002	001	001	000	001	000		000	054	000	000		001
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
23	Pearson Correl	844*	817*	866*	893*	702*	832*	950*	1.000	500*	911*	920*	a	840*
	Sig (2-tailed)	000	000	000	000	002	000	000		048	000	000		000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
25	Pearson Correl	615*	675*	641*	647*	487	370	490	500*	1 000	611*	578*	a	759*
	Sig (2-tailed)	011	004	007	007	055	158	054	048		012	019		001
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
26	Pearson Correl	942*	917*	967*	957*	771*	611*	803*	911*	611*	1 000	993*	a	883*
	Sig (2-tailed)	000	000	000	000	000	012	000	000	012		000		000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
27	Pearson Correl	952*	922*	970*	945*	730*	615*	813*	920*	578*	993*	1 000	a	859*
	Sig (2-tailed)	000	000	000	000	001	011	000	000	019	000			000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
30	Pearson Correl	a	a	a	a	a	a	a	a	a	a	a	a	a
	Sig (2-tailed)													
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
33	Pearson Correl	760*	757*	800*	877*	836*	626*	758*	840*	759*	883*	859*	a	1.000
	Sig (2-tailed)	001	001	000	000	008	009	001	000	001	000	000		
	N	16	16	16	16	16	16	16	16	16	16	16	16	16

** Correlation is significant at the 0 01 level (2-tailed)

* Correlation is significant at the 0 05 level (2-tailed)

a Cannot be computed because at least one of the variables is constant

Table 5.25.1: Correlation coefficients for pesticide in sediments from Nandi-Lower Nyando in February

Correlations

		15	16	17	18	19	21	22	23	25	26	27	30	33
15	Pearson Corre	1 000	992*	998*	999*	998*	.978*	-.045	999*	396	997*	987*	341	499*
	Sig (2-tailed)	.	000	.000	000	000	000	869	000	129	000	000	196	049
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
16	Pearson Corre	992*	1.000	994*	992*	986*	970*	033	993*	471	994*	983*	415	561*
	Sig (2-tailed)	.000	.	.000	.000	000	000	.905	000	066	000	000	110	024
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
17	Pearson Corre	.998*	994*	1.000	998*	995*	976*	-.025	998*	411	997*	987*	334	506*
	Sig. (2-tailed)	000	.000		000	000	.000	.928	000	.114	000	000	206	046
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
18	Pearson Corre	999*	992*	.998*	1.000	997*	976*	-.046	998*	386	997*	986*	339	494
	Sig (2-tailed)	.000	.000	.000	.	.000	000	866	000	140	000	000	199	052
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
19	Pearson Corre	.998*	.986*	.995*	.997*	1.000	977*	-.054	996*	389	994*	982*	323	478
	Sig. (2-tailed)	000	000	.000	000		000	842	000	137	000	000	223	061
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
21	Pearson Corre	978*	.970*	.976*	976*	977*	1 000	-.047	978*	393	974*	.963*	350	500*
	Sig. (2-tailed)	.000	.000	.000	.000	000		862	.000	.132	000	.000	.184	048
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
22	Pearson Corre	-.045	033	-.025	-.046	-.054	-.047	1.000	-.048	363	.010	-.016	567*	673*
	Sig. (2-tailed)	869	905	928	866	842	862		861	167	971	953	022	004
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
23	Pearson Corre	.999*	993*	.998*	998*	996*	.978*	-.048	1.000	402	.996*	989*	341	501*
	Sig. (2-tailed)	000	.000	000	000	000	000	861		123	.000	000	196	048
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
25	Pearson Corre	.396	.471	411	386	.389	.393	.363	402	1 000	.396	393	693*	633*
	Sig. (2-tailed)	.129	066	.114	.140	.137	.132	167	123		129	132	003	.008
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
26	Pearson Corre	.997*	.994*	.997*	.997*	.994*	.974*	.010	996*	396	1 000	990*	364	.516*
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.971	000	129		000	.166	041
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
27	Pearson Corre	.987*	983*	.987*	986*	982*	963*	-.016	989*	393	990*	1.000	367	484
	Sig. (2-tailed)	.000	000	000	000	000	000	.953	.000	132	000		162	057
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
30	Pearson Corre	.341	.415	.334	339	323	.350	567*	341	693*	364	367	1 000	729*
	Sig (2-tailed)	.196	.110	.206	199	223	184	022	196	003	.166	162	.	001
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
33	Pearson Corre	.499*	.561*	.506*	494	478	.500*	673*	.501*	633*	.516*	484	729*	1.000
	Sig. (2-tailed)	.049	024	.046	052	.061	048	.004	048	008	.041	057	001	
	N	16	16	16	16	16	16	16	16	16	16	16	16	16

**Correlation is significant at the 0 01 level (2-tailed)

*Correlation is significant at the 0.05 level (2-tailed)

Table 5.26.1: Correlation coefficients for pesticide in weeds from Nandi-Lower Nyando in February

Correlations

		15	16	17	18	19	21	22	23	25	26	27	30	33
15	Pearson Corre	1 000	550*	911**	555*	431	258	- 109	- 086	- 170	a	578*	a	a
	Sig (2-tailed)		027	000	032	096	335	689	753	528		019		
	N	16	16	16	15	16	16	16	16	16	16	16	16	16
16	Pearson Corre	550*	1 000	763**	729**	618*	863**	- 118	103	- 125	a	516*	a	a
	Sig (2-tailed)	027		001	002	011	000	662	704	644		041		
	N	16	16	16	15	16	16	16	16	16	16	16	16	16
17	Pearson Corre	911**	763**	1 000	736**	536*	559*	- 120	- 023	- 147	a	573*	a	a
	Sig (2-tailed)	000	001		002	033	024	657	934	587		020		
	N	16	16	16	15	16	16	16	16	16	16	16	16	16
18	Pearson Corre	555*	729**	736**	1 000	726**	754**	- 185	- 218	126	a	743**	a	a
	Sig (2-tailed)	032	002	002		002	001	509	435	655		002		
	N	15	15	15	15	15	15	15	15	15	15	15	15	15
19	Pearson Corre	431	618*	536*	726**	1 000	661**	- 140	- 055	011	a	939**	a	a
	Sig (2-tailed)	096	011	033	002		005	604	839	969		000		
	N	16	16	16	15	16	16	16	16	16	16	16	16	16
21	Pearson Corre	258	863**	559*	754**	661**	1 000	- 045	209	- 027	a	435	a	a
	Sig (2-tailed)	335	000	024	001	005		870	438	920		092		
	N	16	16	16	15	16	16	16	16	16	16	16	16	16
22	Pearson Corre	- 109	-.118	- 120	- 185	- 140	- 045	1 000	314	- 151	a	- 145	a	a
	Sig (2-tailed)	689	662	657	509	604	870		237	578		593		
	N	16	16	16	15	16	16	16	16	16	16	16	16	16
23	Pearson Corre	- 086	.103	- 023	- 218	-.055	209	.314	1 000	- 220	a	- 197	a	a
	Sig (2-tailed)	753	704	934	435	839	438	237		413		464		
	N	16	16	16	15	16	16	16	16	16	16	16	16	16
25	Pearson Corre	- 170	- 125	- 147	126	011	-.027	- 151	- 220	1 000	a	- 041	a	a
	Sig (2-tailed)	528	644	587	655	969	920	578	413			879		
	N	16	16	16	15	16	16	16	16	16	16	16	16	16
26	Pearson Corre	a	a	a	a	a	a	a	a	a	a	a	a	a
	Sig (2-tailed)													
	N	16	16	16	15	16	16	16	16	16	16	16	16	16
27	Pearson Corre	578*	516*	573*	743**	939**	435	- 145	- 197	- 041	a	1 000	a	a
	Sig (2-tailed)	019	041	020	002	000	092	593	464	879				
	N	16	16	16	15	16	16	16	16	16	16	16	16	16
30	Pearson Corre	a	a	a	a	a	a	a	a	a	a	a	a	a
	Sig (2-tailed)													
	N	16	16	16	15	16	16	16	16	16	16	16	16	16
33	Pearson Corre	a	a	a	a	a	a	a	a	a	a	a	a	a
	Sig (2-tailed)													
	N	16	16	16	15	16	16	16	16	16	16	16	16	16

* Correlation is significant at the 0 05 level (2-tailed)

** Correlation is significant at the 0 01 level (2-tailed)

a Cannot be computed because at least one of the variables is constant

Table 5.31.1: Correlation coefficients for pesticide in water from Kericho-Upper Nyando in May

Correlations

		1	3	4	5	6	7	8	9	10	11	12	13	14
1	Pearson Corr	1 000	198	181	764*	564*	507*	316	136	097	313	308	188	261
	Sig (2-tailed)		463	503	001	023	045	234	616	721	238	245	486	329
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
3	Pearson Corr	198	1.000	729*	366	441	308	701*	788*	740*	869*	662*	804*	912*
	Sig (2-tailed)	463		001	163	088	245	002	000	001	000	005	000	000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
4	Pearson Corr	181	.729*	1 000	275	223	-.143	979*	993*	993*	345	961*	987*	933*
	Sig (2-tailed)	503	.001		302	407	597	000	000	000	191	000	000	000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
5	Pearson Corr	764*	.366	.275	1 000	835*	239	414	240	182	526*	395	317	434
	Sig (2-tailed)	001	163	302		000	372	111	371	500	036	130	232	093
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
6	Pearson Corr	564*	441	223	835*	1 000	214	362	214	160	669*	366	323	435
	Sig (2-tailed)	023	088	407	000		426	169	426	555	005	164	222	092
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
7	Pearson Corr	507*	.308	-.143	239	214	1 000	- 099	- 084	- 130	515*	- 171	- 072	092
	Sig (2-tailed)	045	245	.597	372	426		716	757	630	041	526	791	736
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
8	Pearson Corr	316	.701*	.979*	414	362	- 099	1 000	961*	957*	368	981*	974*	926*
	Sig (2-tailed)	234	002	.000	.111	169	716		000	000	161	000	000	000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
9	Pearson Corr	136	788*	.993*	240	214	- 084	961*	1 000	996*	413	938*	993*	953*
	Sig. (2-tailed)	616	000	000	371	426	757	000		000	112	000	000	000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
10	Pearson Corr	097	740*	993*	182	160	- 130	957*	996*	1 000	341	938*	985*	926*
	Sig (2-tailed)	.721	001	000	500	555	630	000	.000		196	000	000	000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
11	Pearson Corr	313	869*	345	526*	669*	515*	368	413	341	1 000	330	464	654*
	Sig (2-tailed)	238	000	191	036	005	041	161	112	196		212	070	006
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
12	Pearson Corr	308	662*	961*	395	366	- 171	981*	938*	938*	330	1 000	954*	892*
	Sig (2-tailed)	245	005	000	.130	164	526	000	000	000	212		000	000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
13	Pearson Corr	188	804*	987*	317	323	- 072	974*	993*	985*	464	954*	1 000	969*
	Sig (2-tailed)	486	000	.000	232	222	791	.000	000	000	070	000		000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
14	Pearson Corr	261	912*	933*	434	435	092	926*	953*	926*	654*	892*	969*	1 000
	Sig (2-tailed)	329	000	000	093	.092	736	000	000	000	006	000	000	
	N	16	16	16	16	16	16	16	16	16	16	16	16	16

**Correlation is significant at the 0 01 level (2-tailed)

*Correlation is significant at the 0 05 level (2-tailed)

Table 5.32.1: Correlation coefficients for pesticide in sediments from Kericho-Upper Nyando in May

Correlations

		1	3	4	5	6	7	8	9	10	11	12	13	14
1	Pearson Correla	1 000	989*	995*	953*	819*	992*	883*	986*	914*	- 065	593*	798*	967*
	Sig (2-tailed)		000	000	000	000	000	000	000	000	811	016	000	000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
3	Pearson Correla	989*	1 000	987*	917*	848*	993*	911*	979*	939*	006	580*	770*	940*
	Sig (2-tailed)	000		000	000	000	000	000	000	000	982	019	000	000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
4	Pearson Correla	995*	987*	1 000	946*	802*	997*	878*	993*	914*	- 070	603*	801*	966*
	Sig (2-tailed)	000	000		000	000	000	000	000	000	797	013	000	000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
5	Pearson Correla	953*	917*	946*	1 000	791*	926*	834*	947*	862*	- 096	636*	865*	981*
	Sig (2-tailed)	000	000	000		000	000	000	000	000	724	008	000	000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
6	Pearson Correla	819*	848*	802*	791*	1 000	822*	849*	774*	882*	338	441	720*	779*
	Sig (2-tailed)	000	000	000	000		000	000	000	000	200	087	002	000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
7	Pearson Correla	992*	993*	997*	926*	822*	1 000	894*	989*	928*	- 027	594*	778*	952*
	Sig (2-tailed)	000	000	000	000	000		000	000	000	922	015	000	000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
8	Pearson Correla	883*	911*	878*	834*	849*	894*	1 000	900*	957*	144	731*	610*	868*
	Sig (2-tailed)	000	000	000	000	000	000		000	000	594	001	012	000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
9	Pearson Correla	986*	979*	993*	947*	774*	989*	900*	1 000	921*	- 081	669*	783*	971*
	Sig (2-tailed)	000	000	000	000	000	000	000		000	765	005	000	000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
10	Pearson Correla	914*	939*	914*	862*	882*	928*	957*	921*	1 000	234	706*	659*	897*
	Sig (2-tailed)	000	000	000	000	000	000	000	000		383	002	005	000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
11	Pearson Correla	- 065	006	- 070	- 096	338	- 027	144	- 081	234	1 000	145	- 067	- 082
	Sig (2-tailed)	811	982	797	724	200	922	594	765	383		591	806	762
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
12	Pearson Correla	593*	580*	603*	636*	441	594*	731*	669*	706*	145	1 000	387	694*
	Sig (2-tailed)	016	019	013	008	087	015	001	005	002	591		139	003
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
13	Pearson Correla	798*	770*	801*	865*	720*	778*	610*	783*	659*	- 067	387	1 000	820*
	Sig (2-tailed)	000	000	000	000	002	000	012	000	005	806	139		000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
14	Pearson Correla	967*	940*	966*	981*	779*	952*	868*	971*	897*	- 082	694*	820*	1 000
	Sig (2-tailed)	000	000	000	000	000	000	000	000	000	762	003	000	
	N	16	16	16	16	16	16	16	16	16	16	16	16	16

** Correlation is significant at the 0 01 level (2-tailed)

* Correlation is significant at the 0 05 level (2-tailed)

Table 5.33.1: Correlation coefficients for pesticide in weeds from Kericho-Upper Nyando in May

Correlations

		1	3	4	5	6	7	8	9	10	11	12	13	14
1	Pearson Corre	1 000	984*	987*	.973*	-.018	975*	885*	905*	588*	977*	709*	917*	968*
	Sig. (2-tailed)		.000	.000	.000	.948	000	.000	000	017	000	002	000	000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
3	Pearson Corre	984*	1 000	.981*	969*	- 102	971*	860*	903*	590*	982*	678*	887*	969*
	Sig. (2-tailed)	.000		000	000	707	000	000	000	016	000	004	000	000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
4	Pearson Corre	.987*	.981*	1.000	974*	.000	983*	874*	929*	577*	978*	.729*	931*	985*
	Sig. (2-tailed)	000	.000		000	1 000	000	000	000	019	000	001	000	000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
5	Pearson Corre	.973*	.969*	974*	1 000	-.008	959*	847*	906*	654*	979*	753*	896*	984*
	Sig. (2-tailed)	.000	000	000		975	000	000	000	006	000	001	000	000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
6	Pearson Corre	-.018	-.102	.000	-.008	1 000	-.002	-.047	244	- 159	- 103	071	073	- 029
	Sig. (2-tailed)	948	.707	1 000	975		993	.864	.363	556	704	793	787	914
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
7	Pearson Corre	.975*	.971*	983*	.959*	-.002	1 000	897*	915*	597*	978*	709*	923*	961*
	Sig. (2-tailed)	.000	.000	.000	.000	993		000	000	015	000	002	000	000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
8	Pearson Corre	885*	.860*	874*	.847*	-.047	897*	1 000	830*	663*	899*	616*	801*	857*
	Sig. (2-tailed)	.000	.000	.000	.000	864	000		000	005	.000	011	000	000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
9	Pearson Corre	.905*	.903*	.929*	906*	.244	915*	.830*	1.000	470	.882*	.675*	839*	.915*
	Sig. (2-tailed)	.000	.000	.000	.000	.363	000	.000		.066	.000	.004	000	.000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
10	Pearson Corre	588*	.590*	.577*	654*	-.159	597*	.663*	470	1 000	.682*	.699*	594*	.641*
	Sig. (2-tailed)	.017	.016	.019	.006	556	015	.005	.066		.004	.003	015	008
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
11	Pearson Corre	977*	.982*	.978*	.979*	-.103	978*	.899*	882*	682*	1.000	735*	908*	978*
	Sig. (2-tailed)	.000	.000	.000	.000	704	000	000	000	.004		001	000	000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
12	Pearson Corre	.709*	.678*	.729*	.753*	.071	709*	.616*	675*	.699*	735*	1 000	855*	777*
	Sig. (2-tailed)	.002	.004	.001	.001	793	002	011	004	003	.001		000	000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
13	Pearson Corre	917*	.887*	931*	896*	073	923*	801*	839*	594*	908*	855*	1 000	906*
	Sig. (2-tailed)	.000	.000	.000	.000	787	000	000	000	015	.000	000		000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
14	Pearson Corre	.968*	969*	985*	984*	- 029	961*	857*	.915*	641*	978*	777*	906*	1 000
	Sig. (2-tailed)	.000	.000	.000	.000	.914	.000	.000	000	008	000	000	000	
	N	16	16	16	16	16	16	16	16	16	16	16	16	16

**Correlation is significant at the 0.01 level (2-tailed)

*Correlation is significant at the 0 05 level (2-tailed)

Table 5.34.1: Correlation coefficients for pesticide in water from Nandi-Lower Nyando in May

Correlations

		15	16	17	18	19	21	22	23	25	26	27	30	33
15	Pearson Corre	1.000	043	.a	.016	296	077	098	- 005	042	208	405	- 019	813*
	Sig (2-tailed)		873	.	953	266	777	719	985	876	441	120	945	000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
16	Pearson Corre	.043	1 000	a	985*	147	990*	990*	996*	998*	386	-061	- 115	-066
	Sig (2-tailed)	.873			000	588	000	.000	.000	000	140	824	671	808
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
17	Pearson Corre	a	a	a	a	a	a	a	a	a	a	a	a	a
	Sig (2-tailed)													
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
18	Pearson Corre	016	985*	a	1 000	188	972*	979*	982*	986*	452	- 037	-.165	- 089
	Sig (2-tailed)	.953	.000	.		485	000	000	.000	000	079	891	542	742
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
19	Pearson Corre	.296	.147	.a	.188	1.000	243	202	.081	133	461	847*	104	479
	Sig (2-tailed)	.266	588	.	.485		365	453	765	622	072	000	702	060
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
21	Pearson Corre	.077	990*	a	.972*	.243	1.000	988*	976*	986*	382	065	- 054	018
	Sig. (2-tailed)	.777	000		000	.365		000	.000	000	144	810	843	947
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
22	Pearson Corre	.098	.990*	a	979*	202	988*	1.000	982*	987*	430	003	- 127	- 017
	Sig. (2-tailed)	.719	000	.	000	453	000		000	000	096	990	639	950
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
23	Pearson Corre	-.005	996*	a	982*	081	976*	982*	1.000	995*	.359	-.141	- 145	- 136
	Sig. (2-tailed)	.985	.000		.000	.765	000	.000		000	172	601	592	617
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
25	Pearson Corre	.042	.998*	a	986*	.133	986*	987*	.995*	1.000	.380	-.071	-.084	-.072
	Sig. (2-tailed)	.876	.000		000	622	000	000	000		146	793	758	791
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
26	Pearson Corre	.208	.386	a	452	461	382	430	359	380	1 000	336	-.194	165
	Sig (2-tailed)	.441	140		079	072	144	096	172	146		203	471	541
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
27	Pearson Corre	.405	-.061	a	-.037	.847*	065	003	-.141	- 071	336	1 000	333	657*
	Sig. (2-tailed)	.120	.824		.891	000	.810	.990	.601	793	203		207	006
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
30	Pearson Corre	-.019	-.115	a	-.165	104	- 054	- 127	-.145	- 084	-.194	333	1 000	110
	Sig. (2-tailed)	945	.671		.542	702	.843	639	592	758	471	207		686
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
33	Pearson Corre	.813*	-.066	a	-.089	.479	018	-.017	- 136	-.072	165	657*	110	1 000
	Sig (2-tailed)	000	808		742	060	.947	950	617	791	541	006	686	
	N	16	16	16	16	16	16	16	16	16	16	16	16	16

