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IMPACTS OF PESTICIDES ON HUMAN HEALTH AND ENVIRONMENT IN THE RIVER NYANDO CATCHMENT, KENYA

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ABSTRACT

River relies on rain fed agriculture. Important crops grown include cereals, cash crops fruits and vegetables. Farming is one of the contributors' of pollution to Lake Victoria. Organophosphates and other banned organochlorine pesticides such as lindane, aldrin and dieldrin were used by farmers. The pesticides transport was by storm water run-off and air drift into the lake. Environmental risk assessment background information was collected through questionnaire and interviews of farmers to determine knowledge and safe use of pesticides. Fourteen pesticides were identified as commonly used of which four are toxic to bees and five to birds. The farmers identified declines in the number of pollinating insects, the disappearance of Red-billed Oxpecker (*Buphagus erythrorthynchus)* and wild bird's fatalities. The general knowledge among farmers about chemicals risks, safety, and chronic illnesses was low. Activities that increases environmental awareness and safety of pesticides should be initiated by the agrochemical firms and government

KEYWORDS: Environment, Farming, Lake Victoria, Pesticides

INTRODUCTION

In many African countries agriculture is considered to be the key to economic development. 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 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. Farming is more intensive in the tropical savannah zones than in the arid and semi-arid areas where cattle, sheep and goat rearing predominate. Safe storage and disposal of pesticides and fertilizers remain a challenge in the agricultural areas. Rapid expansion of the agriculture due to increasing population has resulted in increased demand for agro-chemicals in Kenya and Pesticides have become an integral part of plant, livestock and public health protection (NES, 2006). However, increasing evidence suggests that pesticides have intrinsic public health and environmental risks during their production, import, use, storage and disposal (Stadlinger et al. 2013). Many pesticides used in all societies have been associated with toxicity to human (Jacobs and Dinham, 2001) and others are suspected to be carcinogenic, mutagenic, and endocrine disruptors (Colborn et al., 2004). Current registration practices are put in place to, as far as possible, ensure that proper use of pesticides minimizes risks to environmental and human health, but controls and enforcement of regulations are less than strict in the River Nyando basin, reflecting a situation common to many developing countries (Stadlinger et al. 2013). The pesticides when used properly may pose low risk to the environment and human health as long as strict controls are put in place.

Point sources arising from stored obsolete pesticides have been identified as locally very important threats to the African environment (Elfvendahl et al., 2004; NES, 2006), while the consequences of diffuse use in agriculture has been less studied. Recently, work by Sereda et al., (2009) indicated that pyrethroids found in human breast milk may come from agricultural use. Bouwman and Kylin (2009) pointed out the need to include agricultural and other uses of pesticides when evaluating risks to infants from pesticides used for vector control.

The reported rapid degradation of some pesticides in Kenyan soil not withstanding (Wandiga et al., 1996) the potential for bioaccumulation and bio-concentration of these pesticides pose serious ecological and health concerns for the environment. All types of land use in the lake Victoria catchment in one way or another affects the quality of its water and that of the tributaries (Shephard et al., 2000). Pesticides leaching or draining from agricultural land may pollute surface and ground water. The Nyando and Kagera Rivers carry higher sediments, pesticides and nutrients loads into the lake than other rivers (Calamari et al.; 1995). This has created a significant pollution problem that threatens the use of the lake's resources for national development (Odada et al., 2009).

The pollution problem in Kenya's part of Lake Victoria was noted by the committee for Inland Fisheries of Africa (CIFA) sub-committee meeting held in Mwanza (Tanzania) in 1989 since Kenya has the least catchment area with 6 major rivers carrying pollutants into the lake. The relatively secluded Kenya's part of Lake Victoria, Winam Gulf is the most polluted part of the lake (Calamari et al.; 1995). Winam Gulf catchment) comprises the North and Southern lakeshores in Kenya, including the River Nyando and Sondu-Miriu basins with a total area of 11,994 km^2. Some incidences of pesticide poisoning of fish was highlighted by the press in May 1999, the fish was purported to be harvested from the lake by use of endosulfan, an organochlorine insecticide. This resulted in a ban by the European Union (EU) on all fish import from Lake Victoria (LVEMP/MoALD& M, 1999).