**Correlation is significant at the 0 01 level (2-tailed)

a Cannot be computed because at least one of the variables is constant

Table 5.35.1: Correlation coefficients for pesticide in sediments from Nandi-Lower Nyando in May

Correlations

		15	16	17	18	19	21	22	23	25	26	27	30	33
15	Pearson Correla	1 000	948*	949*	943*	983*	599*	993*	944*	935*	918*	945*	023	788*
	Sig (2-tailed)		000	000	000	000	018	000	000	000	000	000	933	000
	N	16	16	16	16	16	15	15	16	16	16	16	16	16
16	Pearson Correla	948*	1 000	978*	950*	950*	489	939*	835*	948*	968*	947*	- 072	851*
	Sig (2-tailed)	000		000	000	000	065	000	000	000	000	000	790	000
	N	16	16	16	16	16	15	15	16	16	16	16	16	16
17	Pearson Correla	949*	978*	1 000	984*	952*	557*	936*	821*	979*	977*	983*	- 120	815*
	Sig (2-tailed)	000	000		000	000	031	000	000	000	000	000	658	000
	N	16	16	16	16	16	15	15	16	16	16	16	16	16
18	Pearson Correla	943*	950*	984*	1 000	931*	547*	934*	840*	993*	965*	989*	- 116	817*
	Sig (2-tailed)	000	000	000		000	035	000	000	000	000	000	669	000
	N	16	16	16	16	16	15	15	16	16	16	16	16	16
19	Pearson Correla	983*	950*	952*	931*	1 000	639*	973*	907*	918*	910*	941*	- 041	755*
	Sig (2-tailed)	000	000	000	000		010	000	000	000	000	000	879	001
	N	16	16	16	16	16	15	15	16	16	16	16	16	16
21	Pearson Correla	599*	489	557*	547*	639*	1 000	554*	562*	532*	511	569*	- 063	388
	Sig (2-tailed)	018	065	031	035	010		040	029	041	052	027	825	153
	N	15	15	15	15	15	15	14	15	15	15	15	15	15
22	Pearson Correla	993*	939*	936*	934*	973*	554*	1 000	945*	932*	898*	938*	083	782*
	Sig (2-tailed)	000	000	000	000	000	040		000	000	000	000	769	001
	N	15	15	15	15	15	14	15	15	15	15	15	15	15
23	Pearson Correla	944*	835*	821*	840*	907*	562*	945*	1 000	847*	775*	834*	093	696*
	Sig (2-tailed)	000	000	000	000	000	029	000		000	000	000	731	003
	N	16	16	16	16	16	15	15	16	16	16	16	16	16
25	Pearson Correla	.935*	848*	979*	993*	918*	532*	932*	847*	1 000	957*	978*	- 124	821*
	Sig. (2-tailed)	.000	.000	000	000	000	041	000	000		000	000	647	000
	N	16	16	16	16	16	15	15	16	16	16	16	16	16
26	Pearson Correla	918*	968*	977*	965*	910*	511	898*	775*	957*	1 000	958*	- 138	851*
	Sig (2-tailed)	000	.000	000	000	000	052	000	000	000		000	611	000
	N	16	16	16	16	16	15	15	16	16	16	16	16	16
27	Pearson Correla	945*	947*	983*	989*	941*	569*	938*	834*	978*	958*	1 000	- 140	759*
	Sig (2-tailed)	000	000	000	000	000	027	000	000	000	000		605	001
	N	16	16	16	16	16	15	15	16	16	16	16	16	16
30	Pearson Correla	023	- 072	- 120	- 116	- 041	- 063	083	093	- 124	- 138	- 140	1 000	219
	Sig (2-tailed)	933	790	658	669	879	825	769	731	647	611	605		415
	N	16	16	16	16	16	15	15	16	16	16	16	16	16
33	Pearson Correla	.788*	851*	815*	817*	755*	388	782*	696*	821*	851*	759*	219	1 000
	Sig (2-tailed)	000	000	000	000	001	153	001	003	000	000	001	415	
	N	16	16	16	16	16	15	15	16	16	16	16	16	16

** Correlation is significant at the 0 01 level (2-tailed)

* Correlation is significant at the 0 05 level (2-tailed)

Table 5.36.1: Correlation coefficients for pesticide in weeds from Nandi-Lower Nyando in May

Correlations

		15	16	17	18	19	21	22	23	25	26	27	30	33
15	Pearson Correl	1 000	887*	949*	-.055	- 064	.837*	200	603*	832*	529*	913*	303	911*
	Sig (2-tailed)	.	.000	.000	840	.815	.000	.458	013	000	035	000	254	000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
16	Pearson Correl	887*	1.000	.890*	173	.178	.895*	213	447	846*	.706**	839*	372	877*
	Sig (2-tailed)	.000		.000	.521	509	000	429	083	000	.002	000	156	000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
17	Pearson Correl	949*	.890*	1.000	192	139	.809*	220	578*	815*	486	919**	329	859*
	Sig (2-tailed)	.000	.000		477	606	.000	414	019	000	056	000	213	000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
18	Pearson Correl	-.055	.173	192	1.000	933*	058	131	-.228	- 009	- 057	- 037	- 238	- 149
	Sig (2-tailed)	840	.521	.477	.	000	830	628	396	973	835	891	375	582
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
19	Pearson Correl	-.064	.178	.139	933*	1.000	.008	082	-.218	- 057	- 069	- 088	-.197	- 170
	Sig. (2-tailed)	.815	.509	.606	000		.977	.764	418	835	800	.746	465	530
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
21	Pearson Correl	.837*	895*	809*	.058	.008	1 000	305	482	858*	.593*	824*	316	826*
	Sig. (2-tailed)	.000	.000	000	830	.977		251	059	000	015	000	233	000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
22	Pearson Correl	.200	213	.220	131	.082	305	1 000	473	219	243	181	033	199
	Sig. (2-tailed)	.458	429	.414	628	.764	251		064	415	365	501	904	460
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
23	Pearson Correl	603*	447	.578*	-.228	-.218	482	.473	1 000	.535*	.379	.691*	432	625*
	Sig. (2-tailed)	.013	083	.019	.396	.418	.059	064		033	.148	003	095	010
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
25	Pearson Correl	.832*	846*	.815*	-.009	-.057	858*	219	535*	1 000	784*	.918*	586*	931*
	Sig. (2-tailed)	.000	000	.000	973	835	.000	415	033		000	000	017	000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
26	Pearson Correl	529*	.706*	486	-.057	-.069	593*	243	379	784*	1 000	641*	622*	781*
	Sig. (2-tailed)	.035	.002	.056	.835	800	.015	365	148	000		007	.010	.000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
27	Pearson Correl	913*	839*	919*	- 037	- 088	.824*	181	691*	918*	641*	1 000	583*	945*
	Sig. (2-tailed)	.000	.000	.000	891	.746	.000	501	003	000	007		018	.000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
30	Pearson Correl	.303	372	.329	-.238	- 197	316	- 033	432	586*	622*	583*	1 000	557*
	Sig. (2-tailed)	254	156	.213	375	.465	.233	904	095	017	010	018		025
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
33	Pearson Correl	.911*	877*	859*	- 149	- 170	.826*	199	625*	931*	781*	945*	557*	1 000
	Sig. (2-tailed)	000	.000	.000	.582	530	.000	460	.010	000	.000	000	025	
	N	16	16	16	16	16	16	16	16	16	16	16	16	16

**. Correlation is significant at the 0.01 level (2-tailed)

*. Correlation is significant at the 0 05 level (2-tailed).

Table 5.41.1: Correlation coefficients for pesticide in water from Kericho-Upper Nyando in September

Correlations

		1	3	4	5	6	7	8	9	10	11	12	13	14
1	Pearson Correl	1.000	097	986*	971*	994*	969*	977*	407	922*	988*	- 140	933*	983*
	Sig. (2-tailed)		.721	000	000	000	000	000	118	000	000	606	000	000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
3	Pearson Correl	.097	1 000	- 018	.083	037	024	185	910*	382	- 008	162	059	- 027
	Sig. (2-tailed)	.721	.	946	.759	891	.929	492	000	144	977	549	828	921
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
4	Pearson Correl	.986*	-.018	1.000	985*	996*	.973*	975*	288	886*	994*	- 162	943*	996*
	Sig. (2-tailed)	.000	946		000	000	000	000	280	000	000	548	000	000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
5	Pearson Correl	.971*	.083	985*	1 000	976*	951*	994*	369	907*	969*	- 162	934*	987*
	Sig. (2-tailed)	.000	.759	.000		.000	000	000	160	000	000	548	000	000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
6	Pearson Correl	.994*	037	.996*	.976*	1.000	.978*	.975*	341	909*	.997*	-.142	944*	988*
	Sig. (2-tailed)	.000	.891	.000	.000		.000	.000	196	000	000	600	000	000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
7	Pearson Correl	.969*	.024	.973*	951*	.978*	1.000	949*	317	873*	987*	- 008	976*	964*
	Sig. (2-tailed)	.000	.929	000	.000	000		000	232	000	000	977	000	000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
8	Pearson Correl	977*	.185	.975*	994*	975*	949*	1 000	462	941*	964*	- 138	933*	974*
	Sig. (2-tailed)	.000	.492	.000	.000	000	000		072	000	000	611	000	000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
9	Pearson Correl	.407	.910*	288	.369	341	.317	462	1 000	608*	297	041	346	289
	Sig. (2-tailed)	.118	.000	.280	.160	196	232	072		012	264	880	190	278
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
10	Pearson Correl	.922*	382	886*	.907*	909*	873*	941*	608*	1 000	891*	- 065	866*	876*
	Sig. (2-tailed)	000	.144	.000	.000	.000	000	.000	012		000	812	000	.000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
11	Pearson Correl	988*	-.008	994*	969*	.997*	.987*	964*	297	891*	1 000	- 099	957*	986*
	Sig. (2-tailed)	000	977	000	000	000	.000	.000	264	000		714	000	000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
12	Pearson Correl	-.140	.162	- 162	-.162	- 142	-.008	- 138	041	-.065	- 099	1 000	100	-.181
	Sig. (2-tailed)	.606	.549	548	548	600	977	.611	880	812	714		.712	502
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
13	Pearson Correl	.933*	.059	943*	934*	944*	976*	.933*	346	866*	957*	100	1 000	934*
	Sig. (2-tailed)	.000	828	000	000	000	000	.000	190	000	000	712		000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
14	Pearson Correl	.983*	-.027	996*	987*	988*	964*	974*	289	876*	986*	-.181	934*	1 000
	Sig. (2-tailed)	.000	921	000	000	.000	000	000	278	000	000	502	000	
	N	16	16	16	16	16	16	16	16	16	16	16	16	16

**. Correlation is significant at the 0.01 level (2-tailed)

*. Correlation is significant at the 0 05 level (2-tailed)

Table 5.42.1: Correlations for pesticide in sediments from Kericho-Upper Nyando in September

Correlations

		1	3	4	5	6	7	8	9	10	11	12	13	14
1	Pearson Correla	1 000	097	986*	971*	994*	969*	977*	407	922*	988*	- 140	933*	983*
	Sig (2-tailed)		721	000	000	000	000	000	118	000	000	606	000	000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
3	Pearson Correla	097	1 000	- 018	083	037	024	185	910*	382	- 008	162	059	- 027
	Sig (2-tailed)	721		946	759	891	929	492	000	144	977	549	828	921
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
4	Pearson Correla	986*	- 018	1 000	985*	996*	973*	975*	288	886*	994*	- 162	943**	996*
	Sig (2-tailed)	000	946		000	000	000	000	280	000	000	548	000	000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
5	Pearson Correla	971*	083	985*	1 000	976*	951*	994*	369	907*	969*	- 162	934*	987*
	Sig (2-tailed)	000	759	000		000	000	000	160	000	000	548	000	000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
6	Pearson Correla	994*	037	996*	976*	1 000	978*	975*	341	909*	997*	- 142	944*	988*
	Sig. (2-tailed)	000	891	000	000		000	000	196	000	000	600	000	000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
7	Pearson Correla	969*	024	973*	951*	978*	1 000	949*	317	873*	987*	- 008	976*	964*
	Sig (2-tailed)	000	929	000	000	000		000	232	000	000	977	000	000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
8	Pearson Correla	977*	185	975*	994*	975*	949*	1 000	462	941*	964*	- 138	933*	974*
	Sig. (2-tailed)	000	492	000	000	000	000		072	000	000	611	000	000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
9	Pearson Correla	407	910*	288	369	341	317	462	1 000	608*	297	041	346	289
	Sig (2-tailed)	118	000	280	160	196	232	072		012	264	880	190	278
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
10	Pearson Correla	922*	382	886*	907*	909*	873*	941*	608*	1 000	891*	- 065	886*	876*
	Sig (2-tailed)	000	144	000	000	000	000	000	012		000	812	000	000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
11	Pearson Correla	988*	- 008	994*	969*	997*	987*	964*	297	891*	1 000	- 099	957*	986*
	Sig (2-tailed)	000	977	000	000	000	000	000	264	000		714	000	000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
12	Pearson Correla	- 140	162	- 162	- 162	- 142	- 008	- 138	041	- 065	- 099	1 000	100	- 181
	Sig (2-tailed)	606	549	548	548	600	977	611	880	812	714		712	502
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
13	Pearson Correla	933*	059	943*	934*	944*	976*	933*	346	886*	957*	100	1 000	934*
	Sig (2-tailed)	000	828	000	000	000	000	000	190	000	000	712		000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
14	Pearson Correla	983*	- 027	996*	987*	988*	964*	974*	289	876*	986*	- 181	934*	1 000
	Sig (2-tailed)	000	921	000	000	000	000	000	278	000	000	502	000	
	N	16	16	16	16	16	16	16	16	16	16	16	16	16

** Correlation is significant at the 0 01 level (2-tailed)

* Correlation is significant at the 0 05 level (2-tailed)

Table 5.43.1: Correlation coefficients for pesticide in weeds from Kericho-Upper Nyando in September

Correlations

		1	3	4	5	6	7	8	9	10	11	12	13	14
1	Pearson Correla	1 000	750*	592*	841*	594*	680*	726*	066	904*	202	830*	489	173
	Sig (2-tailed)		001	016	000	015	004	001	807	000	453	000	054	522
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
3	Pearson Correla	750*	1 000	104	979*	966*	161	287	116	517*	057	616*	120	034
	Sig (2-tailed)	001		701	000	000	550	281	669	040	835	011	657	900
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
4	Pearson Correla	592*	104	1 000	264	- 110	906*	886*	- 015	742*	606*	802*	659*	546*
	Sig (2-tailed)	016	701		323	685	000	000	956	001	013	000	006	029
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
5	Pearson Correla	841*	979*	264	1 000	909*	347	468	137	663*	104	728*	270	097
	Sig (2-tailed)	000	000	323		000	187	067	613	005	701	001	311	722
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
6	Pearson Correla	594*	966*	-.110	909*	1 000	- 070	097	131	326	- 069	429	- 063	- 062
	Sig (2-tailed)	015	000	685	000		798	721	630	218	801	097	818	819
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
7	Pearson Correla	680*	161	906*	347	- 070	1 000	945*	061	865*	389	780*	790*	380
	Sig (2-tailed)	004	550	000	187	798		000	823	000	136	000	000	146
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
8	Pearson Correla	726*	287	886*	468	097	945*	1 000	176	905*	383	839*	777*	490
	Sig (2-tailed)	001	281	000	067	721	000		514	000	143	000	000	054
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
9	Pearson Correla	066	116	-.015	137	131	061	176	1 000	278	156	148	258	395
	Sig (2-tailed)	807	.669	956	613	630	823	514		297	564	585	335	130
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
10	Pearson Correla	904*	517*	742*	663*	326	865*	905*	278	1 000	321	872*	724*	406
	Sig (2-tailed)	000	040	001	005	218	000	000	297		225	000	002	119
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
11	Pearson Correla	202	057	606*	104	- 069	389	383	156	321	1 000	519*	228	629*
	Sig (2-tailed)	453	835	013	701	801	136	143	564	225		040	395	009
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
12	Pearson Correla	830*	616*	802*	728*	429	780*	839*	148	872*	519*	1 000	609*	546*
	Sig (2-tailed)	.000	011	000	001	097	000	000	585	000	040		012	029
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
13	Pearson Correla	489	120	659*	270	- 063	790*	777*	258	724*	228	609*	1 000	572*
	Sig (2-tailed)	054	657	006	311	818	000	000	335	002	395	012		021
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
14	Pearson Correla	173	034	546*	097	- 062	380	490	395	406	629*	546*	572*	1 000
	Sig (2-tailed)	522	900	029	722	819	146	054	130	119	009	029	021	
	N	16	16	16	16	16	16	16	16	16	16	16	16	16

** Correlation is significant at the 0 01 level (2-tailed)

* Correlation is significant at the 0 05 level (2-tailed)

Table 5.44.1: Correlation coefficients for in water from Nandi-Lower Nyando in September

Correlations

		15	16	17	18	19	21	22	23	25	26	27	30	33
15	Pearson Correla	1 000	750**	592*	841**	594*	680**	726**	066	904**	202	830**	489	173
	Sig (2-tailed)		001	016	000	015	004	001	807	000	453	000	054	522
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
16	Pearson Correla	750**	1 000	104	979**	966**	161	287	116	517*	057	616*	120	034
	Sig (2-tailed)	001		701	000	000	550	281	669	040	835	011	657	900
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
17	Pearson Correla	592*	.104	1 000	264	-.110	906**	886**	- 015	742**	606*	802**	659**	546*
	Sig (2-tailed)	.016	701		323	685	000	000	956	001	013	000	006	029
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
18	Pearson Correla	841**	979**	264	1 000	909**	347	468	137	663**	104	728**	270	097
	Sig (2-tailed)	000	.000	323		000	187	067	613	005	701	001	311	722
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
19	Pearson Correla	594*	966**	-.110	909**	1 000	- 070	097	131	326	- 069	429	- 063	- 062
	Sig (2-tailed)	015	000	685	000		798	721	630	218	801	097	818	819
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
21	Pearson Correla	680**	161	906**	347	- 070	1 000	945**	061	865**	389	780**	790**	380
	Sig (2-tailed)	004	550	000	187	798		000	823	000	136	000	000	146
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
22	Pearson Correla	726**	287	886**	468	097	945**	1 000	176	905**	383	839**	777**	490
	Sig (2-tailed)	001	281	000	067	721	000		514	000	143	000	000	054
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
23	Pearson Correla	066	116	- 015	137	131	061	176	1 000	278	156	148	258	395
	Sig (2-tailed)	807	669	956	613	.630	823	514		297	564	585	335	130
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
25	Pearson Correla	904**	.517*	.742**	663**	326	865**	905**	278	1 000	321	872**	724**	406
	Sig (2-tailed)	000	040	001	005	218	000	000	297		225	000	002	119
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
26	Pearson Correla	202	057	606*	104	- 069	389	383	156	321	1 000	519*	228	629**
	Sig (2-tailed)	453	835	013	701	801	136	143	564	225		040	395	009
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
27	Pearson Correla	830**	616*	802**	728**	429	780**	839**	148	872**	519*	1 000	609*	546*
	Sig (2-tailed)	000	.011	000	001	097	000	000	585	000	040		012	029
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
30	Pearson Correla	489	120	659**	270	- 063	790**	777**	258	724**	228	609*	1 000	572*
	Sig (2-tailed)	054	657	006	311	818	000	000	335	002	395	012		021
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
33	Pearson Correla	173	034	546*	097	- 062	380	490	395	406	629**	546*	572*	1 000
	Sig (2-tailed)	522	900	.029	722	819	146	054	130	119	009	029	021	
	N	16	16	16	16	16	16	16	16	16	16	16	16	16