The EU demanded that the three East Africa 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 (LVEMP/MoALD& M, 1999). 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 (LVEMP, 2003). Although there are individual reports on pesticide concentration in fish (Henry and Kishimba; 2006), water (Getenga et al., 2004), soil and sediments (Abong'o, 2009) from parts of the lake, there is no comprehensive analysis of pesticides use, distribution and fate in Lake Victoria or any of its drainage systems. Lack of basic information on pesticides use, overfishing, water hyacinth invasion and sewer pollution have resulted in the decline of fish in the lake (LVEMP, 2003). However the absence of surveillance programs for pesticide residue levels in the agricultural and fisheries products from the Lake Victoria basin has wider policy and market implications. Absence of such programmes may be detrimental to the fish export from the East Africa states due to increasingly stringent regulation in the importing countries on residue limits in imported fisheries and agricultural/horticultural products. Lake Victoria fishing earns Kenya between KSh 4 billion and KSh. 6 billion (USD 85 million) annually from fish exports revenue (LVEMP, 2003), that might be lost if pollution from agrochemicals is allowed to continue.

The River Nyando has been identified as the most polluted drainage basin in the Kenyan side of the lake (Shepherd et al., 2000). The drainage system traverses formerly three districts (Kericho, Nandi, and Nyando), which are major agricultural and industrial zones in Western Kenya. It serves as a recipient for effluents from tea, coffee, lime and sugar factories. Farming is intense and a wide range of pesticides are used in the drainage basin. In ddition, it has the highest slope and rate of sediment transport of all the rivers draining into Lake Victoria. Arguably, poor land-use management practices (e.g., cultivating on slopes adjacent to rivers and on river banks, draining of wetlands and clearance of forest cover to give additional arable land) and intensive use of agrochemicals have resulted in a high flow of nutrients and sediments that have negative impacts on River Nyando and Lake Victoria ecosystems (Peters and Meyback, 2000). Although some studies regarding levels of pesticides in fish, water, soil and sediments have been done in Kenya, surveys of risks to farmers while using pesticides are few (Kariuki, 2008).

Because of the CIFA's concerns in 1989, the imposition of a fish import ban by the EU in 1999 and based on evidence from data available from studies conducted within the lake basin, it is important to focus on the pollution status of the Winam Gulf catchment with special focus on the River Nyando drainage basin. Studying River Nyando is important for restoration and management of the lake as part of a long-term strategy to conserve the ecosystem function in the lake basin. If a well-targeted comprehensive analysis of data on pesticide use, distribution and fate is done for one drainage system, the results can form the basis for the study of the other waterways and of the lake itself.

This study was performed to identify agrochemicals used in different areas along the River Nyando drainage basin in both the large and small-scale agriculture through participatory rural appraisal (PRA) methods (Bernard, 1994). This was in assessing the effects of agrochemicals on environment and human health in the basin. Fourteen selected areas were visited in February, May, September and December 2005 and in similar periods in 2006 mainly to capture the effects of different seasons and farming activities on the agrochemical usage.

MATERIAL AND METHODS

The Study Area

The Nyando drainage, has a catchments area of 3450 km^2, a total length of 170 km and lies between 0˚ 25'S to 0˚10'N and 34˚ 50'W to 35˚50'E. The climate is sub-humid with a mean annual temperature of 23 ˚C and the mean annual rainfall of 1360 mm that varies from 1000 mm near Lake Victoria to over 1600 mm in the highlands (NES, 2002). The annual rainfall has a bi-model pattern with peaks during the long rains (April-May) and short rains (October-December). The rainfall is controlled by north and southward movement of the Inter-Tropical Convergence Zone (ITCZ) during the dry seasons (January-March).

The River Nyando Drainage Basin

The River Nyando (Figure 1) has two main tributaries, small Nyando (Kericho sub-catchment) and Ainamotua (Nandi sub-catchment). Awach-Kano, a smaller river flows into the main River Nyando 15km downstream of the Nyando-Ainamotua confluence. The Nyando basin drains major agricultural and industrial zones of Western Kenya. The average annual and monthly run-off flows are 18.0 m^3s^{-1} and 18.3 m^3s^{-1}, respectively (Calamari et al.; 1995). Compared to all other rivers emptying into Lake Victoria, Nyando has the highest average sediment transport capacity index (0.30) and average slope (5%) (LVEMP, 2003).