** Correlation is significant at the 0 01 level (2-tailed)

* Correlation is significant at the 0 05 level (2-tailed)

Table 5.45.1: Correlations for pesticide in sediments from Nandi-Lower Nyando in September

Correlations

		15	16	17	18	19	21	22	23	25	26	27	30	33
15	Pearson Correla	1.000	665*	727*	757*	445	747*	889*	860*	- 156	645*	754*	579*	366
	Sig (2-tailed)		.005	001	001	084	001	000	000	565	007	001	019	163
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
16	Pearson Correla	665*	1 000	990*	951*	602*	838*	521*	871*	373	957*	851*	296	492
	Sig (2-tailed)	005		000	000	014	000	038	000	154	000	000	266	053
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
17	Pearson Correla	727*	990*	1 000	950*	646*	840*	597*	892*	334	938*	849*	330	506*
	Sig (2-tailed)	001	000		000	007	000	015	000	206	000	000	212	045
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
18	Pearson Correla	.757*	.951*	950*	1 000	397	939*	614*	967*	082	921*	932*	331	376
	Sig (2-tailed)	001	.000	000		128	000	011	000	763	000	000	210	151
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
19	Pearson Correla	445	602*	646*	397	1 000	253	436	348	699*	524*	230	150	570*
	Sig (2-tailed)	084	014	007	128		345	092	186	003	037	392	578	021
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
21	Pearson Correla	747*	838*	840*	939*	253	1 000	627*	939*	- 086	820*	925*	321	214
	Sig (2-tailed)	001	000	000	000	345		009	000	753	000	000	225	426
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
22	Pearson Correla	889*	521*	597*	614*	436	627*	1 000	752*	- 108	466	597*	529*	307
	Sig (2-tailed)	.000	038	015	011	092	009		001	692	069	015	035	247
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
23	Pearson Correla	860*	871*	892*	967*	348	939*	752*	1 000	- 084	857*	941*	415	309
	Sig (2-tailed)	000	000	000	000	186	000	001		757	000	000	110	244
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
25	Pearson Correla	- 156	373	334	082	699*	- 086	- 108	- 084	1 000	323	- 045	- 005	445
	Sig (2-tailed)	565	154	206	763	003	753	692	757		222	867	985	084
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
26	Pearson Correla	645*	957*	938*	921*	524*	820*	466	857*	323	1 000	879*	387	459
	Sig (2-tailed)	007	000	000	000	037	000	069	000	222		000	139	074
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
27	Pearson Correla	.754*	.851*	849*	932*	230	925*	597*	941*	- 045	879*	1 000	509*	262
	Sig (2-tailed)	.001	000	000	000	392	000	015	000	867	000		044	327
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
30	Pearson Correla	579*	296	330	331	150	321	529*	415	- 005	387	509*	1 000	425
	Sig (2-tailed)	019	266	212	210	578	225	035	110	985	139	044		101
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
33	Pearson Correla	.366	492	506*	376	570*	214	307	309	445	459	262	425	1 000
	Sig (2-tailed)	163	053	045	151	021	426	247	244	084	074	327	101	
	N	16	16	16	16	16	16	16	16	16	16	16	16	16

** Correlation is significant at the 0.01 level (2-tailed)

* Correlation is significant at the 0 05 level (2-tailed)

Table 5.46.1: Correlation coefficients for pesticide in weeds from Nandi-Lower Nyando in September

Correlations

		15	16	17	18	19	21	22	23	25	26	27	30	33
15	Pearson Corre	1.000	.012	-.072	.399	-.128	-.131	-.226	532*	519*	-.160	-186	-042	389
	Sig. (2-tailed)		.964	.791	126	638	628	400	034	048	553	491	877	136
	N	16	16	16	16	16	16	16	16	15	16	16	16	16
16	Pearson Corre	.012	1.000	.894*	067	-165	809*	803*	708*	394	875*	943**	382	785*
	Sig. (2-tailed)	964		.000	807	540	000	000	002	146	000	000	144	000
	N	16	16	16	16	16	16	16	16	15	16	16	16	16
17	Pearson Corre	-.072	.894*	1 000	118	014	742*	836*	621*	173	956*	910*	342	756*
	Sig. (2-tailed)	.791	.000		663	958	001	000	010	537	000	000	195	001
	N	16	16	16	16	16	16	16	16	15	16	16	16	16
18	Pearson Corre	.399	.067	.118	1 000	-.069	-.149	-.009	544*	-047	-087	-101	-149	-041
	Sig. (2-tailed)	.126	.807	.663		.798	582	973	030	867	.748	710	581	879
	N	16	16	16	16	16	16	16	16	15	16	16	16	16
19	Pearson Corre	-.128	-.165	.014	-.069	1.000	-.143	-.153	-.134	-.171	-084	-097	-143	159
	Sig. (2-tailed)	638	.540	.958	798		597	.572	620	541	757	721	596	556
	N	16	16	16	16	16	16	16	16	15	16	16	16	16
21	Pearson Corre	-.131	.809*	742*	-.149	-.143	1 000	.674*	427	601*	810*	825*	466	632*
	Sig. (2-tailed)	628	.000	.001	582	597		.004	099	.018	000	000	069	009
	N	16	16	16	16	16	16	16	16	15	16	16	16	16
22	Pearson Corre	-.226	.803*	.836*	-.009	-.153	674*	1.000	470	067	882*	821*	460	553*
	Sig. (2-tailed)	.400	.000	.000	973	.572	.004		066	811	000	000	073	026
	N	16	16	16	16	16	16	16	16	15	16	16	16	16
23	Pearson Corre	.532*	.708*	621*	544*	-.134	427	470	1 000	405	527*	595*	349	.730*
	Sig. (2-tailed)	.034	002	.010	030	620	.099	066		134	036	015	185	001
	N	16	16	16	16	16	16	16	16	15	16	16	16	16
25	Pearson Corre	.519*	.394	.173	-.047	-.171	.601*	067	405	1 000	196	262	156	553*
	Sig (2 tailed)	048	146	.537	867	541	.018	.811	134		483	345	.578	033
	N	15	15	15	15	15	15	15	15	15	15	15	15	15
26	Pearson Corre	-.160	875*	956*	-.087	-.084	810*	882*	527*	196	1 000	931*	522*	720*
	Sig. (2-tailed)	.553	.000	.000	.748	.757	000	000	036	483		000	.038	.002
	N	16	16	16	16	16	16	16	16	15	16	16	16	16
27	Pearson Corre	-.186	943*	.910*	-101	-097	825*	821*	595*	262	931*	1 000	447	747*
	Sig. (2-tailed)	491	.000	.000	.710	.721	.000	.000	015	345	000		083	001
	N	16	16	16	16	16	16	16	16	15	16	16	16	16
30	Pearson Corre	-.042	382	342	-.149	-.143	466	.460	349	156	.522*	447	1.000	314
	Sig. (2-tailed)	.877	.144	.195	.581	596	.069	.073	.185	578	.038	.083		236
	N	16	16	16	16	16	16	16	16	15	16	16	16	16
33	Pearson Corre	.389	.785*	.756*	-.041	159	.632*	.553*	.730*	553*	720*	.747*	314	1.000
	Sig. (2-tailed)	.136	.000	001	879	556	.009	.026	001	033	.002	001	236	
	N	16	16	16	16	16	16	16	16	15	16	16	16	16

*Correlation is significant at the 0.05 level (2-tailed)

**Correlation is significant at the 0.01 level (2-tailed)

Table 5.51.1: Correlation coefficients for pesticide in water from Kericho-Upper Nyando in December

Correlations

		1	3	4	5	6	7	8	9	10	11	12	13	14
1	Pearson Corr	1.000	012	-.072	399	-.128	-.131	- 226	532*	519*	- 160	- 186	- 042	389
	Sig (2-tailed)		964	.791	126	638	628	400	034	048	553	491	877	136
	N	16	16	16	16	16	16	16	16	15	16	16	16	16
3	Pearson Corr	012	1.000	.894*	067	- 165	809*	803*	708*	394	875*	943*	382	785*
	Sig (2-tailed)	964		000	807	540	000	000	002	146	000	000	144	000
	N	16	16	16	16	16	16	16	16	15	16	16	16	16
4	Pearson Corr	- 072	894*	1.000	118	014	.742*	836*	621*	173	956*	910*	342	756*
	Sig (2-tailed)	791	000		663	958	001	000	010	537	000	000	195	001
	N	16	16	16	16	16	16	16	16	. 15	16	16	16	16
5	Pearson Corr	399	.067	118	1.000	- 069	- 149	- 009	544*	- 047	- 087	- 101	- 149	- 041
	Sig (2-tailed)	126	.807	.663		798	582	973	030	867	748	710	581	879
	N	16	16	16	16	16	16	16	16	15	16	16	16	16
6	Pearson Corr	- 128	-.165	.014	- 069	1.000	- 143	- 153	- 134	-.171	- 084	- 097	- 143	159
	Sig (2-tailed)	638	540	958	798		597	572	620	541	.757	721	596	556
	N	16	16	16	16	16	16	16	16	15	16	16	16	16
7	Pearson Corr	- 131	.809*	742*	-.149	-.143	1.000	674*	427	601*	810*	825*	466	632*
	Sig (2-tailed)	628	000	.001	582	597		.004	099	018	000	000	069	009
	N	16	16	16	16	16	16	16	16	15	16	16	16	16
8	Pearson Corr	-.226	803*	836*	- 009	-.153	674*	1.000	470	067	882*	821*	460	553*
	Sig (2-tailed)	400	.000	000	973	572	004		066	811	000	000	073	026
	N	16	16	16	16	16	16	16	16	15	16	16	16	16
9	Pearson Corr	532*	.708*	.621*	544*	-.134	427	470	1 000	405	527*	595*	349	730*
	Sig (2-tailed)	034	.002	.010	030	620	099	066		134	036	015	185	001
	N	16	16	16	16	16	16	16	16	15	16	16	16	16
10	Pearson Corr	519*	.394	.173	- 047	-.171	601*	067	405	1 000	196	262	156	553*
	Sig (2-tailed)	048	146	.537	867	541	018	811	134		483	345	578	033
	N	15	15	15	15	15	15	15	15	15	15	15	15	15
11	Pearson Corr	-.160	875*	956*	- 087	- 084	810*	882*	527*	196	1 000	931*	522*	720*
	Sig (2-tailed)	.553	000	000	748	757	000	000	036	483		000	038	002
	N	16	16	16	16	16	16	16	16	15	16	16	16	16
12	Pearson Corr	- 186	943*	910*	-.101	- 097	825*	821*	595*	262	931*	1 000	447	747*
	Sig (2-tailed)	491	.000	000	.710	.721	000	000	015	345	000		083	001
	N	16	16	16	16	16	16	16	16	15	16	16	16	16
13	Pearson Corr	-.042	.382	.342	-.149	-.143	466	460	349	156	522*	447	1.000	314
	Sig (2-tailed)	877	.144	.195	.581	596	069	073	.185	578	038	083		236
	N	16	16	16	16	16	16	16	16	15	16	16	16	16
14	Pearson Corr	.389	785*	.756*	-.041	159	632*	553*	730*	553*	720*	747*	314	1 000
	Sig (2-tailed)	.136	000	.001	879	556	009	026	001	033	002	.001	236	
	N	16	16	16	16	16	16	16	16	15	16	16	16	16

*Correlation is significant at the 0.05 level (2-tailed)

**Correlation is significant at the 0.01 level (2-tailed)

Table 5.52.1: Correlations for pesticide in sediments from Kericho-Upper Nyando in December

Correlations

		1	3	4	5	6	7	8	9	10	11	12	13	14
1	Pearson Corre	1 000	935*	935*	882*	902*	925*	910*	288	885*	727*	953*	902*	651*
	Sig (2-tailed)		.000	000	000	000	000	000	279	000	001	000	000	006
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
3	Pearson Corre	935*	1 000	840*	878*	818*	905*	878*	149	874*	587*	865*	803*	583*
	Sig (2-tailed)	000		000	000	000	000	000	581	000	017	000	000	018
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
4	Pearson Corre	935*	840*	1 000	896*	895*	912*	947*	380	914*	742*	981*	941*	648*
	Sig (2-tailed)	.000	000		.000	000	000	000	146	000	001	000	000	007
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
5	Pearson Corre	882*	878*	.896*	1 000	838*	977*	971*	016	989*	489	863*	834*	349
	Sig (2-tailed)	000	000	.000		000	000	000	954	000	054	000	000	185
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
6	Pearson Corre	902*	818*	.895*	838*	1 000	910*	868*	367	878*	794*	917*	863*	614*
	Sig. (2-tailed)	000	000	.000	000		000	000	162	000	000	000	000	011
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
7	Pearson Corre	925*	905*	.912*	977*	910*	1 000	978*	111	989*	551*	896*	829*	467
	Sig (2-tailed)	000	000	.000	000	000		000	683	000	027	000	000	068
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
8	Pearson Corre	910*	878*	.947*	971*	868*	978*	1 000	168	986*	545*	910*	848*	488
	Sig. (2-tailed)	000	000	000	000	000	000		534	000	029	000	000	055
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
9	Pearson Corre	288	.149	.380	.016	367	111	168	1 000	098	650*	445	417	777*
	Sig. (2-tailed)	279	581	.146	954	162	683	534		718	006	084	108	000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
10	Pearson Corre	885*	874*	.914*	989*	878*	989*	986*	098	1 000	516*	882*	829*	419
	Sig (2-tailed)	000	000	.000	000	000	000	000	718		041	000	000	106
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
11	Pearson Corre	727*	587*	.742*	489	794*	551*	545*	650*	516*	1 000	804*	839*	714*
	Sig. (2-tailed)	001	017	001	054	000	027	029	006	041		000	000	002
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
12	Pearson Corre	953*	865*	981*	863*	917*	896*	910*	445	882*	804*	1 000	942*	705*
	Sig. (2-tailed)	.000	000	.000	000	000	000	000	084	000	000		000	002
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
13	Pearson Corre	902*	803*	941*	834*	863*	829*	848*	417	829*	839*	942*	1 000	610*
	Sig. (2-tailed)	000	000	000	000	000	000	000	108	000	000	000		012
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
14	Pearson Corre	651*	583*	648*	349	614*	467	488	777*	419	714*	705*	610*	1 000
	Sig (2-tailed)	006	018	007	185	011	068	055	000	106	002	002	012	
	N	16	16	16	16	16	16	16	16	16	16	16	16	16

** Correlation is significant at the 0 01 level (2-tailed)

* Correlation is significant at the 0 05 level (2-tailed)

Table 5.53.1: Correlation coefficients for pesticide in weeds from Kericho-Upper Nyando in December

Correlations

		1	3	4	5	6	7	8	9	10	11	12	13	14
1	Pearson Corre	1.000	.891**	.975**	.956**	.943**	.891**	.943**	.904**	.954**	.988**	.929**	.351	.831**
	Sig. (2-tailed)		.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.182	.000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
3	Pearson Corre	.891**	1.000	.878**	.825**	.827**	.834**	.870**	.804**	.810**	.872**	.920**	.224	.846**
	Sig. (2-tailed)	.000		.000	.000	.000	.000	.000	.000	.000	.000	.000	.405	.000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
4	Pearson Corre	.975**	.878**	1.000	.919**	.942**	.810**	.947**	.925**	.919**	.990**	.895**	.260	.726**
	Sig. (2-tailed)	.000	.000	.	.000	.000	.000	.000	.000	.000	.000	.000	.331	.001
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
5	Pearson Corre	.956**	.825**	.919**	1.000	.926**	.813**	.895**	.870**	.871**	.925**	.861**	.271	.848**
	Sig. (2-tailed)	.000	.000	.000		.000	.000	.000	.000	.000	.000	.000	.311	.000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
6	Pearson Corre	.943**	.827**	.942**	.926**	1.000	.811**	.927**	.936**	.875**	.937**	.856**	.361	.776**
	Sig. (2-tailed)	.000	.000	.000	.000		.000	.000	.000	.000	.000	.000	.170	.000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
7	Pearson Corre	.891**	.834**	.810**	.813**	.811**	1.000	.857**	.757**	.873**	.851**	.835**	.513*	.853**
	Sig. (2-tailed)	.000	.000	.000	.000	.000		.000	.001	.000	.000	.000	.042	.000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
8	Pearson Corre	.943**	.870**	.947**	.895**	.927**	.857**	1.000	.928**	.872**	.939**	.879**	.299	.773**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000		.000	.000	.000	.000	.260	.000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
9	Pearson Corre	.904**	.804**	.925**	.870**	.936**	.757**	.928**	1.000	.850**	.918**	.845**	.346	.689**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.001	.000		.000	.000	.000	.190	.003
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
10	Pearson Corre	.954**	.810**	.919**	.871**	.875**	.873**	.872**	.850**	1.000	.962**	.874**	.373	.714**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000		.000	.000	.155	.002
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
11	Pearson Corre	.988**	.872**	.990**	.925**	.937**	.851**	.939**	.918**	.962**	1.000	.915**	.334	.748**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000	.000		.000	.206	.001
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
12	Pearson Corre	.929**	.920**	.895**	.861**	.856**	.835**	.879**	.845**	.874**	.915**	1.000	.411	.865**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000		.114	.000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
13	Pearson Corre	.351	.224	.260	.271	.361	.513*	.299	.346	.373	.334	.411	1.000	.425
	Sig. (2-tailed)	.182	.405	.331	.311	.170	.042	.260	.190	.155	.206	.114		.101
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
14	Pearson Corre	.831**	.846**	.726**	.848**	.776**	.853**	.773**	.689**	.714**	.748**	.865**	.425	1.000
	Sig. (2-tailed)	.000	.000	.001	.000	.000	.000	.000	.003	.002	.001	.000	.101	
	N	16	16	16	16	16	16	16	16	16	16	16	16	16

**. Correlation is significant at the 0.01 level (2-tailed)

*. Correlation is significant at the 0.05 level (2-tailed)

Table 5.54.1: Correlation coefficients for pesticide in water from Nandi-Lower Nyando in December

Correlations

		15	16	17	18	19	21	22	23	25	26	27	30	33
15	Pearson Correl	1 000	.710*	053	705*	784*	855*	791*	758*	737*	741*	571*	585*	777*
	Sig. (2-tailed)		.002	.846	.005	.000	000	000	001	001	001	021	017	000
	N	16	16	16	14	16	16	16	16	16	16	16	16	16
16	Pearson Correl	710*	1.000	038	375	511*	660*	403	345	329	298	175	374	350
	Sig. (2-tailed)	.002		889	186	.043	.005	122	190	214	261	516	153	184
	N	16	16	16	14	16	16	16	16	16	16	16	16	16
17	Pearson Correl	.053	.038	1 000	.258	053	024	030	036	060	008	- 012	092	- 008
	Sig. (2-tailed)	.846	889		373	845	.930	911	895	826	978	964	736	978
	N	16	16	16	14	16	16	16	16	16	16	16	16	16
18	Pearson Correl	705*	.375	258	1 000	956*	521	856*	958*	963*	950*	743*	864*	934*
	Sig. (2-tailed)	005	186	.373		000	056	000	000	000	000	002	000	000
	N	14	14	14	14	14	14	14	14	14	14	14	14	14
19	Pearson Correl	784*	.511*	053	.956*	1 000	628*	902*	973*	973*	960*	762*	875*	966*
	Sig. (2-tailed)	000	043	845	.000		009	000	000	.000	000	001	000	000
	N	16	16	16	14	16	16	16	16	16	16	16	16	16
21	Pearson Correl	855*	660*	024	521	.628*	1 000	641*	584*	572*	564*	718*	592*	.619*
	Sig. (2-tailed)	000	.005	930	056	009		007	018	021	023	002	016	011
	N	16	16	16	14	16	16	16	16	16	16	16	16	16
22	Pearson Correl	.791*	403	.030	856*	902*	641*	1 000	913*	910*	908*	696*	774*	932*
	Sig. (2-tailed)	.000	.122	.911	000	.000	.007		000	000	000	003	000	000
	N	16	16	16	14	16	16	16	16	16	16	16	16	16
23	Pearson Correl	.758*	345	036	958*	973*	584*	913*	1 000	.999*	998*	798*	872*	989*
	Sig. (2-tailed)	.001	.190	895	.000	000	.018	000		000	.000	.000	000	000
	N	16	16	16	14	16	16	16	16	16	16	16	16	16
25	Pearson Correl	737*	.329	060	963*	973*	572*	910*	999*	1 000	996*	808*	878*	986*
	Sig. (2-tailed)	001	.214	826	000	000	021	000	000		000	000	000	000
	N	16	16	16	14	16	16	16	16	16	16	16	16	16
26	Pearson Correl	.741*	.298	.008	.950*	960*	564*	908*	998*	996*	1 000	800*	859*	988*
	Sig. (2-tailed)	.001	261	.978	000	000	023	000	000	000		000	000	000
	N	16	16	16	14	16	16	16	16	16	16	16	16	16
27	Pearson Correl	.571*	.175	-.012	.743*	762*	.718*	696*	798*	808*	800*	1 000	.836*	804*
	Sig. (2-tailed)	.021	.516	.964	.002	.001	.002	003	000	.000	000		.000	.000
	N	16	16	16	14	16	16	16	16	16	16	16	16	16
30	Pearson Correl	.585*	.374	092	864*	875*	592*	774*	872*	878*	859*	836*	1 000	843*
	Sig. (2-tailed)	.017	153	.736	000	000	.016	000	000	000	000	000		000
	N	16	16	16	14	16	16	16	16	16	16	16	16	16
33	Pearson Correl	.777*	350	- 008	934*	966*	619*	932*	989*	986*	988*	804*	843*	1 000
	Sig. (2-tailed)	.000	.184	978	000	.000	.011	000	000	000	000	000	000	
	N	16	16	16	14	16	16	16	16	16	16	16	16	16

** Correlation is significant at the 0.01 level (2-tailed)

* Correlation is significant at the 0.05 level (2-tailed)

Table 5.55.1: Correlations for pesticides in sediments from Nandi-Lower Nyando in December

Correlations

		15	16	17	18	19	21	22	23	25	26	27	30	33
15	Pearson Correl	1.000	.753*	675*	413	612*	600*	848*	504*	613*	368	560*	098	273
	Sig. (2-tailed)		.001	.004	.112	.012	014	000	046	012	161	024	718	307
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
16	Pearson Correl	.753*	1.000	965*	693*	543*	943*	792*	734*	955*	701*	931*	179	437
	Sig. (2-tailed)	001		000	003	030	000	000	001	000	002	000	508	091
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
17	Pearson Correl	.675*	.965*	1.000	690*	669*	907*	823*	842*	937*	825*	984*	351	578*
	Sig. (2-tailed)	.004	000		003	005	.000	000	000	000	000	000	183	019
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
18	Pearson Correl	413	693*	690*	1 000	283	695*	486	646*	717*	488	.705*	092	264
	Sig. (2-tailed)	.112	003	.003		288	003	056	007	002	055	002	736	323
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
19	Pearson Correl	612*	.543*	669*	283	1 000	381	766*	671*	470	635*	637*	536*	592*
	Sig. (2-tailed)	.012	.030	005	.288		145	001	004	066	008	.008	032	016
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
21	Pearson Correl	600*	.943*	.907*	.695*	381	1 000	634*	633*	948*	655*	893*	077	328
	Sig. (2-tailed)	.014	000	.000	003	145		008	008	000	006	000	777	214
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
22	Pearson Correl	848*	.792*	823*	486	766*	634*	1 000	857*	677*	742*	756*	570*	685*
	Sig. (2-tailed)	.000	.000	000	056	001	008		000	004	001	001	021	003
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
23	Pearson Correl	.504*	734*	842*	646*	671*	633*	857*	1 000	691*	927*	851*	746*	841*
	Sig. (2-tailed)	.046	.001	.000	007	.004	.008	.000		.003	000	000	001	000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
25	Pearson Correl	613*	955*	937*	717*	.470	946*	677*	691*	1 000	668*	936*	124	354
	Sig. (2-tailed)	012	.000	.000	002	066	000	004	003		005	000	647	179
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
26	Pearson Correl	.368	701*	825*	488	635*	655*	742*	927*	668*	1 000	856*	741*	892*
	Sig. (2-tailed)	.161	002	000	055	008	006	001	000	005		000	001	000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
27	Pearson Correl	.560*	.931*	984*	705*	637*	893*	756*	851*	936*	856*	1 000	379	598*
	Sig. (2-tailed)	.024	000	.000	002	008	.000	001	000	000	000		148	.014
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
30	Pearson Correl	098	.179	.351	092	536*	.077	.570*	746*	124	.741*	379	1 000	885*
	Sig. (2-tailed)	.718	508	.183	.736	.032	.777	021	001	647	001	148		000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
33	Pearson Correl	.273	437	578*	264	592*	328	685*	841*	354	892*	598*	.685*	1.000
	Sig. (2-tailed)	.307	.091	.019	323	016	214	003	000	.179	000	014	000	
	N	16	16	16	16	16	16	16	16	16	16	16	16	16

**. Correlation is significant at the 0.01 level (2-tailed)

*. Correlation is significant at the 0.05 level (2-tailed)

Table 5.56.1: Correlation coefficients for pesticides in weed from Nandi-Lower Nyando in December

Correlations

		15	16	17	18	19	21	22	23	25	26	27	30	33
15	Pearson Corr	1.000	246	.112	-.054	-.063	626*	-.111	280	463	486	495	929*	805*
	Sig. (2-tailed)	.	.359	.681	843	816	009	682	293	071	057	051	000	000
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
16	Pearson Corr	.246	1.000	.935*	900*	884*	061	-.239	-.077	080	001	047	372	154
	Sig. (2-tailed)	.359	.	.000	000	.000	821	372	778	768	998	863	156	569
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
17	Pearson Corr	112	935*	1.000	968*	962*	.068	-.217	-.057	-.030	-.046	-.041	249	120
	Sig. (2-tailed)	681	.000		000	000	802	419	835	912	865	881	353	657
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
18	Pearson Corr	-.054	.900*	.968*	1.000	997*	-.106	-.170	-.040	-.092	-.088	-.134	122	-.014
	Sig. (2-tailed)	843	.000	.000		000	697	.530	882	734	745	621	652	959
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
19	Pearson Corr	-.063	884*	962*	997*	1.000	-.107	-.159	-.035	-.101	-.085	-.138	110	-.048
	Sig. (2-tailed)	816	000	.000	000	.	694	557	898	711	.755	610	686	861
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
21	Pearson Corr	626*	061	.068	-.106	-.107	1.000	-.195	-.075	037	138	209	566*	459
	Sig. (2-tailed)	009	821	802	697	694		469	784	892	611	438	022	074
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
22	Pearson Corr	-.111	-.239	-.217	-.170	-.159	-.195	1.000	358	674*	803*	731*	-.137	-.131
	Sig. (2-tailed)	682	.372	.419	.530	.557	.469	.	174	004	000	001	613	630
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
23	Pearson Corr	.280	-.077	-.057	-.040	-.035	-.075	358	1.000	646*	546*	544*	205	324
	Sig. (2-tailed)	.293	.778	.835	882	898	.784	.174		007	029	.029	447	221
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
25	Pearson Corr	463	.080	-.030	-.092	-.101	.037	674*	646*	1.000	880*	.951*	406	335
	Sig. (2-tailed)	.071	.768	912	.734	711	892	004	007		000	000	118	205
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
26	Pearson Corr	.486	.001	-.046	-.088	-.085	138	803*	546*	880*	1.000	921*	449	389
	Sig. (2-tailed)	.057	.998	865	.745	755	611	000	029	000		000	081	137
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
27	Pearson Corr	.495	047	-.041	-.134	-.138	209	731*	544*	951*	921*	1.000	395	324
	Sig. (2-tailed)	.051	.863	.881	621	610	438	001	029	000	000		130	220
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
30	Pearson Corr	.929*	372	249	122	110	566*	-.137	205	406	449	395	1.000	766*
	Sig. (2-tailed)	.000	156	353	652	686	022	613	447	118	081	130		001
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
33	Pearson Corr	.805*	154	120	-.014	-.048	459	-.131	324	335	389	324	766*	1.000
	Sig. (2-tailed)	.000	569	657	959	861	074	630	221	205	137	220	001	
	N	16	16	16	16	16	16	16	16	16	16	16	16	16

**Correlation is significant at the 0 01 level (2-tailed).

*Correlation is significant at the 0 05 level (2-tailed)

Appendix 5.3: Representative chromatograms of pesticides in matrice analysed

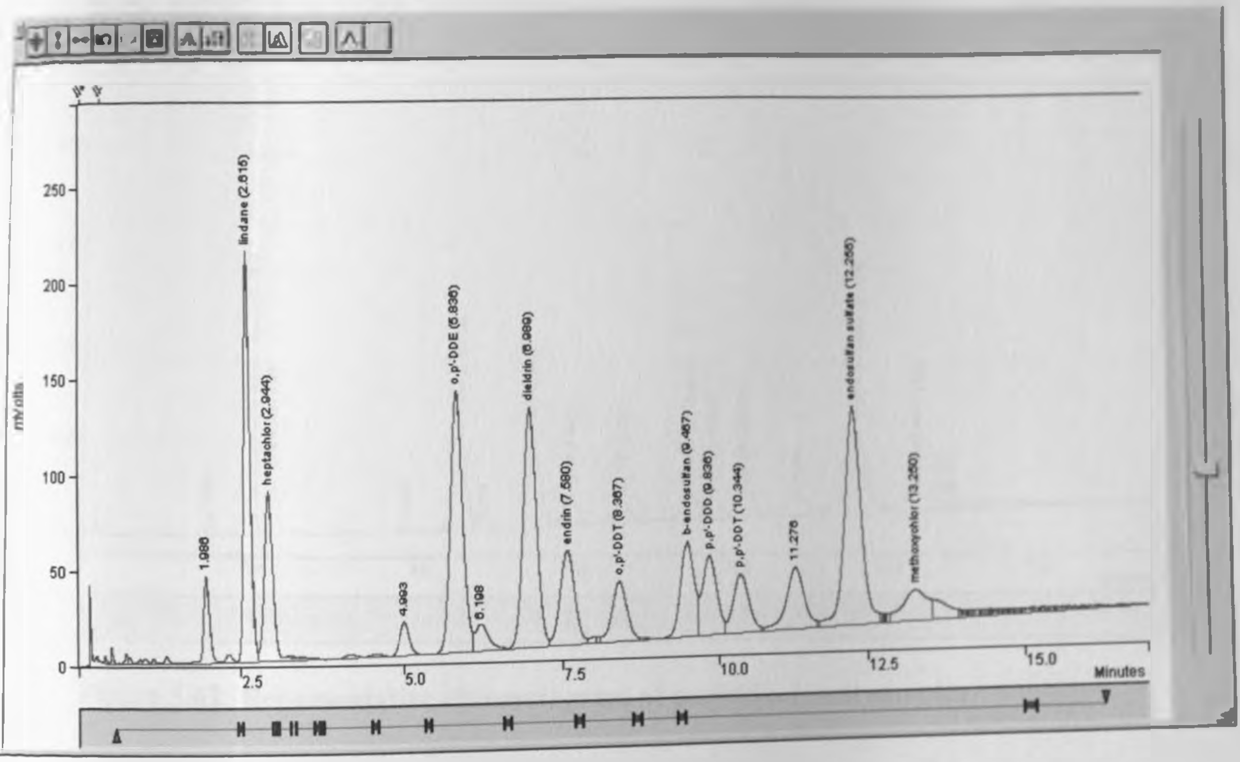

Figure 5.61: Representative chromatogram for organochlorine pesticide standards mixture