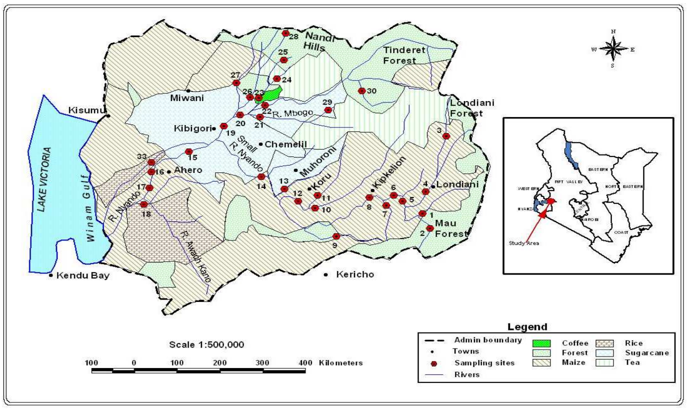

Figure 1: Map of River Nyando Basin Showing the Sampling Sites

Population and Land Use

The population of Nyando basin is about 746,000, an average population density of 214 persons km^{-2}, and a population growth of about 3.2 % yr^{-1} (Kenya CBS, 2009). High livestock densities are common throughout the basin. The forests are being cleared for charcoal burning and to increase arable land; wetlands are also drained to increase arable land. 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 and tea estates and relatively large-scale maize and horticulture (Abong'o, 2009). The nature of the soils (alluvial) 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 suffers from periodic inundation, particularly after heavy rains in the adjacent escarpments and hills. There is a widespread land degradation throughout the River Nyando basin that currently affects an estimated 1444-1932 km^2 (39.5-52.9%) of the area (Shepherd et.al, 2000; Odada et.al. 2009).

Methodology

To gain information on the benefits from pesticides and other agro-chemicals used and their perceived negative effects on the agro-ecosystem and human health, questionnaire with both open and closed end questions, field observation checklist and measurements of areas of some farms were used. The farmers whose farms are adjacent to river banks (≤ 10 m riparian zone) within some selected urban centres and use agrochemicals on their farms or livestock constituted the target population, with 80% of the total population engaged in small-scale intensive farming and an average of farm size of 3.5 hectares per household (Kenya CBS, 2000).

The sampling size was calculated using the formula for determining sample size in social science research (Mugenda and Mugenda, 1999). Random sampling was used to select sampling areas from which 64 people from each of the three former districts were interviewed. Purposive sampling was used to select key informants who included chiefs, agricultural officers and scientists from Kenya Agricultural Research Institute (KARI) and Lake Victoria Environmental Management Project (LVEMP) and pesticide retailers in the catchment. Data on existing agrochemicals safe use, handling practices, hazards and challenges involved in their use was collected using Participatory Rural Appraisal (PRA) techniques which included interviews with key informants and focus group discussion (Bernard, 1994**).** Unstructured questions were used as interview guides to ensure that data collected met the objectives of the study.

A total of 150 farmers were interviewed in the whole catchments area (Table 1). The questionnaires provided the information on, sizes of farms, types of farming and the crops grown, number and types of livestock, the planting seasons, types and quantities of chemicals used, major pests problems, farmers' knowledge and attitude towards agrochemicals use, their perception on environmental and health problems connected to use of pesticides or other chemicals. It was difficult to get an understanding of the quantities of pesticides used and the sizes of farms through questionnaires, therefore quantitative measurements of sizes of twelve farms were taken.

Table 1: Description of Sampling Sites

Site	Local Name	GIS Position	Altitude (m)	Number of Farmers Interviewed	<10m Riparian Zone	Subsistence Agriculture	Forest Cover	HS ≤ 1km Upstream	Livestock Rearing	Sugar-Cane	Coffee	Tea	Rice	Perennial Floods
1	Kedowa bridge	E035.54474º S00.23427°	7515±2.78	19	√	√	√	-	√	-	-	-	-	-
4	Masaita at Londiani Township	E035.58415ºS00. 16274º	7507±3.89	15	√	√	√	-	√	-	-	-	-	√
5	Masaita at Lambel farm	E035.53546ºS00. 19706º	6740±3.98	3	√	√	-	-	√	-	-	-	-	-
7	Kimoson	E035.46373ºS00. 20716º	6308±7.09	5	√	√	-	-	√	-	-	-	-	-
8	Nyando at Kipkelion	E035.46185ºS00. 20679º	6307±8.45	8	√	√	-	√	√	-	-	-	-	-
13	Homalime	E035.29911ºS00. 18453º	4344±3.67	12	-	√	-	-		√	-	-	-	-
16	Nyando at Ahero Bridge	E034.92069ºS00. 17211º	3829±2.09	13	√	√	-	√	√	√	-	-	-	√
19	Ainamutua-Kibigori	E035.05595ºS00. 07583º	3965±7.09	12	√	√	-	-	√	√	-	-	-	-
22	Anopsiwa	E035.117937ºN0 0.02969º	4228±4.03	10	√	-	-	-	-	√	-	-	-	-
23	Anopngetuny	E035.117467ºS0 0.02825º	4363±2.89	10	√	-	-	-	-	√	√	-	-	-
26	Kapngorium at Bridge	E035.0997ºN00. 05356º	6066±3.89	12	√	√	-	√	√	-	-	√	-	-
27	Kundos at Bridge	E035.06172ºN00 .05110º	6080±3.23	12	√	√	-	-	√	-	-	√	-	-
30	Chebirirkut at Tinderet Dam	E035.34793OS0 0.03673^0	5986±4.73	6	√	-	-	-	-	-	-	√	-	-
33	Ahero Irrigation Channel	E034.90789ºS00. 17173º	3778±2.56	13	√	√	-	√	√	-	-	-	√	√