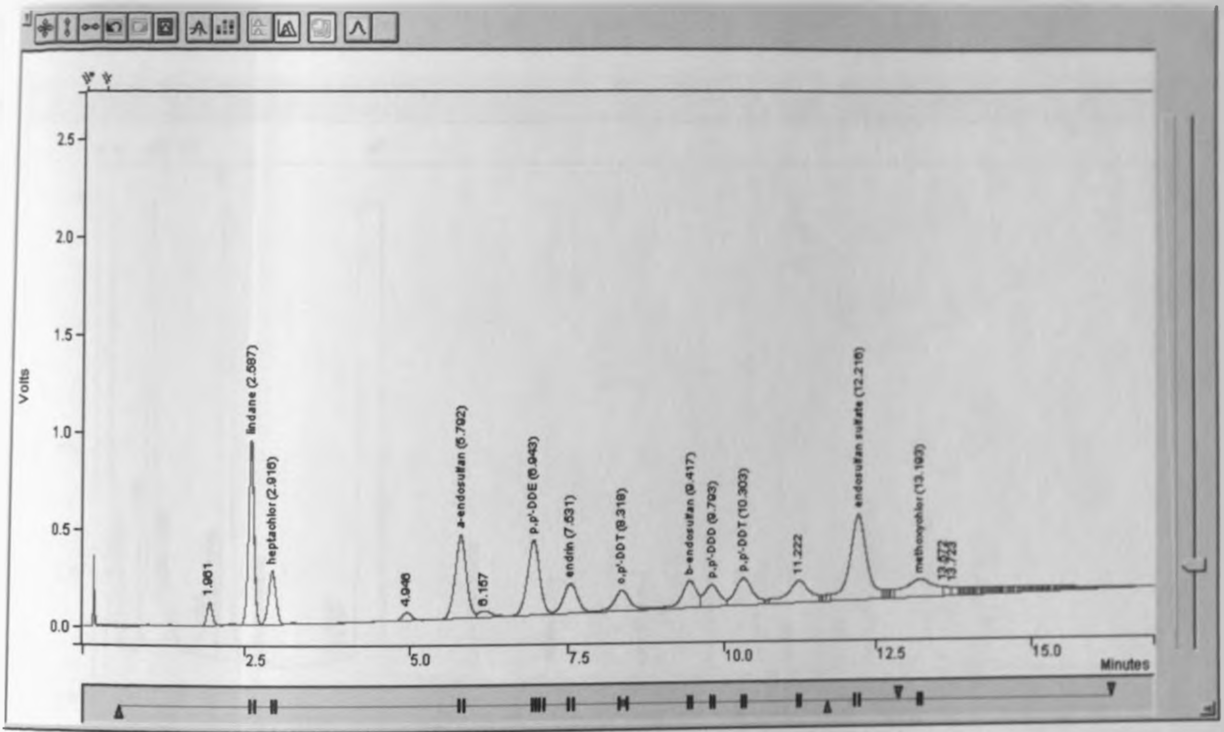

Figure 5.62: Representative chromatogram of pesticides in soil samples

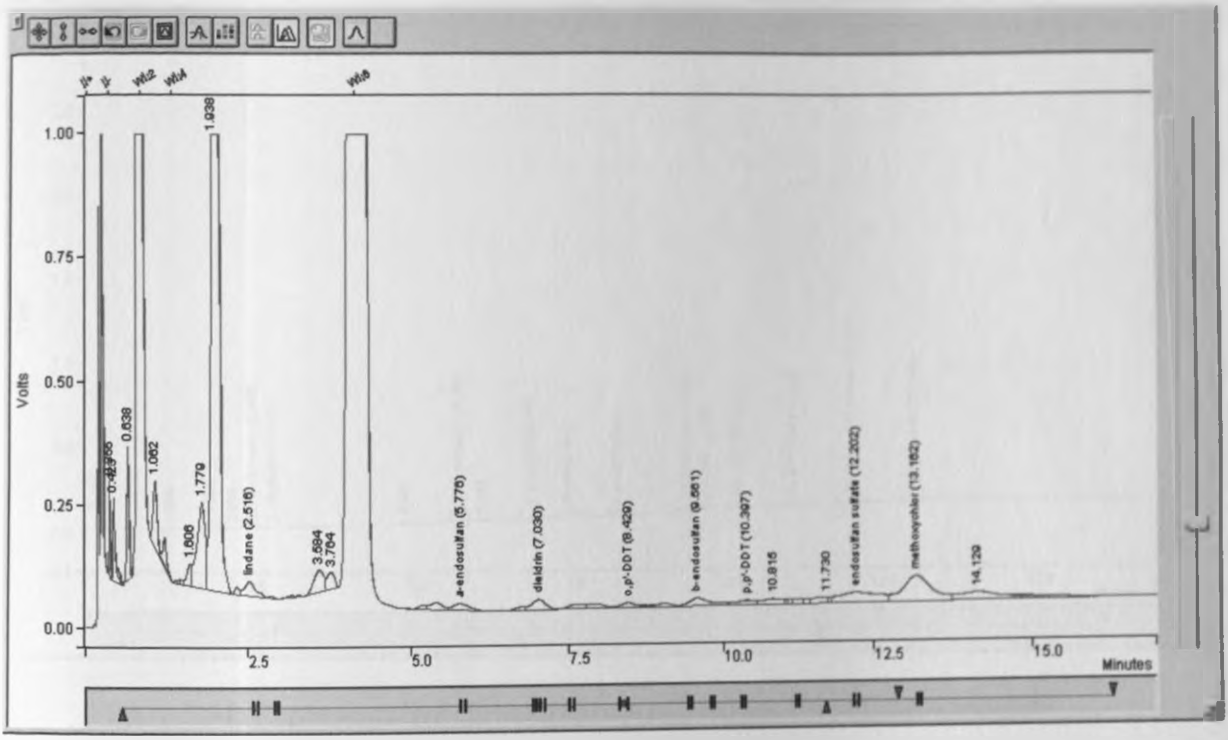

Figure 5.63: Representative of water sample chromatograms

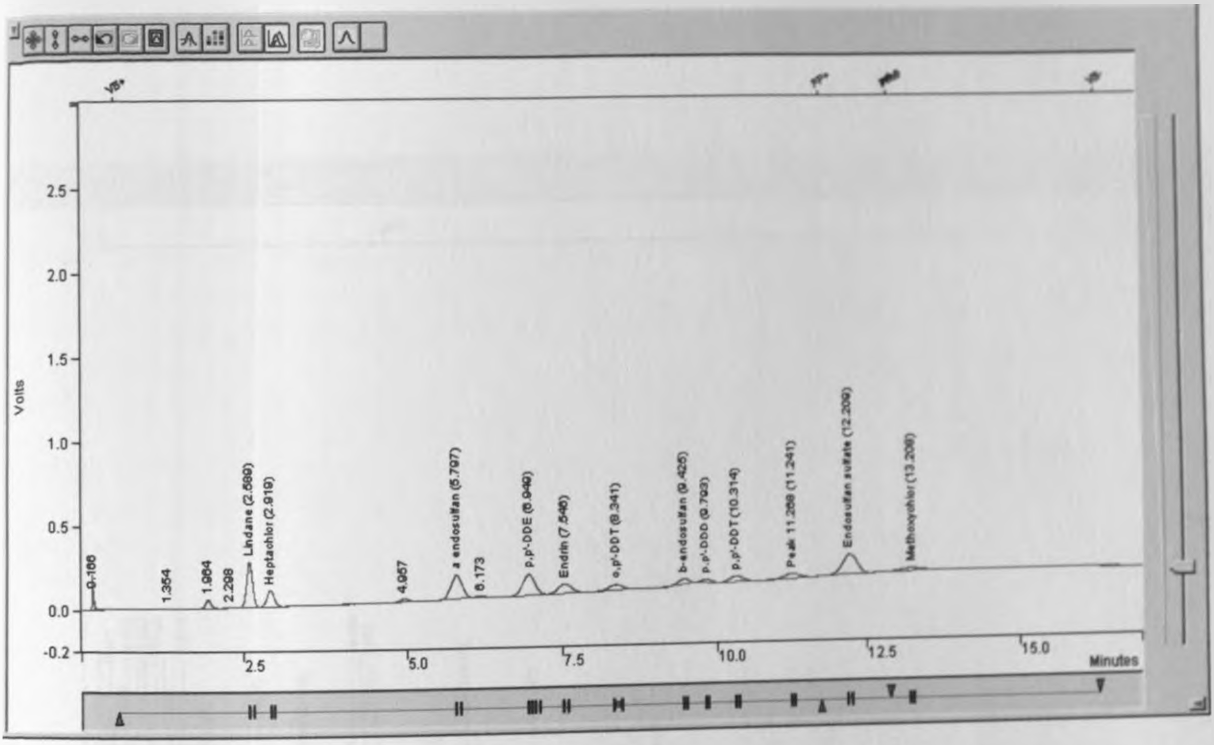

Figure 5.64: Representative chromatogram of pesticides in sediment samples

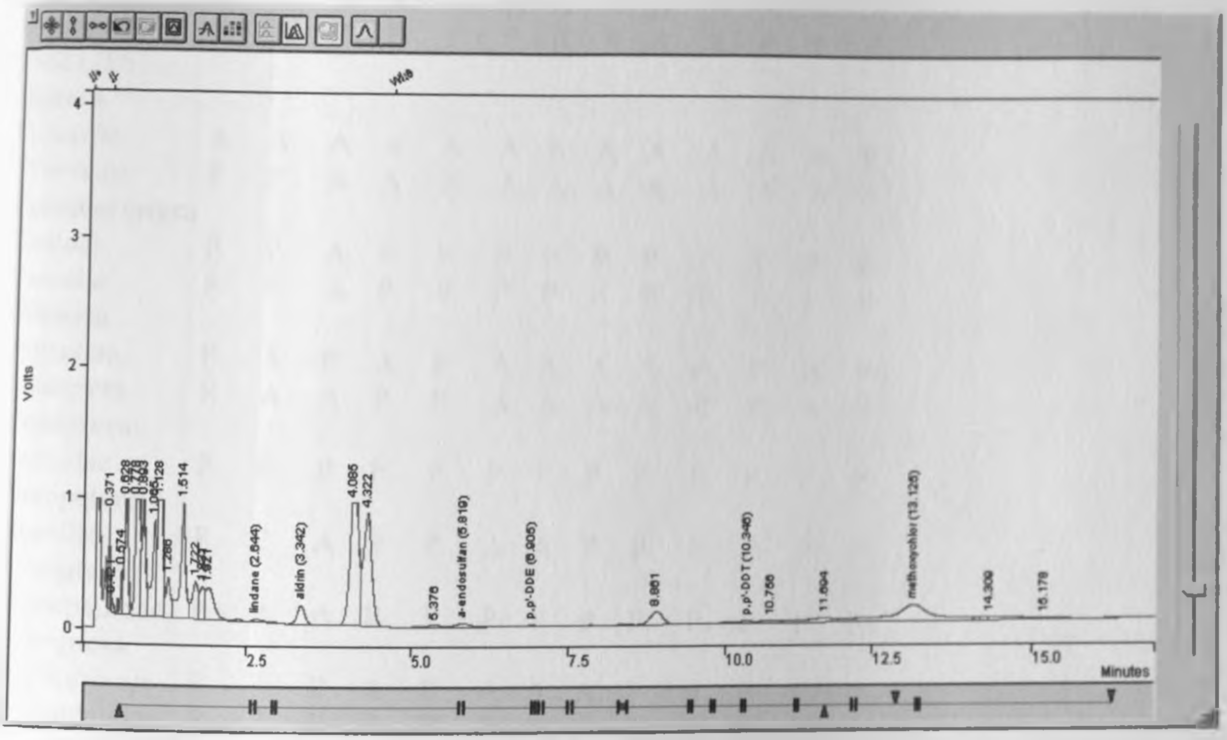

Figure 5.65: Representative chromatogram of aquatic weed samples

Appendix 6.0: Macro invertebrates Data

Table 6.11: Diversity of benthic macro invertebrates in Kericho-Upper Nyando in 2005

Taxon/Sites	1	3	4	5	6	7	8	9	10	11	12	13	14
BIVALVES													
Corbicule sp.	P	P	P	P	P	A	A	P	A	P	P	P	P
WORMS													
Hirudinae	A	A	A	A	A	A	A	A	A	A	A	A	A
Oligochaeta	P	A	P	P	P	P	P	A	A	P	P	P	P
INSECTS													
Diptera													
Culicidae	A	A	A	A	A	A	A	A	A	A	A	A	P
Atherix sp.	P	P	A	A	A	A	A	A	A	A	A	A	A
Ephemeriptera													
Baetidae	P	P	A	P	P	P	P	P	P	P	P	P	P
Caenidae	P	P	A	P	P	P	P	P	P	P	P	P	P
Odonata													
Zygoptera	P	A	P	A	P	A	A	A	A	A	P	A	P
Anisoptera	P	A	A	P	P	A	A	A	A	P	P	A	P
Hemiptera													
Corixidae	P	P	P	P	P	P	P	P	P	P	P	P	P
Plecopetera													
Stoneflies	P	P	A	P	P	A	A	P	P	P	P	P	P
Tricoptera													
Limnephilidae	P	P	A	P	P	P	P	P	P	P	P	P	P
Coleoptera													
Psepharus sp.	P	P	P	A	P	A	A	A	P	A	P	P	P
Hydrophilidae	P	P	P	P	P	P	P	P	P	P	P	P	P
Acariforms													
water mites	P	P	P	P	P	P	P	P	P	P	P	P	P
Neuroptera													
Spongillaflies	A	A	A	P	A	A	A	A	A	A	A	A	A
Total	**13**	**10**	**7**	**11**	**12**	**7**	**7**	**8**	**8**	**10**	**12**	**10**	**13**

Present "P" or Absent "A"

Table 6.12: Diversity of benthic macro invertebrates in Kericho-Upper in 2006.

Taxon/Sites	1	3	4	5	6	7	8	9	10	11	12	13	14
BIVALVES													
Corbicule sp.	P	P	P	P	P	A	P	P	A	P	P	P	P
WORMS													
Hirudinae	A	A	A	A	A	A	A	A	A	A	A	A	A
Oligochaeta	P	P	P	P	P	P	P	P	P	P	P	P	P
INSECTS													
Diptera													
Culicidae	A	A	A	A	A	A	A	A	A	A	A	A	P
Atherix sp.	P	P	A	A	A	A	A	P	A	A	A	A	A
Ephemeriptera													
Baetidae	P	P	A	P	P	P	P	P	P	P	P	P	P
Caenidae	P	P	A	P	P	P	P	P	P	P	P	P	P
Odonata													
Zygoptera	P	A	A	A	P	A	A	A	P	P	P	P	P
Anisoptera	P	A	A	P	P	A	A	A	A	P	P	P	P
Hemiptera													
Corixidae	P	P	P	P	P	P	P	P	P	P	P	P	P
Plecopetera													
Stoneflies	P	P	A	P	P	P	P	P	P	P	P	P	P
Tricoptera													
Limnephilidae	P	P	P	A	P	P	P	P	P	P	P	P	P
Coleoptera													
Psepharus sp.	P	P	P	P	P	P	A	A	A	A	P	A	P
Hydrophilidae	P	P	P	P	P	P	P	P	P	P	P	P	P
Acariforms													
water mites	P	P	P	P	P	P	P	P	P	P	P	P	P
Neuroptera													
Spongillaflies	A	A	A	A	A	A	A	A	A	A	A	A	A
Total	13	9	7	10	12	7	7	10	9	11	12	11	13

Present "P" or Absent "A"

Table 6.21: Diversity of benthic macro invertebrates in Nandi-Lower Nyando in 2005.

Taxon/Sites	**15**	**16**	**17**	**18**	**19**	**21**	**22**	**23**	**25**	**26**	**27**	**30**	**33**
BIVALVES													
Corbicule sp.	P	A	A	A	P	A	A	A	P	A	A	A	P
WORMS													
Hirudinae	A	A	A	P	A	A	A	P	A	A	A	A	P
Oligochaeta	A	A	A	P	P	A	A	P	P	P	P	P	P
INSECTS													
Diptera													
Culicidae	A	A	A	A	P	P	A	A	A	A	A	P	P
Atherix sp.	A	A	A	A	A	P	A	P	A	A	P	A	A
Ephemeriptera													
Baetidae	P	A	A	P	P	P	P	P	P	P	P	P	A
Caenidae	P	A	A	P	P	P	P	P	P	P	P	P	A
Odonata													
Zygoptera	A	A	A	A	A	P	P	P	A	A	P	P	A
Anisoptera	A	A	A	A	A	P	P	P	P	A	P	P	A
Hemiptera													
Corixidae	P	A	A	A	P	P	P	P	P	P	P	P	A
Plecopetera													
Stoneflies	A	A	A	A	P	P	P	P	P	P	P	P	A
Tricoptera													
Limnephilidae	P	A	A	A	P	P	P	P	P	P	P	P	A
Coleoptera													
Psepharus sp.	A	A	A	A	A	A	P	A	P	A	P	A	A
Hydrophilidae	A	A	A	A	A	A	P	P	P	P	P	A	A
Acariforms													
water mites	A	A	A	A	P	P	P	P	P	P	P	P	A
Neuroptera													
Spongillaflies	A	A	A	A	A	P	A	A	P	A	P	A	A
TOTAL	5	0	0	4	9	11	10	12	12	8	13	10	4

Present "P" or Absent "A"

Table 6.22: Diversity of benthic macro invertebrates in Nandi -Lower Nyando in 2006

Taxon/Sites	15	16	17	18	19	21	22	23	25	26	27	30	33
BIVALVES													
Corbicule sp.	A	P	A	A	P	A	A	A	P	A	P	A	P
WORMS													
Hirudinae	A	A	A	P	A	A	A	P	A	A	A	A	P
Oligochaeta	P	P	A	P	P	A	A	P	P	P	P	P	P
INSECTS													
Diptera													
Culicidae	A	A	A	A	A	A	A	A	A	A	A	P	A
Atherix sp.	A	A	A	A	A	P	A	P	A	A	P	A	A
Ephemeriptera													
Baetidae	P	A	A	A	P	P	P	P	P	P	P	P	A
Caenidae	P	A	A	P	P	P	P	P	P	P	P	P	A
Odonata													
Zygoptera	A	A	A	P	A	A	A	P	P	A	P	P	A
Anisoptera	A	A	A	A	A	A	A	P	P	A	P	P	A
Hemiptera													
Corixidae	P	A	A	A	P	P	P	P	P	P	P	P	A
Plecopetera													
Stoneflies	A	A	A	A	P	P	A	P	P	P	P	P	A
Tricoptera													
Limnephilidae	P	A	A	A	P	P	A	P	P	P	P	P	A
Coleoptera													
Psepharus sp.	A	A	A	A	A	P	P	A	P	P	P	P	A
Hydrophilidae	A	A	A	A	A	P	P	P	P	P	P	A	A
Acariforms													
water mites	A	A	A	A	P	P	P	P	P	P	P	P	P
Neuroptera													
Spongillaflies	A	A	A	A	A	P	A	A	A	A	A	A	A
Total	5	2	0	4	8	10	6	12	12	9	13	11	4

Present "P" or Absent "A"

Table 6.31: Density and Distribution of benthic macro invertebrates in Kericho-Upper Nyando in 2005

Taxon/Sites	1	3	4	5	6	7	8	9	10	11	12	13	14
BIVALVES													
Corbicule sp.	5	6	17	30	5			3		6	1	3	12
WORMS													
Hirudinae													
Oligochaeta	20	19	25	22	16	12	12	4	4	2	21	4	22
INSECTS													
Diptera													
Culicidae	6												11
Atherix sp.	1	23						15					
Ephemeriptera													
Baetidae	188	24		211	182	14	12	88	169	126	125	59	150
Caenidae	49	10		39	66	3	8	65	55	20	18	38	61
Odonata													
Zygoptera	26				3				3	6		9	2
Anisoptera	12			10	6					1		4	2
Hemiptera													
Corixidae	34	16	20	21	17	15	18	8	12	23	10	14	22
Plecopetera													
Stoneflies	63	3		21	79	25	16	45	46	36	26	1	11
Tricoptera													
Limnephilidae	17	11	24	22	19	28	48	9	15	52	65	5	24
Coleoptera													
Psepharus sp.	10	3	28		6						1		5
Hydrophilidae	11	9	13	18	15	14	8	13	8	4	3	10	23
Acariforms													
water mites	36	10	15	26	33	28	33	28	10	25	9	1	14
Neuroptera													
Spongillaflies				10									
Total	**478**	**134**	**142**	**430**	**447**	**139**	**155**	**278**	**322**	**301**	**279**	**148**	**35**

Density (No. /m^2)

Table 6.32: Density and Distribution of benthic macro invertebrates in Kericho-Upper Nyando in 2006

Taxon/Sites	1	3	4	5	6	7	8	9	10	11	12	13	14
BIVALVES													
Corbicule sp.	15	3	1	1	6		1	1		1	1	6	3
WORMS													
Hirudinae													
Oligochaeta	35		39	1	1	1	5			6	6	1	17
INSECTS													
Diptera													
Culicidae													3
Atherix sp.	3	9						9					
Ephemeriptera													
Baetidae	195	164		131	125	107	46	94	139	78	61	81	173
Caenidae	30	130		93	88	67	23	72	99	60	44	60	111
Odonata													
Zygoptera	4		10		8						3	3	
Anisoptera	1			56	11					1	3	6	1
Hemiptera													
Corixidae	54	2	22	11	8	1	6	9	7	15	17	10	8
Plecopetera													
Stoneflies	59	3		9	70	3	10	38	19	12	13	4	18
Tricoptera													
Limnephilidae	34	29		64	35	35	28	21	27	20	71	12	11
Coleoptera													
Psepharus sp.	3	29	27		3	28			1		8	2	1
Hydrophilidae	19	6	7	9	14	1	2	11	8	11	5	8	14
Acariforms													
water mites	47	72	61	34	62	29	27	36	6	16	11	3	13
Neuroptera													
Spongillaflies				4									
TOTAL	**499**	**44**	**157**	**413**	**431**	**272**	**148**	**291**	**306**	**220**	**243**	**196**	**373**

Table 6.41: **Density and Distribution of benthic macro invertebrates in Nandi-Lower Nyando in 2005**

Taxon/Sites	15	16	17	18	19	21	22	23	25	26	27	30	33
BIVALVES													
Corbicule sp.		1			21				24		1		16
WORMS													
Hirudinae				158				30					159
Oligochaeta	3	7		15	83			9	38	25	17	38	148
INSECTS													
Diptera													
Culicidae												7	
Atherix sp.						8		15			15		
Ephemeriptera													
Baetidae	13			12	122	60	30	46	99	37	48	21	
Caenidae	8			6	51	26	18	34	45	32	37	12	
Odonata													
Zygoptera								3	3		19	2	
Anisoptera								14	3		7	7	
Hemiptera													
Corixidae	1				15	42	21	14	47	17	35	9	2
Plecopetera													
Stoneflies					4	48		22	67	31	23	14	
Tricoptera													
Limnephilidae	6				18	35		24	58	38	22	31	
Coleoptera													
Psepharus sp.						3	4		9	3	28	3	
Hydrophilidae						10	13	32	56	23	16		6
Acariforms													
water mites					7	41	8	34	45	14	18	21	
Neuroptera													
Spongillaflies						2							
Total	**31**	**8**	**0**	**191**	**321**	**275**	**94**	**277**	**494**	**220**	**286**	**165**	**331**

Table 6.42: Density and Distribution of benthic macro invertebrates in Nandi-Lower Nyando in 2006

Taxon/Sites	15	16	17	18	19	21	22	23	25	26	27	30	33
BIVALVES													
Corbicule sp.	6				10			1	19				10
WORMS													
Hirudinae				138				3					158
Oligochaeta				7	39		6	1	10	12	4	10	122
INSECTS													
Diptera													
Culicidae					3	3	1					2	15
Atherix sp.	4						6	1			11		
Ephemeriptera													
Baetidae	15			7	98	75	65	95	90	86	74	55	
Caenidae				4	10	50	50	65	80	68	65	32	
Odonata													
Zygoptera						17	6	1			3	5	
Anisoptera	3					6	6	1	9		21	1	
Hemiptera													
Corixidae					8	9	9	25	7	36	4	10	2
Plecopetera													
Stoneflies	3				4	7	10	42	35	61	6	5	
Tricoptera													
Limnephilidae	2				11	27	24	15	25	14	10	6	
Coleoptera													
Psepharus sp.									4		13		
Hydrophilidae						6	14	5	21	11	6		2
Acariforms													
water mites					4	18	13	13	15	12	11	28	
Neuroptera													
Spongillaflies						1			1		1		
Total	**27**	**0**	**0**	**156**	**187**	**219**	**210**	**268**	**316**	**300**	**229**	**154**	**309**

Density (No. /m^2)

Table 6.51: Percent macro invertebrate taxonomic grouping in Kericho-Upper Nyando in 2005

Order	1	3	4	5	6	7	8	9	10	11	12	13	14
Bivalve	1.04	4.48	12	6.98	1.1	0	0	1.08	0	2	0.4	3.03	3.3
Hirudinae	0	0	0	0	0	0	0	0	0	0	0	0	0
Oligochaeta	4.18	14.2	18	5.12	3.6	8.63	7.74	1.44	1.2	0.7	7.5	2.7	6.1
Diptera	1.46	17.2	0	0	0	0	0	5.4	0	0	0	0	3.1
Ephemeriptera	49.6	15.36	0	58.14	56	12.3	12.9	55.1	74	49	51	64	59
Odonata	7.95	0	0	2.33	2	0	0	0	0.9	2.3	0	8.78	1.2
Hemiptera	7.11	8.9	14	4.88	3.8	10.8	11.6	2.88	1.8	7.6	3.6	9.46	6.1
Plecopetera	10.2	2.24	0	4.88	18	18	10.3	16.2	14	12	9.3	0.68	3.1
Tricoptera	3.56	6.21	17	5.12	4.3	20.1	31	3.24	3.7	17	23	3.91	6.7
Coleoptera	4.39	28.96	29	4.19	4.7	10.1	5.16	4.68	1.5	1.3	1.4	6.76	7.8
Acariform	5.53	7.46	11	6.02	7.4	20.1	21.3	10	2.9	8.3	3.2	0.68	3.9
Neuroptera	0	0	0	2.6	0	0	0	0	0	0	0	0	0
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

Table 6.52: Percent macro invertebrate taxonomic grouping in Kericho-Upper Nyando in 2006

Order	1	3	4	5	6	7	8	9	10	11	12	13	14
Bivalve	1.1	4.5	12	7	1.1	0	7.7	1.1	0	2	0.4	2	3.2
Hirudinae	0	0	0	0	0	0	0	0	0	0	0	0	0
Oligochaeta	4.2	7.1	18	5.1	3.6	11	7.1	1.4	1	0.7	7.5	2.7	1.6
Diptera	1.5	8.6	0	0	0	0	0	5.4	0	0	0	0	2.9
Ephemeriptera	50	25	0	58	56	6.3	12	55	70	11	52	66	40
Odonata	8	0	0	2.3	2	0	0	0	1	2.3	0	8.8	1.1
Hemiptera	7.2	12	14	4.9	3.8	8.9	11	2.9	4	7.6	3.6	9.5	3.2
Plecopetera	13	2.2	0	4.9	18	20	9.5	18	14	12	9.3	0.7	17
Tricoptera	3.6	4.1	17	5.1	4.3	25	29	4.2	5	17	23	3.4	11
Coleoptera	4.4	41	29	4.2	4.7	4.5	4.8	3.7	2	1.3	1.5	6.8	7.1
Acariforms	7.6	7.5	11	6	7.4	25	20	10	3	8.3	3.2	0.7	11
Neuroptera	0	0	0	2.3	0	0	0	0	0	0	0	0	0
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

Table 6.61: Percent macro invertebrate taxonomic grouping in Nandi-Lower Nyando in 2005

Order	15	16	17	18	19	21	22	23	25	26	27	30	33
BIVALVE	0	12.5	0	0	6.5	0	0	0	4.9	0	0.4	0	4.8
Hirudinae	0	0	0	82.72	0	0	0	10.8	0	0	0	0	52
Oligochaeta	9.68	87.5	0	7.85	27	0	0	3.25	7.7	14	5.9	23	41
Diptera	0	0	0	0	0	7.11	0	5.42	0	0	5.2	4.24	0
Ephemeriptera	71	0	0	9.43	57	31.3	51	28.9	16.9	31	30	20	0
Odonata	0	0	0	0	0	0	0	7.13	1.2	0	9.1	5.45	0
Hemiptera	6.43	0	0	0	4.7	19.3	22.3	5.05	9.5	0	12	5.45	0.6
Plecopetera	0	0	0	0	4.3	21.5	0	7.94	18	14.7	8	8.48	0
Tricoptera	19.4	0	0	0	0	10.61	12.7	8.66	20	17	7.7	18.8	0
Coleoptera	0	0	0	0	0	0	4.63	10.5	12.8	12	15	1.82	1.8
Acariform	0	0	0	0	0	10.18	9.11	12.3	9.1	10.4	6.3	12.8	0
Neuroptera	0	0	0	0	0	0	0.3	0	0	0	0	0	0
TOTAL	**100**	**100**	**0**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

Table 6.62: Percent Macro invertebrate taxonomic grouping in Nandi-Lower in 2006

Order	15	16	17	18	19	21	22	23	25	26	27	30	33
Bivalve	0	24	0	0	6.5	0	0	0	5	0	0.4	0	4.8
Hirudinae	0	0	0	73	0	0	0	11	0	0	0	0	48
Oligochaeta	9.7	76	0	18	26	0	0	3.2	8	11	5.9	23	45
Diptera	0	0	0	0	0	2.9	0	5.4	0	0	5.2	4.2	0
Ephemeriptera	68	0	0	9.4	54	32	51	29	17	31	20	20	0
Odonata	0	0	0	0	0	0	0	6.2	1	0	9.1	5.5	0
Hemiptera	3.2	0	0	0	4.7	15	22	5.1	10	7.7	12	5.5	0.6
Plecopetera	0	0	0	0	1.3	17	0	7.9	18	14	8	8.5	0
Tricoptera	19	0	0	0	0	13	0	8.7	20	17	7.7	19	0
Coleoptera	0	0	0	0	0	4.7	18	12	13	12	15	1.8	1.8
Acariforms	0	0	0	0	2.2	15	8.5	12	9	6.4	6.3	13	0
Neuroptera	0	0	0	0	0	0.7	0	0	0	0	0	0	0
Total	**100**	**100**	**0**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

Table 6.71 Physico-chemical parameters in Kericho-Upper Nyando in February 2005

Site/Param	Alt (m)	Temp (°C)	Conduc (µS/cm)	TSS (mg/L)	DO (mg/L)	pH	Turb (NTU)	TP (mg/L)	TN (mg/L)	Area (m^2)	Mean Vel (m/s)	Discharge (m^3/s)	Width (m)
1	7515±2 78	27 10±1 09	139 30±4 12	76 35±1 23	7 65±0 12	7 83±0 01	125.67±3 89	0 207±0 02	3 653±0 012	0 44±0 01	0 639±0 003	0 283±0 003	3 70±0 005
3	7580±6 09	28 13±1 34	77 70±2 45	32 00±1.78	7 01±0 07	7 94±0 78	61 97±1 690	0 083±0 001	3 444±0 004	0 34±0 005	0 380±0 001	0 130±0 010	2 60±0 001
4	7507±3 89	28 06±1 81	96 07±1 76	76 54±1 93	7 21±0 32	8 08±0 94	61 90±1 230	0 11±0 011	2 714±0 020	1 75±0 02	0 460±0 001	0 811±0 021	7 01±0 004
5	6740±3 98	27 73±0 97	111 23±1 80	62 67±1 23	8 24±0 37	8 01±0 02	79 47±1 340	0.156±0 006	3 81±0 001	4 87±0 01	0 430±0 002	2 088±0 031	6 20±0 010
6	6552±6 09	28 07±2 09	103 40±1 76	61 67±1 45	7 36±0 39	8 02±0 01	102 67±2 39	0 127±0 002	2 922±0 04	5 41±0 01	0 390±0 002	2 149±0 087	7 30±0 002
7	6308±7 09	27 67±1 45	76 40±1 98	125 50±1 45	7 15±0 78	7 88±0 09	133 33±2 19	0 146±0 004	2 153±0 01	0 88±0 004	0 530±0 002	0 453±0 052	2 00±0 006
8	6307±8 45	27 33±1 17	93 57±2 78	193 00±4 35	7 62±0 02	7 93±0 13	148 67±2 39	0 183±0 003	3 118±0 02	6 76±0 061	0 600±0 001	0 620±0 045	9 500±0 012
9	6563±5 67	27 3±0 120	81 13±3 65	166 50±3 21	7 24±0 02	9 80±0 32	133 33±1 34	0 225±0 007	2 707±0 004	1 17±0 03	0 560±0 002	0 643±0 098	4 500±0 001
10	5102±9 79	26 97±1 67	166 63±1 78	217 00±2 09	8 25±0 17	7 68±0 25	142 33±1 23	0 166±0 010	2 57±0 020	2 32±0 02	0 390±0 001	0 909±0 021	6 700±0 006
11	4921±8 75	27 27±1 34	169 57±1 34	193 50±2.91	7 47±0 34	8.26±0 21	147 67±3 89	0 219±0 020	1 207±0 002	0 42±0 004	0 610±0 012	0 258±0 012	2 300±0 009
12	4917±4 19	27 23±0 56	163 33±1 47	149 00±01 45	8 01±0 01	8 21±0 34	141 00±2 98	0 18±0 020	2 492±0 020	1 80±0 003	0 560±0 007	1 041±0 001	6 600±0 008
13	4344±3 67	27 23±0 51	169 17±1 98	64.60±1 23	8 35±0 21	7 94±0 84	55 73±0 990	0 295±0 047	1 885±0 012	2 06±0 01	0 34±0 009	0 711±0 011	7 500±0 003

Table 6.72 Physico-chemical parameters in Kericho-Upper Nyando in February 2006

Sites/Param	Alt (m)	Temp (°C)	Condu (µS/cm)	TSS (mg/L)	DO (mg/L)	pH	Turb (NTU)	TP (mg/L)	TN (mg/L)	Area (m^2)	Mean Vel (m3/s)	Discharge (m^3/s)	Width (m)
1	7519±23 09	15 4±1 49	148 3±6 43	27 5±3 13	5 59±0 79	7 28±1 56	73 01±4 81	0 145±0 004	1 406±0 041	0 57±0 01	2 43±	3 80±0 012	1 387±0 981
3	7586±12 81	18 4±0 98	126 8±4 67	78 667±6 91	6 44±0 89	6 93±0 67	75 45±2 87	0 084±0 01	2 177±0 705	0 9±0 04	0 50±0 009	2 70±0 012	0 455±0 012
4	7500±34 08	18 4±3 12	127 8±3 12	53 01±4 56	6 44±0 78	7 11±0 93	89 23±3 56	0 076±0 002	2 297±0 302	1 19±0 003	0 63±0 02	6 01±0 004	0 760±0 021
5	6749±34 45	17 5±1 36	138 7±6 91	31 4±1 15	7 38±1 13	7 45±0 65	93 21±4 67	0 068±0 003	1 571±0 170	1 99±0 12	0 60±0 001	4 50±0 04	1 198±0 036
6	6556±39 41	12 1±0 85	134 8±2 89	28 8±1 98	4 81±0 24	7 54±0 76	84 06±1 74	0 108±0 05	1 721±0 122	4 4±0 43	0 27±0 04	7 40±0 05	1 192±0 046
7	6312±21 06	15 4±0 94	308 10±2 94	52 8±3 64	4 45±1 94	7 8±0 45	30 07±0 56	0 205±0 02	1 387±0 141	0 22±0 005	0 15±0 009	1 70±0 07	0 114±0 001
8	6311±15 97	15 9±0 21	163 50±7 92	62 09±4 32	7 43±3 45	7 42±0 56	81 18±2 15	0 141±0 04	1 584±0 615	3 97±0 05	0 25±0 015	8 1±0 09	1 01±0 019
9	6565±19 34	19 8±1 56	169 03±4 95	30 8±1 68	4 48±2 45	7 5±1 09	35 23±2 12	0 178±0 012	1 551±0 187	0 73±0 02	0 15±0 04	3 50±0 89	0 114±0 023
10	5106±11 92	25 8±0 56	310 12±6 02	88 5±4 78	5 68±2 33	8.1±1 43	36 45±1 94	0 214±0 01	1 162±0 016	2 55±0 07	0 62±0 007	8 00±0 13	1 579±0 045
11	4924±10 02	25 6±2 45	127 70±5 76	38 4±0 79	5 20±2 34	7 13±0 98	27 34±1 34	0 226±0 012	1 439±0 032	0 85±0 009	0 26±0 008	2 70±0 34	0 225±0 076
12	4920±11 34	25 7±3 13	316 02±3 67	63 5±4 90	5 94±0 03	8 15±0 987	31 45±1 90	0 219±0 03	1 377±0 431	4 61±0 21	0 33±0 06	11 3±1 34	1 538±0 045
13	4347±12 95	25 4±2 18	304 56±6 72	96 66±2 98	5 2±0 016	7 95±0 63	38 76±0 97	0 211±0 06	0 434±0 005	2 67±0 96	0 27±0 012	8 4±1.43	0 729±0 003
14	4195±32 56	25 8±1 68	241 92±4 32	165 33±3 56	5 4±0 59	7 76±0 34	93 45±3 45	0 183±0 021	1 294±0 046	11 08±21 45	0 83±0 02	24 8±3 96	0 927±0 073

Table 6.73: Physico-Chemical parameters in Nandi-Lower Nyando in February 2005

Sites/Para	Alt (m)	Temp (°C)	Cond (μS/cm)	TSS (mg/L)	DO (mg/L)	pH	Turb (NTU)	TP (mg/L)	TN (mg/L)	Area (m^2)	Mean Vel (m/s)	Discharge (m^3/s)	Width (m)
14	4192±3.11	27.73±0.99	124.67±2.89	240.00±1.95	7.13±0.01	8.15±0.01	160.00±0.09	0.21±0.01	2.61±0.06	33.30±0.02	0.38±0.01	12.91±1.01	27.00±0.0
15	3901±2.97	27.03±0.43	130.37±1.78	205.50±2.87	6.98±0.03	7.94±0.01	156.33±2.67	0.48±0.07	5.03±0.05	34.50±0.09	0.40±0.07	28.00±1.01	29.00±0.0
16	3829±2.09	27.37±0.38	126.37±1.39	330.50±1.56	7.37±0.04	7.57±0.01	263.33±3.12	0.49±0.01	5.00±0.05	27.52±0.07	1.02±0.01	27.96±1.00	28.60±0.0
17	3785±9.01	27.21±0.21	127.28±1.24	334.30±2.21	7.21±0.03	7.49±0.03	268.37±1.89	0.50±0.06	4.97±0.01	28.40±0.07	1.34±0.04	28.400±1.01	29.00±0.0
18	3785±8.12	26.07±0.45	47.40±1.43	137.38±2.12	7.69±0.01	7.41±0.01	122.00±2.34	0.23±0.01	5.00±0.01	2.85±0.09	0.54±0.01	1.65±0.09	6.20±0.02
19	3965±7.09	26.77±0.65	110.43±1.34	43.00±1.98	6.77±0.01	7.21±0.01	189.40±1.78	0.29±0.02	3.09±0.04	7.32±0.06	0.56±0.02	4.09±0.001	7.00±0.02
21	4155±4.09	26.87±0.45	107.57±0.07	214.00±1.34	6.24±0.02	7.42±0.01	187.67±1.22	0.33±0.04	1.38±0.04	2.73±0.06	0.64±0.03	1.75±0.02	5.00±0.01
22	4328±4.03	27.27±0.63	157.40±0.95	70.32±1.00	7.85±0.02	7.69±0.03	77.30±1.34	0.20±0.05	1.92±0.02	5.13±0.01	0.65±0.04	3.34±0.02	9.30±0.02
23	4363±2.89	27.07±0.36	160.13±0.76	59.34±0.99	7.77±0.01	7.70±0.01	48.63±1.46	0.15±0.01	2.34±0.02	3.67±0.03	0.20±0.01	0.76±0.01	5.50±0.02
25	5975±4.97	26.57±0.45	91.80±0.34	109.34±2.43	7.11±0.01	7.43±0.04	86.53±3.56	0.14±0.05	2.31±0.02	0.37±0.01	0.26±0.02	0.10±0.02	2.40±0.01
26	6066±3.89	26.60±0.34	44.90±0.53	47.99±1.21	7.25±0.02	7.49±0.05	41.87±1.99	0.16±0.07	3.48±0.01	2.23±0.03	0.30±0.01	0.67±0.03	4.60±0.01
27	6080±3.23	26.97±0.63	32.10±0.61	47.34±2.10	7.34±0.05	6.93±0.01	38.07±1.56	0.19±0.07	1.59±0.02	1.21±0.01	0.81±0.03	0.99±0.01	2.50±0.02
30	5986±4.73	27.17±0.47	37.47±0.34	3.33±0.01	7.48±0.01	7.01±0.03	5.47±0.045	0.01±0.07	0.24±0.03	0.03±0.01	0.12±0.01	0.04±0.001	1.90±0.01
33	3778±2.56	26.43±0.64	96.07±0.45	145.83±0.02	7.48±0.01	7.72±0.04	123.67±1.67	0.34±0.03	0.94±0.01	0.25±0.04	0.18±0.01	0.54±0.002	3.20±0.01

Table 6.74: Physico-Chemical parameters in Nandi-Lower Nyando in February 2006

Sites/Para	Alt (m)	Temp (°C)	Cond (µS/cm)	TSS (mg/L)	DO	pH	Turb (NTU)	TP (mg/L)	TN (mg/L)	Area (m^2)	Mean Vel. (m^3/s)	Discharge (m^3/s)	Width (m)
15	3913±5.06	16.30±1.93	206±2.09	813.5±5.07	61.40±0.99	7.51±0.45	383.00±2.01	0.49±0.01	5.84±0.01	38.88±1.46	1.47±0.12	57.22±10.88	23.01±0.91
16	3839±4.01	19.50±2.06	214±4.91	874±3.09	59.40±0.58	7.58±0.10	305.00±1.98	0.41±0.09	5.67±0.21	51.50±3.81	1.30±0.09	67.05±1.02	35.40±0.2
17	3794±3.11	19.10±0.99	220±2.09	879±5.02	60.00±0.53	7.42±0.20	313.00±4.21	0.32±0.05	5.39±0.18	56.20±0.12	1.42±0.10	64.01±2.91	13.41±0.91
18	3797±3.09	20.10±0.74	104±2.09	830±1.09	35.60±0.91	7.35±0.67	265.00±3.12	0.15±0.07	3.21±0.11	38.45±1.09	1.12±0.02	9.84±0.12	8.50±0.32
19	3977±2.91	14.90±1.95	197.90±2.87	381±2.91	61.30±0.31	7.98±0.56	126.00±1.34	0.16±0.03	5.44±0.23	14.35±1.03	0.79±0.06	11.37±1.45	7.64±1.12
21	4161±5.03	13.00±0.63	185.7±3.03	177±1.06	71.50±0.91	7.73±0.42	105.00±1.03	0.14±0.01	0.50±0.03	0.96±0.91	1.00±0.01	0.97±0.01	0.49±0.07
22	4336±4.09	15.70±1.05	254±3.28	129.5±3.95	74.30±0.61	7.83±0.45	61.00±0.14	0.17±0.03	0.92±0.12	6.30±0.07	0.29±0.03	1.86±0.14	9.90±0.42
23	4364±3.10	15.40±0.98	246±3.56	123.5±1.05	59.80±1.31	7.86±0.21	44.00±0.34	0.10±0.01	1.13±0.01	6.16±0.06	0.65±0.02	4.04±0.92	6.10±0.12
25	5991±3.15	19.90±1.00	156.7±1.09	118.5±2.74	64.00±0.12	7.53±0.12	46.00±0.43	0.19±0.07	2.72±0.65	0.69±0.01	0.34±0.01	23.80±2.20	0.22±0.01
26	6072±5.08	15.60±0.54	72.60±2.09	112±1.65	65.30±2.35	6.95±0.65	37.00±0.21	0.09±0.01	1.72±0.04	0.85±0.01	0.92±0.01	0.79±0.02	3.10±0.01
27	6093±4.34	20.60±1.04	50.41±3.91	86.5±1.97	36.30±0.79	6.32±0.18	23.00±0.12	0.09±0.001	1.50±0.09	1.52±0.12	0.52±0.01	0.79±0.06	3.20±0.21
30	5996±3.05	16.90±2.01	41.801±1.93	3.15±0.06	62.40±0.78	5.78±0.42	3.00±0.01	0.02±0.001	0.41±0.05	0.04±0.01	0.27±0.01	0.01±0.001	0.60±0.01
33	5999±3.01	25.50±2.03	127.7±3.17	281±3.10	5.30±0.67	7.1±0.44	226.00±2.11	0.32±0.06	4.21±0.03	0.88±0.04	0.72±0.09	0.64±0.02	0.20±0.03

Table 6.75: Physico-chemical parameters in Kericho-Upper Nyando in May 2005

Site/Para	Alt (m)	Temp (°C)	Cond (µS/cm)	TSS (mg/L)	DO (mg/L)	pH	Turb (NTU)	TP (mg/L)	TN (mg/L)	Area (m^2)	Mean Vel (m/s)	Discharge (m^3/s)	Width (m)
1	7515±6.09	27.10±0.01	139.30±0.01	76.35±0.98	7.65±0.01	7.83±0.02	125.67±2.45	0.21±0.01	3.65±0.01	0.44±0.01	0.64±0.01	0.28±0.02	3.70±0.04
3	7580±3.09	28.13±0.09	77.70±0.016	32.00±0.06	7.01±0.04	7.94±0.06	61.97±1.24	0.08±0.01	3.44±0.01	0.34±0.01	0.38±0.01	0.13±0.03	2.60±0.01
4	7507±2.34	28.06±0.01	96.07±0.01	76.54±0.98	7.21±0.05	8.08±0.07	61.90±1.11	0.11±0.02	2.71±0.03	1.75±0.02	0.46±0.012	0.81±0.01	6.04±0.07
5	6740±2.46	27.73±0.02	111.23±0.01	62.67±0.99	8.24±0.09	8.45±0.02	79.47±1.32	0.16±0.01	3.81±0.02	4.87±0.02	0.43±0.01	2.09±0.01	6.20±0.01
6	6552±2.34	28.07±0.01	103.40±0.01	61.67±0.99	7.36±0.01	8.02±0.02	102.67±0.91	0.13±0.02	2.92±0.01	5.41±0.01	0.39±0.02	2.15±0.01	7.30±0.04
7	6308±1.34	27.67±0.01	76.40±0.01	125.50±1.54	7.15±0.10	7.88±0.01	133.33±2.78	0.15±0.01	2.15±0.03	0.88±0.05	0.53±0.08	0.45±0.01	2.00±0.01
8	6307±3.21	27.33±0.02	93.57±0.01	193.00±2.45	7.62±0.04	7.93±0.03	148.67±2.14	0.18±0.01	3.19±0.01	6.76±0.01	0.60±0.09	0.62±0.01	9.50±0.08
9	6563±2.13	27.30±0.01	81.13±0.02	166.50±2.45	7.24±0.02	9.80±0.02	133.33±1.34	0.23±0.01	2.71±0.01	1.17±0.01	0.56±0.01	0.64±0.01	4.50±0.03
10	5102±3.89	26.97±0.02	166.63±1.21	217.00±1.23	8.25±0.01	7.68±0.01	142.33±1.65	0.17±0.01	2.57±0.01	2.32±0.03	0.39±0.01	0.91±0.02	6.70±0.06
11	4921±4.12	27.27±0.03	169.57±1.11	193.50±1.56	7.47±0.03	8.26±0.03	147.67±2.34	0.23±0.01	1.21±0.01	0.42±0.06	0.61±0.03	0.26±0.04	2.30±0.06
12	4917±1.12	27.23±0.06	163.33±1.90	149.00±0.78	8.01±0.01	8.21±0.01	141.00±1.23	0.18±0.03	2.49±0.01	1.80±0.03	0.56±0.02	1.04±0.07	6.60±0.07
13	4344±1.67	27.23±0.01	169.17±1.01	64.60±0.98	8.35±0.005	7.94±0.05	55.73±2.45	0.30±0.08	1.89±0.01	2.06±0.01	0.34±0.01	0.71±0.07	7.50±0.01
14	4192±2.15	27.73±0.04	124.67±2.12	240.00±2.09	7.13±0.01	8.15±0.01	160.01±0.942	0.21±0.02	2.61±0.03	33.30±0.01	0.38±0.02	12.91±1.06	27.00±1.0