HS-Human Settlement
√ - Classified
- Not Classified

Participatory interviews were held with six Provincial Administration Officers (Chiefs) in Tugunon, Kedowa, Siwot, Koyo, Tinderat-Barasendu and Kobura locations, four scientists (Project manager and three chemists) from LVEMP's pollution loading component at Kisumu and Kenya Agriculture research Institute (KARI) and six District Agriculture and livestock officers, two each from Kericho, Nandi, and Nyando districts to gather the relevant information regarding roles of their institutions in advising farmers on handling of agrochemical. Also three clinical officers, one each from Londiani, Ahero and Kaptumo sub-district hospitals and 22 pesticide retailers in the urban centres within the catchment four in Londiani, three each in Kedowa, Kipkelion and Ahero; 0ne each in Muhoroni and Chemelil, seven in Nandi Hills and four in Koru.

RESULTS

The Agricultural Enterprises in Kericho, Nandi and Nyando Districts

Agriculture is the most important source of income in Nyando catchments; 82% of the farmers interviewed depend entirely on farming, with the production heavily constrained by rain especially in the lower River Nyando basin. Of the available hectares of arable land in drainage basin, 15% is set aside for cash crops such as tea (6%), sugar cane (4%), pyrethrum (3%) and coffee (2%) documented in Table 2. Maize, which is the staple food, is grown mainly for family consumption; only 17% of the farms also grow maize for sale.

The most common food crops grown by households are beans (15%), kales (14%), cabbage (12%), tomatoes (11%), sweet potatoes (8 %), peas (5%), Onions (3%), cassava (2%) and rice (1%). Vegetables are most immediate cash income source. Average income per household ranges from US $ 300 to 1000 per year, but the income can be low during droughts. The food crops occupy 58%, 28% and 49% of the arable land in Kericho, Nandi and Nyando Districts respectively (Table 2). The main cash crops are tea, coffee, and sugar cane which occupy 27%, 11% and 34% of the arable land in the three districts respectively. Much land (54%) in Nandi has been set aside for livestock farming while only 10% and 7% respectively are for that purpose in Kericho and Nyando Districts.

Table 2: Agricultural Enterprise in River Nyando Basin

Crops	Kericho (Ha)	Nandi (Ha)	Nyando (Ha)
Tea	16,000	21000	
Coffee	2850	1500	3000
Sugar cane	4000	2500	20,000
Rice			5,500
Pyrethrum	600		
Cotton			4,000
Tobacco			1,400
Maize	36000	65,000	15,000
Beans	13900	12,000	4,400
Sorghum	700	1500	6,000
Finger Millet	1540	1200	300
Irish potatoes	230	300	
Kales	690	750	150
Tomatoes	1500	500	100
Fruits			1,570
Cabbages	3000	750	500
Livestock	6000	127,000	1,300
Total	**87010**	**234,000**	**62534**

Sources: NYD/SUP/VOL.1/-District Agriculture Office-Nyando (PCPB, 2008)
Hectares- (Ha)

Problems Encountered by the Farmers

Crop pests are the major limiting factor in farming activities as stated by 96% of interviewees. Other common problems are lack of rain fall (43%), poor agricultural soils (33%) especially in lower Nyando area. Also mentioned were the lack of market for farm produce (89%), shortage of pasture land (70%), lack of farm tools (87%), shortage of labour (25%) and lack of fertilizers and pesticides (77%).