Table 6.76: Physico-chemical parameters in Kericho-Upper Nyando in May 2006

Sites/	Alt (m)	Temp (°C)	Condu (µS/cm)	TSS (mg/L)	DO (mg/L)	pH	Turb (NTU)	TP (mg/L)	TN (mg/L)	Area (m^2)	Mean Velo (m^2/s)	Discharge (m^3/s)	Width (m)
1	7519±20.01	27.1±1.34	139.33±3.56	76.34±2.89	7.65±0.01	7.78±0.03	125.67±3.21	0.207±0.03	3.653±0.012	0.12±0.009	0.10±0.01	0.01±0.001	2.50±0.06
3	7588±9.74	28.13±0.85	77.7±1.65	32.01±2.12	7.03±0.04	7.94±0.01	61.97±1.26	0.083±0.001	3.44±0.009	0.29±0.003	0.22±0.01	0.06±0.01	0.18±0.01
4	7511± 32.09	28.07±2.94	96.07±2.54	56.54±2.67	6.87±0.01	8.08±0.05	61.00±0.98	0.11±0.04	2.714±0.170	0.75±0.004	0.24±0.02	0.18±0.001	2.80±0.12
5	6744±30.56	27.73±1.09	111.23±1.95	63.26±3.13	8.24±0.02	7.90±0.06	78.90±2.34	0.156±0.03	3.810±0.034	1.65±0.002	0.21±0.01	0.35±0.001	4.20±0.28
6	6557±19.02	28.07±0.67	103.4±1.45	61.67±2.10	7.36±0.009	8.02±0.03	102.67±1.23	0.127±0.007	2.922±0.061	1.41±0.06	0.66±0.01	0.94±0.001	6.80±0.18
7	6312±18.34	27.67±3.72	82.2±0.98	27.67±1.32	7.15±0.01	8.22±0.06	133.30±2.98	0.146±0.04	2.153±0.140	0.39±0.001	0.95±0.01	0.37±0.012	2.10±0.34
8	6310±14.45	27.33±1.56	93.57±2.45	193±4.52	7.36±0.06	7.93±0.01	148.67±3.45	0.183±0.001	3.118±0.321	2.28±0.12	0.43±0.01	0.99±0.04	6.30±0.51
9	6568±21.02	27.5±2.67	81.13±1.84	166.5±3.45	7.31±0.07	7.80±0.05	133.33±1.23	0.225±0.005	2.707±0.167	1.59±0.03	0.68±0.02	1.09±0.04	3.95±0.12
10	5109±10.93	26.97±1.54	166.63±4.51	217±5.34	8.16±0.04	7.68±0.01	142.33±2.56	0.166±0.003	2.570±0.871	1.79±0.012	0.63±0.01	1.33±0.01	8.40±1.09
11	4928±13.0	27.67±0.98	169.57±1.23	193.5±2.45	7.47±0.08	8.26±0.03	147.67±1.56	0.217±0.002	1.207±0.012	0.65±0.03	0.28±0.02	0.18±0.01	3.70±0.53
12	4921±10.34	27.23±1.56	163.38±1.45	149±2.56	8.01±0.01	8.21±0.01	141.12±2.34	0.18±0.01	2.492±0.041	4.07±0.09	0.37±0.06	1.53±0.01	13.00±2.10
13	4347±12.17	27.3±0.32	169.17±3.78	64.6±1.78	8.35±0.01	7.94±0.02	55.73±2.56	0.295±0.01	1.885±0.014	1.45±0.03	0.38±0.04	0.54±0.04	5.40±0.78
14	4198±28.79	27.73±1.23	124.6±4.23	240±3.49	7.13±0.04	8.15±0.01	160.01±3.09	0.212±0.03	2.609±0.046	2.06±0.88	0.35±0.01	0.67±0.01	0.68±0.01

Table 6.77: Physico-Chemical parameters in Nandi-Lower Nyando in May 2005

Site /Para	Alt (m)	Temp (°C)	Cond (µS/cm)	TSS (mg/L)	DO (mg/L)	pH	Turb (NTU)	TP (mg/L)	TN (mg/L)	Area (m^2)	Mean Vel (m/s)	Discharge (m^3/s)	Width (m)
15	3901±2.92	27.03±0.07	130.37±1.9	205.50±3.45	6.98±0.02	7.94±0.03	156.33±4.12	0.48±0.03	5.03±0.01	34.50±01.21	0.40±0.01	28.00±0.11	29.00±0.0
16	3829±1.89	27.37±0.01	126.37±2.56	330.50±4.83	7.37±0.06	7.57±0.02	263.33±4.17	0.49±0.02	5.00±0.012	27.52±2.31	1.02±0.05	27.96±0.02	28.60±0.5
17	3785±3.15	27.21±0.01	127.28±1.93	334.30±2.89	7.21±0.03	7.49±0.01	268.37±2.91	0.50±0.01	4.97±0.03	28.40±1.45	1.34±0.01	28.40±0.05	29.00±0.9
18	3785±1.56	26.07±0.02	47.40±1.45	137.38±3.62	7.69±0.02	7.41±0.09	122.00±1.93	0.23±0.03	5.00±0.01	2.85±1.34	0.54±0.01	1.65±0.01	6.20±0.32
19	3965±2.45	26.77±0.03	110.43±2.42	43.00±1.01	6.77±0.09	7.21±0.02	189.40±3.21	0.29±0.03	3.09±0.06	7.32±0.032	0.56±0.02	4.09±0.05	7.00±0.45
21	4155±1.78	26.87±0.01	107.57±3.19	214.00±2.01	6.24±0.06	7.42±0.01	187.67±2.91	0.33±0.01	1.38±0.01	2.73±0.05	0.64±0.01	1.75±0.04	5.00±0.19
22	4328±4.78	27.27±0.02	157.40±3.18	70.32±1.07	7.85±0.01	7.69±0.01	77.30±2.56	0.20±0.01	1.92±0.02	5.13±0.07	0.65±0.03	3.34±0.02	9.30±0.97
23	4363±1.92	27.07±0.01	160.13±1.23	59.34±1.12	7.77±0.06	7.70±0.01	48.63±2.13	0.15±0.010	2.34±0.02	3.67±0.07	0.20±0.01	0.76±0.02	5.50±0.45
25	5975±8.92	26.57±0.05	91.80±1.21	109.34±1.43	7.11±0.07	7.43±0.02	86.53±3.67	0.14±0.04	2.31±0.09	0.37±0.01	0.26±0.02	0.10±0.02	2.40±0.67
26	6066±5.61	26.60±0.05	44.90±1.96	47.99±1.12	7.25±0.03	7.49±0.01	41.87±3.19	0.16±0.05	3.48±0.02	2.23±0.34	0.30±0.04	0.67±0.03	4.60±0.97
27	6080±3.24	26.97±0.05	32.10±2.45	47.34±2.56	7.34±0.01	6.93±0.02	38.07±3.45	0.19±0.03	1.59±0.02	1.21±0.02	0.81±0.07	0.99±0.04	2.50±0.56
30	5986±2.11	27.17±0.09	37.47±1.45	3.33±0.02	7.48±0.01	7.01±0.01	5.47±0.02	0.01±0.006	0.24±0.04	0.03±0.002	0.12±0.01	0.04±0.03	1.90±0.54
33	3778±3.12	26.43±0.12	96.07±2.95	145.83±4.67	7.48±0.01	7.72±0.05	123.67±6.12	0.34±0.02	0.94±0.03	0.25±0.02	0.18±0.01	0.54±0.01	3.20±0.56

Table 6.78: Physico-Chemical parameters in Nandi-Lower Nyando in May 2006

Site/Para	Alt (m)	Temp (°C)	Cond (μS/cm)	TSS (mg/L)	DO	pH	Turb(NTU)	TP (mg/L)	TN (mg/L)	Area (m^2)	Mean Vel. (m/s)	Discharge (m^3/s)	Width (m)
15	3907±46 01	27 03±0 01	130 37±2 12	205 50±9 67	6 98±0 10	7 91±0 01	156 33±12 10	0 48±0 03	5 029±0 912	10 50±0 02	0 45±0 001	11 00±1 23	16 00±1 34
16	3835±34 05	27 37±0 05	126 37±3 14	330 50±11 43	7 36±0 12	7 57±0 07	263 33±10 09	0 23±0 009	4 041±0 452	24 50±2 12	0 46±0 09	12 50±2 09	32 00± 2 94
17	3789±27 09	27 09±0 01	128 12±1 91	336 83±14 45	7 39±0 09	7 75±0 31	98 12±2 93	0 21±0 01	4 289±0 010	1 01±0 09	0 36±0 001	1 102±0 09	3 94±0 34
18	3791±26 19	26 07±0 3	47 4±3 45	26 07±2 17	7 69±0 62	7 41±0.10	122 00±9 87	0 29±0 04	3 123±0 210	2 15±0 92	0 76±0 04	1 645±0 53	5 80±0 75
19	3970±32 02	25 04±0 02	107 24±5 96	217 10±2 89	7 78±0 78	7 45±0 21	137 86±11 91	0 23±0 03	1 932±0 010	1 34±0 87	0 38±0 05	1 981±0 06	4 15±0 65
21	4159±46 01	26 87±0 11	107 57±23 09	214 00±11 43	6 24±0 03	7 42±1 01	187 67±9 11	0 329±0 01	1 376±0 060	1 98±0 64	0 31±0 04	0 61±0 02	4 40±1 01
22	4331±43 09	27 27±0 81	157 41±3 97	70 32±4 15	7 87±0 98	7 69±0 56	77 30±2 12	0 197±0 001	1 918±0 121	3 39±0 73	0 33±0 001	1 14±0 08	8 10±0 98
23	4359±41 05	27 07±0 12	160 13±4 92	59 34±1 23	7.77±0 52	7 70±0 34	48 63±1 23	0 151±0 02	2 342±0 320	0 78±0 02	0 62±0 004	0 484±0 01	4 60±0 56
25	5983±45 02	26 57±0 10	91 80±1 34	109 34±12 90	7 11±0 01	7 43±0 61	86 53±5 67	0.141±0 01	2 309±0 091	0 32±0 12	0 27±0 012	0 088±0 01	0 32±0 12
26	6069±47 09	26 60±0 21	44 90±0 98	47 99±2 56	7 25±0 21	7 49±0 18	41 87±2 95	0 161±0 11	3 483±0 742	0 73±0 09	0 60±0 08	0 038±0 001	2 70±0 91
27	6088±43 02	26 97±0 12	32 10±0 45	47 34±1 54	7 37±0 19	6 93±0 78	38 07±3.01	0 178±0 04	1 592±0 092	0 54±0 05	0 26±0 05	0 226±0 009	2 60±0 04
30	5990±40 12	27 17±0 15	37 47±1 31	0 09±0 001	7 48±0 78	7 01±0 45	5 47±0 23	0 012±0 003	0 074±0 121	0 04±0 001	0 25±0 012	0 10±0 002	0 40±0 001
33	3774±23 45	26 43±0 02	96 07±2 87	145 88±12 90	7 10±0 91	7 72±0 12	123 67±9 09	0 365±0 001	3 974±0 012	0 5±0 03	0 86±0 021	0 043±0 001	1 80±0 02

Table 6.79: Physico-chemical parameters in Kericho-Upper Nyando in September 2005

Site /Para	Alt (m)	Temp (°C)	Conduc (µS/cm)	TSS (mg/L)	DO (mg/L)	pH	Turb (NTU)	TP (mg/L)	TN (mg/L)	Area(m^2)	Mean Vel (m/s)	Discharge (m^3/s)	Width (m)
1	7515 00±3 94	26 33±0 03	59 80±1 98	498 00±3 20	8 95±0 02	7 05±0 01	368 00±1 45	0 245±0 001	4 179±0 211	1 86±0 021	1 12±0 02	2 081±0 021	3 70±0 02
3	7580 00±3 78	25 90±0 04	66 00±1 26	270 00±4 71	7 49±0 04	6 76±0 02	152 33±1 44	0 188±0 002	4 846±0 012	0 47±0 001	0 34±0 012	0 164±0 001	2 25±0 02
4	7507 00±4 12	22 87±0 05	57 87±1 38	132 00±3 21	8 23±0 01	6 83±0 009	189 67±1 12	0 290±0 012	3 813±0 092	4 65±0 051	0 77±0 01	3 589±0 028	2 60±0 01
5	6740 00±2 89	26 40±0 03	57 63±2 09	411 50±3 31	7 67±0 03	7 13±0 03	343 33±2 91	0 343±0 031	3 291±0 062	8 52±0 421	0 92±0 09	7 885±0 451	6 10±0 03
6	6552 00±5 12	26 83±0 07	67 13±3 12	431 00±2 12	6 62±0 03	7 13±0 04	270 67±2 13	0 307±0 046	3 494±0 042	5 25±0 350	0 42±0 07	2 246±0 023	7 70±0 07
7	6308 00±3 21	26 17±0 01	200 77±5 01	11 46±1 32	8 36±0 07	7 93±0 03	32 63±1 22	0 170±0 041	3 262±0 062	0 26±0 002	0 23±0 02	0 06±0 001	1 65±0 08
8	6307 00±3 42	26 10±0 01	68 53±2 91	421 00±2 78	8 35±0 09	7 10±0 01	278 67±2 33	0 366±0 061	3 511±0 032	0 38±0 007	0 17±0 009	0 064±0 001	2 00±0 01
9	6563 00±2 17	26 47±0 03	89 80±1 22	46 00±2 34	7 87±0 02	7 59±0 008	83 50±1 98	0 219±0 051	3 279±0 051	0 61±0 012	0 23±0 02	0 142±0 019	3 50±0 02
10	5102 00±2 21	26 03±0 02	104 63±2 34	200 00±3 78	8 55±0 01	7 47±0 03	145 67±2 34	0 280±0 024	3 395±0 045	3 75±0 264	0 69±0 01	2 582±0 186	9 60±0 11
11	4921 00±4 23	25 10±0 03	374 33±6 12	33 50±1 23	5 60±0 01	8 10±0 05	38 60±1 98	1 715±0 026	4 306±0 032	0 56±0 023	0 39±0 03	0 220±0 012	1 80±0 12
12	4917 00±3 12	27 20±0 009	194 70±2 98	133 00±1 45	7 50±0 03	8 15±0 01	29 43±1 00	0 250±0 023	2 902±0 011	0 88±0 023	0 84±0 04	0 740±0 023	3 00±0 03
13	4344 00±2 13	26 90±0 03	124 80±3 45	133 00±4 01	7 60±0 04	7 78±0 02	27 46±1 34	0 409±0 034	3 215±0 067	0 81±0 021	0 22±0 01	0 179±0 009	7 60±0 04
14	4192 00±3 32	26 67±0 04	125 43±2 23	97 50±0 07	7 61±0.04	7 50±0 013	89 63±1 45	0 270±0 013	2 641±0 041	2 00±0 021	0 23±0 021	0 470±0 041	7 10±0 01

Table 6.80 Physico-chemical parameters in Kericho-Upper Nyando in September 2006

Sites/Para	Alt (m)	Temp (°C)	Condu (µS/cm)	TSS (mg/L)	DO (mg/L)	pH	Turb (NTU)	TP (mg/L)	TN (mg/L)	Area (m^2)	Mean Vel (m^3/s)	Discharge (m^3/s)	Width (m)
1	7518±8 12	26 33±0 99	59 83±0 56	498±4 89	8 01±0 76	7 07±0 01	368 00±3 09	0 245±0 01	4 179±0 56	3 71±0 45	0 19±0 007	0 722±0 003	8 20±0 19
3	7589±9 67	26 54±0 53	66 00±1 13	269 67±4 51	7.49±0 12	6 76±0 12	152 33±3 14	0 188±0 05	4 846±0 14	0 47±0 21	0 34±0 05	0.164±0 01	2 25±0 21
4	7510±4 53	26 2±1 01	57 87±2 14	135 67±3 90	8 23±0 34	6 79±0 04	189 67±2 98	0 29±0 01	3 813±0 03	2 47±0 13	0 51±0 009	1 308±0 021	6 80±0 14
5	6748±2 89	26 4±0 72	57 63±2 89	407 00±5 67	7 62±0 65	7 13±0 001	343 33±4 19	0 343±0 06	3 291±0 09	3 50±0 37	0 45±0 006	1 596±0 056	5 70±0 012
6	6556±2 01	26 83±0 12	67 13±3 56	432 33±6 34	6 62±0 21	7 13±0 009	270 67±3 87	0 307±0 01	3 494±0 45	5 25±0 52	0 42±0 03	2 246±0 034	7 70±0 56
7	6313±1 47	26 16±0 41	200 77±4 56	26 67±1 34	8 36±1 09	7 93±0 02	32 63±1.03	0 17±0 009	3 262±0 04	0 26±0 001	0 23±0 01	0 06±0 07	1 65±0 91
8	6315±1 06	26 1±0 97	68 53±1 56	432 67±4 61	8 34±0 99	7 09±0 05	278 67±3 24	0 366±0 05	3 511±0 14	5 04±0 12	0 41±0 01	2 08±0 012	9 30±0 32
9	6568±2 46	26 47±0 45	89 8±2 68	47.00±1 34	7 87±0 43	7 59±0 04	83 5±1 98	0 219±0 03	3 279±0 05	0 61±0 54	0 23±0 03	0 142±0 006	3 50±0 13
10	5108±1 89	26 03±0 34	104 97±2 11	196 30±1 94	7 87±0 89	7 59±0 001	86 78±1 45	0 28±0 02	3 395±0 34	3 75±0 23	0 69±0 009	2 582±0 87	9 60±0 35
11	4926±1 67	25 1±0 56	374 33±5 22	33 67±0 98	5 60±0 56	8 10±0 51	38 60±1.24	1 715±0 98	4 306±0 14	0 56±0 004	0 39±0 001	0 22±0 007	1 80±0 21
12	4923±1 56	27 4±0 34	194 87±2 17	133 33±1 34	7 50±0 87	8 15±0 06	29 43±0.45	0 25±0 01	2 902±0 23	5 64±0 94	0 64±0 003	3 35±0 001	14 00±1 09
13	4349±1 92	25 9±0 01	59 80±2 12	127 98±1 03	8 30±0 75	7 05±0 01	368 00±2 78	0 409±0 005	3 215±0 01	0 81±0 03	0 22±0 01	0 179±0 002	7 60±0 54
14	4195±1 04	26 67±0 02	125 43±5 78	191±2 34	7 61±0 45	7 50±0 99	89 63±1 22	0 27±0 009	2 641±0 34	10 38±0 41	0 33±0 09	3 45±0 002	24 00±0 01

Table 6.81: Physico-Chemical parameters in Nandi-Lower Nyando in September 2005

Sites/Para	Alt (m)	Temp (°C)	Condu (µS/cm)	TSS (mg/L)	DO (mg/L)	pH	Turb (NTU)	TP (mg/L)	TN (mg/L)	Area (m^2)	Mean Vel (m/s)	Discharge (m^3/s)	Width (m)
15	3901±3.09	26.50±0.01	117.10±1.94	227.00±1.03	7.82±0.01	7.38±0.01	89.63±1.88	0.34±0.02	3.96±0.01	39.72±0.02	0.52±0.03	20.06±1.00	33.33±0.01
16	3829±3.56	27.33±0.03	101.90±1.45	335.00±1.12	6.54±0.02	7.20±0.01	160.00±2.92	0.46±0.02	3.78±0.03	34.70±0.06	0.53±0.04	18.50±1.21	49.00±0.09
17	3785±3.61	26.67±0.04	125.63±1.45	342.50±1.01	7.85±0.04	7.47±0.04	189.33±2.89	0.49±0.02	3.34±0.21	19.78±0.03	0.93±0.02	17.89±0.99	16.61±0.34
18	3785±2.12	26.20±0.15	48.10±2.34	104.50±1.03	8.45±0.03	7.04±0.03	92.40±3.09	0.27±0.01	2.59±0.34	3.71±0.04	0.19±0.03	0.72±0.01	8.20±0.05
19	3965±2.34	27.30±0.02	115.80±3.12	242.00±2.12	7.68±0.01	7.66±0.04	103.53±2.98	0.46±0.02	3.25±0.01	3.46±0.02	0.57±0.02	1.98±0.02	10.60±0.56
21	4155±3.36	26.20±0.11	179.07±2.92	78.50±3.21	7.07±0.05	7.87±0.02	67.03±2.12	0.13±0.01	2.21±0.03	8.48±0.05	0.92±0.01	7.80±0.06	7.12±0.45
22	4328±2.90	25.67±0.04	119.27±3.17	290.50±4.12	7.24±0.03	7.98±0.03	99.60±1.33	0.19±0.02	3.56±0.04	1.93±0.02	0.25±0.01	0.49±0.07	4.30±0.21
23	4363±3.29	25.40±0.08	245.67±5.12	44.00±1.23	8.56±0.01	8.14±0.06	33.35±3.33	0.15±0.02	2.36±0.04	2.11±0.02	0.49±0.01	0.49±0.05	4.80±0.02
25	5975±4.12	25.03±0.01	201.83±4.61	91.50±1.38	24.91±0.04	7.80±0.01	60.17±2.97	0.19±0.03	3.42±0.05	0.43±0.0.09	0.37±0.05	0.16±0.01	2.40±0.11
26	6066±1.32	26.00±0.09	70.80±2.41	51.50±2.19	7.67±0.01	7.49±0.03	37.97±2.61	0.07±0.01	3.63±0.10	0.60±0.07	0.46±0.04	0.27±0.02	1.70±0.03
27	6080±2.13	24.47±0.009	67.57±2.95	34.00±1.78	6.01±0.04	7.19±0.01	26.60±3.12	0.06±0.003	1.96±0.01	0.95±0.01	0.30±0.001	0.29±0.02	2.60±0.03
30	5986±1.67	25.47±0.12	67.57±2.31	36.00±1.23	6.01±0.02	7.19±0.02	26.60±3.12	0.01±0.001	0.02±0.01	1.50±0.04	0.51±0.02	0.77±0.03	2.60±0.01
33	3778±3.41	25.27±0.01	130.50±3.91	8.00±1.29	7.18±0.01	6.21±0.01	6.53±0.23	0.96±0.03	2.94±0.02	0.99±0.02	0.10±0.01	0.12±0.02	0.40±0.04

Table 6.82: Physico-Chemical parameters in Nandi-Lower Nyando in September 2006

Sites/Para	Alt (m)	Temp (°C)	Cond (µS/cm)	TSS (mg/L)	DO	pH	Turb(NTU)	TP (mg/L)	TN (mg/L)	Area (m^2)	Mean Vel. (m^3/s)	Discharge (m^3/s)	Width (m)
15	3908±41.09	26.83±0.23	117.10±2.98	231.67±11.01	7.82±0.10	7.28±0.06	149.33±9.20	0.34±0.01	3.958±0.12	38.72±1.10	0.518±0.01	20.06±1.97	33.33±2.90
16	3835±39.04	27.33±0.40	101.90±4.10	330.33±8.21	6.72±0.12	7.20±0.01	160.11±8.09	0.27±0.007	2.14±0.021	34.70±0.94	0.53±0.019	18.50±0.94	49.00±1.49
17	3791±25.00	26.67±0.30	125.63±0.99	296.33±17.62	7.82±0.009	7.47±0.60	189.33±3.13	0.19±0.009	2.05±0.001	19.78±0.05	0.918±0.02	17.89±2.23	16.61±1.56
18	3785±21.09	26.20±0.19	48.10±1.21	104.00±3.01	8.44±0.62	7.04±0.02	92.40±5.83	0.11±0.008	1.14±0.002	3.71±0.013	0.19±0.03	0.72±0.02	8.20±0.94
19	3971±30.01	27.30±0.74	115.80±6.10	239.33±3.19	7.68±0.78	7.66±0.01	103.53±7.54	0.46±0.001	3.227±0.05	8.48±0.02	0.919±0.012	7.80±1.98	7.12±1.32
21	4163±42.00	26.13±0.86	179.07±20.21	81.00±5.12	7.07±0.03	7.87±0.17	67.03±4.06	0.14±0.003	2.205±0.04	1.70±0.001	0.24±0.009	0.41±0.07	4.40±0.23
22	4334±41.01	25.67±0.23	191.27±4.01	295.67±5.90	7.24±0.02	7.98±0.21	99.60±5.36	0.20±0.001	3.575±0.01	8.70±0.04	2.13±0.04	18.53±2.34	8.00±0.97
23	4369±34.01	25.40±0.09	245.67±3.12	43.67±0.78	8.56±0.52	8.14±0.01	32.60±0.78	0.15±0.002	2.356±0.003	2.11±0.03	0.19±0.011	0.49±0.012	4.80±0.32
25	5970±37.08	25.03±0.32	201.83±0.99	90.67±9.10	6.22±0.01	7.80±0.03	60.17±3.07	0.19±0.001	3.424±0.001	0.43±0.06	0.37±0.020	0.16±0.009	2.40±0.14
26	6069±42.11	26.00±0.14	70.80±1.01	51.67±3.94	7.64±0.21	7.49±0.06	37.97±1.14	0.07±0.002	3.627±0.004	0.67±0.01	0.84±0.007	0.56±0.01	2.60±0.62
27	6085±39.15	25.47±0.32	67.57±0.76	35.33±0.84	6.01±0.19	7.19±0.35	26.60±1.18	0.06±0.001	1.962±0.008	0.95±0.03	0.30±0.002	0.29±0.009	2.60±0.621
30	5988±36.27	25.27±0.71	130.50±1.67	0.67±0.040	7.18±0.78	6.21±0.31	3.53±0.010	0.01±0.009	0.07±0.004	0.15±0.001	0.11±0.001	0.02±0.001	0.40±0.021
33	3781±19.26	27.33±0.07	141.63±2.05	271.30±16.34	6.68±0.91	6.96±0.35	189.33±19.01	0.94±0.013	2.10±0.009	0.06±0.001	0.06±0.001	0.03±0.001	0.03±0.001

Table 6.83: Physico-chemical parameters in Kericho-Upper Nyando in December 2005

Sites/Para	Alt (m)	Temp (°C)	Cond (µS/cm)	TSS (mg/L)	DO (mg/L)	pH	Turb (NTU)	TP (mg/L)	TN (mg/L)	Area(m^2)	Mean Vel (m/s)	Discharge (m^3/s)	Width (m)
1	7515±4.19	15.40±0.01	148.30±2.09	27.50±0.09	55.90±0.21	7.28±0.01	73 00±1.90	0.15±0.01	1.41±0.02	0.57±0.08	2.43±0.08	1.39±0.05	1.32±0.04
3	7580±3.51	18 40±0.02	126 80±1.34	78.67±2.32	64.40±0.34	6.93±0.03	75.00±0 972	0.08±0.003	2.18±0.04	0.90±0.06	0.50±0.02	0.46±0.01	1 20±0.03
4	7507±1.97	18 40±0.03	127 80±1.98	53.00±1.01	64.40±0.98	7.11±0.04	89.00±1 93	0.08±0.008	2.30±0.03	1.19±0.01	0.63±0.01	0.76±0.03	2.59±0.04
5	6740±3 21	17.50±0.03	138.70±3.22	31.40±0.98	73.80±0.65	7.45±0.06	93.00±1 87	0.07±0.002	1.57±0.04	1.99±0.03	0.60±0.05	1.20±0.02	7.80±0.06
6	6552±2.89	12.10±0.04	134.80±1.34	28.80±0.45	48 10±0.11	7.54±0.05	84.00±2.43	0.11±0.05	1.72±0.06	4.40±0.01	0.27±0.03	1.19±0.01	4.10±0.03
7	6308±3.41	15.40±0.01	308 00±2.92	52.80±01.23	44.50±0.12	7.80±0.05	30.00±2.65	0.21±0.04	1.39±0.06	0.22±0.02	0.15±0.02	0.11±0.03	2.60±0 01
8	6307±2.94	15.90±0 04	163.50±2.11	62.00±0.17	74.30±0.34	7.42±0.04	81.00±2.33	0 14±0.01	1.58±0.04	3 97±0.01	0.25±0.03	1.01±0.01	2.40±0.02
9	6563±1.22	19.80±0.05	169.00±3.82	30.80±0.96	44.80±0.44	7.50±0.04	35.00±3.12	0.19±0.05	1.55±0.01	0.73±0.03	0.15±0.01	0.11±0.01	4.30±0.03
10	5102±3.21	25.80±0.04	310.00±4.92	88.50±1.34	5.68±012	8.10±0.03	36.00±1.99	0.21±0.01	1.16±0.03	2.55±0.01	0.62±0.03	1.58±0.06	6.10±0 06
11	4921±2.11	25.60±0.06	127.70±2.11	38.40±1.43	5.20±0.01	7.13±0.03	227.00±2.99	0.23±0.02	1.44±0.01	0.85±0.01	0.26±0.01	0.25±0.01	2.10±0.09
12	4917±4.11	25.70±0.01	316 00±1.34	63.50±3.34	5.94±0.98	8.15±0.02	31.00±2.11	0.22±0.01	1.38±0.04	4.61±0.01	0.33±0.03	1.54±0.04	4.70±0.05
13	4344±1.22	25.40±0.03	304.00±1.22	96.66±4.12	5.20±0.31	7.95±0.012	38.00±1.77	0.21±0.07	0.43±0.01	2.67±0.03	0.27±0.04	0.73±0.02	4.00±0 07
14	4192±2.11	25.80±0.01	241.00±1.98	165.33±4.56	5.40±0.34	7.76±0.01	93.00±2.01	0.18±0.03	1.29±0.03	11.08±1.02	0.83±0.05	0.93±0.02	12 60±0.0

Table 6.84: Physico-chemical parameters in Kericho-Upper Nyando in December 2006

Site/	Alt (m)	Temp (°C)	Condu (µS/cm)	TSS (mg/L)	DO (mg/L)	pH	Turb (NTU)	TP (mg/L)	TN (mg/L)	Area (m^2)	Mean Vel (m^{-1}s)	Discharge (m^3/s)	Width (m)
1	7519±9 04	14 90±1 06	157 50±4 39	24 30±1 09	6 90±0 06	7.71±0 06	69 00±1 05	0 059±0 001	1 395±0 061	0 12±0 04	0 05±0 001	0 006±0 001	3 30±0 01
3	7588±7 81	19 40±1 94	128 20±2 42	41 00±3 95	6 00±0 12	7 81±0 04	79 00±2 45	0 052±0 003	2 704±0 012	0 43±0 05	0 26±0 009	0 113±0 001	2 40±0 006
4	7509±6 98	17 80±1 04	130 10±2 91	3 30±0 019	5 98±0 34	7 67±0 01	91 00±1 25	0 027±0 002	2 039±0 023	0 54±0 009	0 31±0 004	0 166±0 007	7 00±0 007
5	6749±0 92	16 90±2 11	143 00±2 54	14 30±1 06	7 55±0 09	7 51±0 009	98 00±1 45	0 032±0 001	2 439±0 780	0 92±0 006	0 37±0 005	0 348±0 006	3 90±0 003
6	6558±12 34	13 00±1 03	139 00±3 00	0 03±0 001	5 20±0 01	7 73±0 06	79 00±01 89	0 028±0 003	0 198±0 040	1 11±0 01	0 32±0 001	0 361±0 009	6 90±0 001
7	6312±6 43	14 80±1.14	312 00±1 01	30 00±0 003	5 80±0 05	8 15±0 04	34 00±1 67	0 111±0 01	0 793±0 032	0 10±0 001	0 03±0 001	0 004±0 001	1 20±0 021
8	6310±10 23	15 00±1 67	169 40±4 13	28 30±3 87	8.21±0 01	8 23±0 01	89 00±1 43	0 045±0 006	1 431±0 021	0 95±0 01	0 28±0 002	0 266±0 003	7 80±0 003
9	6568±7 89	21 30±2 56	159 00±2 31	20 00±1 09	5 00±0 02	7 95±0 05	29 00±0 89	0 05±0 004	0 439±0 034	0 53±0 02	0 18±0 002	0 116±0 003	2 50±0 012
10	5108±3 15	26 10±2 54	317 00±6 15	40 30±3 45	6 33±0 07	7 83±0 04	41 00±1 34	0 139±0 002	0 727±0 020	1 74±0 07	0 41±0 003	0 424±0 004	7 90±0 003
11	4928±6 13	24 60±1 56	128 40±2 43	25 00±1 98	5 97±0 01	8 62±0 01	219 00±4 26	0 25±0.004	0 829±0 012	0 32±0 001	0 10±0 004	0 034±0 006	11 90±0 005
12	4920±12 51	25 30±1 34	321 00±5 89	77.50±3 46	6 24±0 02	8 77±0 01	36 00±1 45	0 26±0 004	0 694±0 021	1 58±0 003	0 19±0 005	0 305±0 003	7 90±0 009
13	4347±10 92	26 00±0 98	131 20±2 45	36 00±1 09	4 82±0 03	8 80±0 02	40.00±1 90	0 245±0 004	0 528±0 012	0 77±0 04	0 09±0 004	0 075±0 003	24 50±0 03
14	4197±10.23	23 90±2 14	320 00±1 78	22 00±0 2 89	5 99±0 06	8 35±0 04	89 00±2 93	0 141±0 07	0 95±0 045	3 91±0 045	0 34±0 01	1 361±0 001	21 00±0 04

Table 6.85: Physico-Chemical parameters in Nandi-Lower Nyando in December 2005

Sites/Para	Alt (m)	Temp (°C)	Conduc (µS/cm)	TSS (mg/L)	DO (mg/L)	pH	Turb (NTU)	TP (mg/L)	TN (mg/L)	Area (m_2)	Mean Vel (m/s)	Discharge (m^3/s)	Width (m)
15	3901 00±1 98	16 30±0 01	206 00±1 92	813 50±2 89	61 40±0 02	7 51±0 01	383 00±2 91	0 485±0 012	5 835±0 008	38 88±0 98	1 47±0 01	57 216±2 13	17 00±0 02
16	3829 00±2 65	19 50±0 03	214 00±1 32	874 00±1 92	59 40±0 04	7 58±0 02	305 00±1 23	0 412±0 030	5 67±0 034	51 50±0 12	1 30±0 09	67 05±2 98	34 80±0 04
17	3785 00±2 95	19 10±0 04	220 00±2 82	879 00±2 12	60 00±0 03	7 42±0 01	313 00±1 94	0 318±0 032	5 392±0 041	56 20±0 53	1 42±0 07	64 00±1 98	13 35±0 01
18	3785 00±2 21	20 10±0 05	104 00±3 41	830 00±2 45	35 60±0 02	7 35±0 05	265 00±2 12	0 151±0 021	3 212±0 037	38 45±0 62	1 12±0 02	9 84±1 13	7 90±0 09
19	3965 00±2 30	14 90±0 02	197 9±4 12	381 00±1 72	61 30±0 05	7.98±0 03	126 00±1 67	0 163±0 011	5 435±0 021	14 35±0 12	0 79±0 01	11 369±1 65	8 50±0 04
21	4155 00±3 41	13 00±0 03	185 70±3 15	177 00±1 32	71 50±0 01	7.73±0 21	105 00±1 23	0 141±0 009	0 504±0 011	0 96±0 54	1 00±0 03	0 966±0 02	0 43±0 02
22	4328 00±3 91	15 70±0 03	254 00±1 95	129 50±1 34	74 30±0 09	7 83±0 03	61 00±1 01	0 169±0 003	0 918±0 027	6 30±0 18	0 29±0 03	1 859±0 98	9 20±0 03
23	4363 00±2 56	15 40±0 03	246 00±3 98	123 50±3 96	59 80±0 02	7 86±0 01	44 00±0 98	0 102±0 002	1 130±0 018	6 16±0 10	0 65±0 07	4 035±0 045	5 50±0 01
25	5975 00±5 23	19 90±0 01	156 70±1 67	118 50±1 93	64 00±0 03	7 53±0 09	46 00±0 12	0 189±0 006	2 723±0 121	0 69±0 002	0 34±0 05	2 38±0 011	0 16±0 04
26	6066 00±2 94	15 60±0 05	72 60±1 83	112 00±1 92	65 30±0 02	6 95±0 02	37.00±0 87	0 088±0 001	1 723±0 017	0 85±0 02	0 92±0 02	0 787±0 012	2 50±0 01
27	6080 00±2 56	20 60±0 05	50 40±0 98	86 50±1 29	36 30±0 07	6 32±0 05	23.00±0.43	0 085±0 001	1 496±0 030	1 52±0 03	0 52±0 01	0 792±0 05	2 60±0 05
30	5986 00±2 45	16 90±0 04	4 80±0 92	3 15±0 02	62 40±0 11	5 78±0 01	3 00±0 21	0 021±0 001	0 410±0 003	0 04±0 01	0 27±0 04	0 011±0 03	0 14±0 02
33	3778 00±2 89	25 50±0 03	127 70±1 00	281 00±3 92	5 30±0 03	7 10±0 01	226 00±1 56	0 324±0 022	4 210±0 012	0 88±0 02	0 72±0 02	0 638±0 031	0 25±0 02

Table 6.86: Physico-Chemical parameters in Nandi-Lower Nyando in December 2006

Site/Para	Alt (m)	Temp (°C)	Cond (μS/cm)	TSS (mg/L)	DO	pH	Turb(NTU)	TP (mg/L)	TN (mg/L)	Area (m^2)	Mean Vel. (m^3/s)	Discharge (m/s)	Width (m)
15	3911±43 00	17 60±	309 30±5 13	253 30±12 09	6 67±0 02	7 65±0 12	379 02±10 23	0 706±0 15	2 727±0 05	7 24±0 621	0 35±0 002	2 54±0 015	43 20±1 02
16	3838±7 06	20 00±	249 30±5 10	18 92±1 10	6 31±0 01	7 64±0 19	312 01±14 23	0 532±0 009	2 321±0 14	12 27±0 97	0 16±0 09	2 00±0 03	51 20±2 43
17	3789±21 40	18 60±	216 80±2 30	19 67±2 45	6 78±0 05	7 82±0 23	309 83±2 13	0 321±0 019	1 567±0 21	5 05±0 34	0 40±0 008	2 052±0 06	48 00±0 43
18	3789±17 10	21 00±	106 60±2 34	12 56±2 11	4 56±0 001	7 59±0 04	269 75±1 94	0 121±0 01	1 23±0 10	1 32±0 45	0 05±0 001	0 07±0 004	23 00±2 51
19	3970±24 11	15 90±	203 70±10 78	17 30±1 30	6 25±0 02	8 01±0 015	130 01±2 04	0 107±0 01	0 528±0 06	5 00±0 10	0 44±0 01	2 216±0 51	3 90±0 021
21	4160±18 00	14 00±	189 50±17 03	34 30±3 98	7 67±0 019	8 11±0 009	100 56±2 011	0 148±0 03	0 245±0 01	1 54±0 74	0 12±0 001	0 192±0 02	7 80±0 050
22	4331±20 01	14 80±	256 90±4 0	16 30±1.71	6 89±0 04	8 31±0 50	67 56±1 22	0 086±0 010	0 599±0 02	5 07±0 06	0 08±0 001	0 414±0 12	4 90±0 150
23	4369±26 23	16 10±	249 00±3 12	43 70±1 12	6 21±0 06	8 35±0 18	48 23±0 43	0 093±0 009	0 898±0 07	0 52±0 010	0 36±0 002	0 187±0 05	1 90±0 160
25	5979±31 11	21 00±	148 40±1 45	47 70±9 14	6 90±0.012	7 94±0 12	49 05±0 95	0 111±0 030	1 605±0 20	0 4±0 01	0 22±0 01	0 091±0 012	3 00±0 210
26	6069±35 09	14 80±	69 60±1 32	28 00±1 74	7 12±0 01	7 71±0 21	42 01±0 67	0 093±0 014	1 552±0 34	0 76±0 001	0 59±0 023	0 448±0 003	2 30±0 780
27	6085±29 21	22 00±	48 80±1 09	47 70±1 41	4 65±0 03	7 91±0 30	21 03±0 87	0 114±0 01	0 989±0 016	0 63±0 010	0 23±0 012	0 15±0 01	2 10±0 170
30	5989±21 21	17.30±	16 70±1 92	0 01±0 001	7 00±0 01	7 20±0 07	2 01±0 04	0 012±0 009	0 038±0 009	0 06±0 005	0 08±0 009	0 005±0 001	0 60±0 030
33	3783±13 11	24 80±	129 10±1 25	13.87±0 34	3 97±0 034	7 81±0 21	229 09±0 78	0 209±0 01	0 542±0 006	0 48±0 001	0 06±0 004	0 03±0 004	1 90±0 170