Raiding of crops by wildlife was problematic to 36% of the farmers in lower Nyando catchment. The pest problems have got worse (18%), the pests have become resistant to pesticides, the climate change have resulted in droughts, floods and storms and other climatic events that disrupt livelihoods by causing loss of income since farming activity depends entirely on the quantity and duration of rain (Robert T.Watson et.al., 1997). 43% of the farmers were of the opinion that some areas are more affected by climatic events now compared to 1980's.

Major pests problem in the area are maize stalk borer (*Buseola sp.* Lepidoptera) (86%), aphids (*Aphidae sp*, Homoptera) (70%), cutworm (*Agrotis sp*, Lepidoptera) (60%), diamond back moth (*Plutella xylostella*, Lepidoptera) (50%), onion trips (*Thrips tabaci*, Thysanoptera) (28%), termites (20%), tobacco mosaic virus (9%), and weeds (4%).

Types of Pesticides and Levels of Usage

Synthetic pesticides are used in the drainage basin. Pesticides are used more frequently in vegetables production than in maize (91% compared to 9%). 42% of households use pesticides in grain storage, although this use is declining. In maize and vegetable production, no herbicides are used since the households practice weeding instead of using herbicides. Herbicides are, however used in large scale tea, coffee and sugar cane plantations. Insecticides are often used more than fungicides. The farmers use between four and ten different compounds (Table 3).

Table 3: Agrochemicals Used in River Nyando Basin and their Recommended Rates

Pesticides/Fertilizers	Crops	Recommended Rate
Karate	Tomatoes, kales, cotton	1kg a.. ha^{-1}
Milraz	Tomatoes	300-500 g a.i. ha^{-1}
Dithane/Mancozeb	Tomatoes	300-500 g a.i. ha^{-1}
Actellic	cereals-maize and sorghum	100 g a.i. per 90 kg sack against storage pests
Dimethoate	vegetables, fruits trees, tobacco	750-1500 ml a.i. ha^{-1}
Ridomil	Tomatoes	500-1,000 g a.i. ha^{-1}.
Milthane	Tomatoes	500-1,000 g a.i. ha^{-1}.
Furdan 5G	rice and horticulture nursery beds	1000-1500 g a.i. ha^{-1}.
Diazinon	Tea, coffee	1000g a.i ha^{-1}
Kocide	coffee	2000-2500 g a.i. ha^{-1}
Dipterex	maize and sorghum	1000 g a.i. ha^{-1}
Linulon	sugarcane	5000 g a.i. ha^{-1}
Round Up	Sugarcane	360g a.i. ha^{-1}
Fenthion	coffee	983g a.i.ha^{-1}
Fenitrothion	Tea, coffee	500 g a.i. ha^{-1}
Urea	sugarcane and occasionally rice	50-100 kg ha^{-1}
CAN	all crops	50-120 kg ha^{-1}
DAP and MAP	all crops	75-150 kg ha^{-1}, basal application

Source: PCPB, 2008: CAN-Ammoniun Calcium Nitrogen, DAP-Diammonium Ammonium Phosphate MAP-Monoammonium Phosphate

Specific information on agrochemicals used in the catchment area and their recommended rates of application are given in Table 3. Most Pesticides are used during the short rain season (October to December) when farmers grow vegetables in bulk. Vegetables are grown throughout the year with the highest peak during short rain season. All the households that keep livestock (cattle, sheep, goat, donkeys) use pesticides against ticks (that spread east coast fever, Anaplasimosi, Babesiosi and heartwater) and tsetse flies (that spread Trypanosomiasis). Chlorfenviphos [(EZ)-2-chloro-1-(2,4-dichlorophenyl)ethenynl]diethyl phosphate] is the most commonly used pesticide on livestock followed by amitraz (*N*,*N'*-[(Methylimino)dimethylidyne]di-2,4-xylidine) (Table 4). The spraying of pesticides (97%) is usually done by male adult farmers and very rarely by women.

Table 4: Pesticides Used in River Nyando Basin their Classifications and Toxicity to Bees and Birds

Product Name	Active Ingredient	Types of Pesticides	Toxic Classification*	Active Ingredient Toxicity Towards Bees and Birds**	Used by % Household
Dursban	Chlorpyrifos	Insecticide	WHO:II	Toxic to bees, LD_{50} (oral) 0.36µg bee^{-1}, LD50 (contact) 0.07µg bee^{-1}; toxicity to birds. 32-102 mg kg^{-1} body mass (chicken), Dietary LC_{50} (8d), 423 mg kg $^{-1}$ body mass bobwhite quail	56
Dithane/Sancozab	Mancozeb	Fungicide	WHO:III	Acute, 48 hour LD_{50} 140.6 µg bee^{-1}	60
Sumithin	Fenitrothion	Insecticide	WHO:II	Acute, 48 hour LD_{50} 0.16µg bee^{-1}	78
Neocidal	Diazinon	Insecticide	WHO:II	Acute, 48 hour LD_{50} 0.09 µg bee^{-1}	47
Antracol	Propinab	Fungicide	WHO:III	-	12
Furadan	Carbofuran	Insecticide	WHO: I	Acute, 48 hour LD_{50} 0.036 µg bee^{-1}	36
Caprado 50 WP	Copper Oxychloride	Fungicide	WHO:III	-	9
Karate	λ-cyhalothrin	Fungicide	WHO:II.	Highly toxic to bees, LD50 (oral) 0.038 µg bee^{-1}, LD50 (contact) 0.9 µg/bee $^{-1}$	9
Round Up	Glyphosate	Herbicides	WHO:II	-	48
Gramoxone	Paraquat	Herbicides	WHO:II	-	33
Ambush CY	Cypermethrin	Insecticide	WHO:III	Acute, 48 hour LD_{50} 0.02 µg bee^{-1}	49
Thiodan EC	Endosulfan	Insecticide	WHO:II	Acute, 48 hour LD_{50} 7.81 µg bee^{-1}, acute oral 205-245 mg kg^{-1} body mass (mallard ducks); 620-1000 mg kg-1body mass (ring-necked pheasant)	13
Stalladone	Chlorfenviphos	Insecticide	WHO: I	LD50 (24h, oral) 0.55 µg bee^{-1}, (tropical); 4.1 µg bee^{-1}, acute oral LC_{50} pheasant 107 mg kg^{-1} body mass ; LC_{50} pigeons 16 mg kg^{-1} body mass, ; LC_{50} mallard ducks 490 mg kg^{-1} body mass LC_{50} house sparrow 122 mg kg^{-1} body mass.	64
Tactic/Tixfix	Amitraz	Acaricide	WHO:III	Low toxicity to bees LD50 (contact) 50 µg bee^{-1},; LD_{50} bobwhite quail 788 mg kg^{-1} body mass; LC_{50} (8d) mallard ducks 7000 mg kg^{-1} body mass, Japanese quail 1800 mg kg^{-1} body mass.	40

WHO **(**2002): Classification from I to III, with I being the most hazardous

**Tomlin (2001)

No data provided

The dose of the most commonly used pesticides according to the households range between 750-1500 mL a.i ha^{-1} (a.i, active ingredient) to 3000-5000 mL a.i ha^{-1} in some areas. Round Up (glyphosate), with application rate of 3000-5000 mL a.i ha^{-1} is the most common herbicide used in the plantations (Table 3). Pesticides are sprayed between twice and ten times per year. All the respondents mentioned that aerial spraying is only done in large tea estates in Kericho and Tinderet areas. Knapsack spraying is used by 98 % of the farmers in coffee, sugarcane, vegetables, and crops grown on small scale. Of the farmers, 89% purchase whole container of the agrochemical, while 11 % buy the chemicals from other farmers.

Farmer's Knowledge and Attitude towards Pesticide Usage

The pesticides were considered effective by 97% of the users. However there is increasing concern among 86% of farmers about the health risks from such usage. Other concerns were escalating prices of pesticides and fertilizers among all the farmers interviewed and lack of user knowledge among other. The future use of pesticides will increase or level off as reported by 82% of interviewees since new products are being introduced into the market.

Low purchasing power (60%) and health risks (36%) are reasons for a decrease in pesticide usage rather than current needs. Forty eight percent of farmers do not use the exact doses recommended by the manufacturers because of low purchasing power and poverty. Ten percent of farmers in Londiani and Kipkelion areas have used ecological farming but still find the use of pesticides better. Only ten farmers (9%) mentioned about the negative environmental effects of pesticides.

The majority of the farmers are literate, but 86% have never used safety information and instruction on pesticide container, while 32% have read it between at least thrice or each time they use the pesticide in question. The main information source for the farmers on chemical use are through the agricultural sector government workers from division and location levels, non-governmental organizations (NGOS) and radios while chemical companies only have direct contacts with the farmers growing typical cash crops such as coffee, tea and sugarcane. Only 20% of the farmers have the equipment recommended by the chemical companies.

Quantification of Pesticides Usage

Measured doses used on specific areas proved to be in the same order of magnitude stated by the farmers during the interviews (between 250 and 5000 g a.i ha^{-1}). Doses ranging from 750 to 1500 mL a.i ha^{-1} were also mentioned. The total amount of the pesticides used on the 12 farms measured with a total area of 28 hectares was 20 kg (710 g a.i ha^{-1}). Three of the twelve farmers were using recommended doses of 250 g a.i ha^{-1} by manufacturers

The Link between Pesticide Use and Environmental Problems and Health

According to the farmers the most significant environmental effects of pesticides usage were, decline in abundance of pollinating bees (40%) and butterflies (18%), the disappearance of the red-billed oxpecker (*Buphagus erythrorthynchus*) (20%) and other non-target insects dying (12%) when or after spraying and wildlife mortalities (10%). The birds disappeared when the government subsidized a common facility for livestock in the 1980's. Since then the birds have only been observed in forest areas. Only 3% of the farmers had seen signs of poisoned birds so the alternative that the birds moved to another habitat for other reasons, such as the lack of ticks and insects parasites on the animals cannot be excluded.

Pollination and bacteria in the soil are the most important ecosystem services ranked by 58% of the farmers in the Nyando basin. This indicated local ecological knowledge. There is need for change to effective but less harmful farming methods. Chlopyrifos, a systematic insecticide used against a wide range of pests such as thrips, caterpillars and leaf miners was reported to be responsible for the highest number (15 %) of symptoms of ill health in the study area followed by fenitrothion (*O*,*O*-Dimethyl *O*-(3-methyl-4-nitrophenyl) phosphorothioate) (10%) and diazinon (*O*,*O*-Diethyl *O*- [4-methyl-6-(propan-2-yl)pyrimidin-2-yl] phosphorothioate) (8%). Over 9% of the farmers had felt ill after exposure to pesticides but could not attribute this to any specific one. That the use of a number of pesticides (chlordane, heptachlor, endrin, lindane, aldrin, dieldrin, DDT etc.) has been banned or restricted in Kenya was known to 56 % of the farmers. The remaining farmers had no information on the restrictions or bans while some have never heard of these pesticides. Ten percent of farmers in Londiani and Kipkelion areas have used unlabelled pesticides obtained from their relatives from the neighbouring former Nakuru District. None of the farmers was aware of any obsolete or stockpiles of the banned or restricted pesticides in the River Nyando catchment area.

DISCUSSIONS

The focus group discussions in Kedowa, Kimoson and Ahero irrigation channel areas, interviews and observations in the same areas indicated that horticulture and maize farming in Nyando catchment was concentrated around Londiani and Kipkelion, Nandi Hill and Koru areas. More pesticides are used in horticulture than in maize farming, because vegetables are prone to attack by pests and are also the immediate household cash crops. Use of pesticides in grain storage is declining because new storage facility called drum (capacity 100-1000 L) has been introduced.

A drum is closed systems for storing grains in absence of oxygen and thereby creating an environment unfriendly to pests. Livestock are generally valued more than agricultural products in Kericho and Nandi Districts than Nyando, which explains the difference in attitude towards pesticides use on livestock and agriculture respectively (Table 2).

Change to other pest management methods is inhibited by an “economic barrier” created by dependency on pesticides since the farmers depend on cash from harvest and are unwilling to try new techniques. Many farmers have knowledge about organic farming as alternative method, but this type of production is still very uncommon in this region although there are signs of an increased demand for organic products by customers. Most farmers along the Nyando drainage basin lack knowledge on safe use of pesticides, environmental and health risks and alternative pest management methods. Even though many are concerned about health risks and environmental problems, the majority would use more pesticides if they had more money.

Pesticide usage depends on pests’ outbreaks and farmer’s purchasing power. Out of the fourteen commonly used pesticides in the Nyando catchment area 14.3% are classified by World Health Organization (WHO 2002) as highly hazardous, 50% moderately hazardous and 35.7% slightly hazardous (Table 4). Chlopyrifos, fenitrothion and diazinon are moderately toxic (WHO, class II) and known cholinesterase inhibitor. From interview results it is clear that 44% of the farmers in river Nyando catchment area are not aware of the ban or restriction imposed on some pesticides in Kenya (PCPB, 2008), these pesticides can easily find their ways into the region from other districts such as Nakuru where obsolete stock piles have been reported (NES, 2006).

The interviews indicated a low awareness among farmers about risks and safe handling of pesticides, and a high level of injuries and chronic illness. The dose used and the spraying intervals seldom correlate with those recommended by the manufacturer. Many farmers miss safety information and recommendations of dose on the containers from the manufacturers since they buy repacked chemicals from other farmers. The interview answers reflected a more “common sense reasoning’ than the text on the container. Simple safety equipment such as protective clothing and gloves, or a cloth around the mouth is used when available.

For the assessment of endpoint ecological hazards, loss of pollinating insects and birds and biological control of tick parasites were chosen, because from the interview results, they were valued by the communities as ecologically relevant for the agro-ecosystem assessed. Many of the vegetables, grains and fruits production in Nyando catchments area are pollinated by bees and birds. These pollinators are also susceptible to pesticides used in the area and they are valued as important ecosystem services by the farmers.

The interviews with the farmers indicated that in agro-ecosystems where organic farming is practiced more arthropods are 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. In spite of relatively low pesticides dosages, detrimental effects on ecosystem services in the Nyando catchments areas were reported by farmers. A declining bees' population was mentioned as one of the negative effects. 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 to expand arable land to meet a population increase. Since bees produce honey, the population declines were easily 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 similar effects have occurred or can be expected.

Birds living in cultivated areas have decreased substantially since the 1980's. It seemed likely that the pesticides are responsible for the disappearance since it coincided in time when central facilities for livestock dipping were introduced. Few birds are excellent indicator species of pesticide pollution. They are sensitive to pesticides, relatively easy to spot and more vulnerable to environmental pollution than other vertebrates ((Tomil, 2001)**.** A major cause for this decline was believed to be the depletion of food (the insects and weeds) they feed on due to pesticides used. Birds can also be affected directly by the pesticide poisonings **(**White et al., 1982) or even acute toxicity (Pimental *et al*., 1992). The decline may have resulted either directly by poisoning of the bird or indirectly by reducing the birds' food source. If people without a specific interest in birds have noticed that the birds have disappeared, it is likely that other less conspicuous birds have also been affected by pesticides. In future if River Nyando basin communities adopt biological control as an alternative pest management, then birds will have to be reintroduced to the area. Approximately 85-90% of the pesticides amounts used in agriculture never reach the pests; much is carried away from agricultural fields by rain run-off (advection) or wind drift, (Moses et al, 1993). Effects of 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; many factors complicate determining the actual risk. As in this study, there are a number of pesticides interacting with each other. Out of the fourteen commonly used pesticides in the Nyando catchment four are toxic to bees and five to birds (Table 4).

The agricultural activities in the River Nyando drainage basin, specifically the use of fertilizers and pesticides, are among the major sources of pollution loads on the Kenya's Lake Victoria (Peters and Meyback, 2000). Since Kenya has an active and growing programme to help stakeholders build their capacities to manage chemicals safely (NES, 2006), the general approach is to provide awareness, legal and policy framework and training in key chemical safety elements. Pesticides use should not be the only pest management practice. Farmers should be encouraged to weed instead of using herbicides. Other important preventive strategies are the 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 can be 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). According to interviews with the agricultural sector government workers in the three districts the use of pesticides will increase in future. An assessment of toxicity risks of these pesticides in soil, water, aquatic fauna and flora along River Nyando drainage basin will be reported in a subsequent paper.

CONCLUSIONS

This study documents a list of agro-chemicals used along the River Nyando drainage basin, their recommended rates of applications, environmental and human health impacts and toxicity to birds and bees. Most of the pesticides used in Nyando catchment area are organophosphate and are moderately hazardous, but some individual farmers still use banned or restricted organochlorine pesticides. There are major pests' problems in River Nyando catchments and therefore an active pest management programme is necessary to secure the harvest in the region. Most farmers are ignorant of the safe use and handling of the pesticides, which results in some injuries and chronic illnesses.

From the results of this study and other studies conducted within Lake Victoria catchment area (Getenga et. al., 2004; Abong'o, 2009), it would be important to monitor and ascertain the residue levels of organophosphates, banned or restricted organochlorine pesticides in soil, and aquatic environment along the other drainage basins in Lake Victoria.

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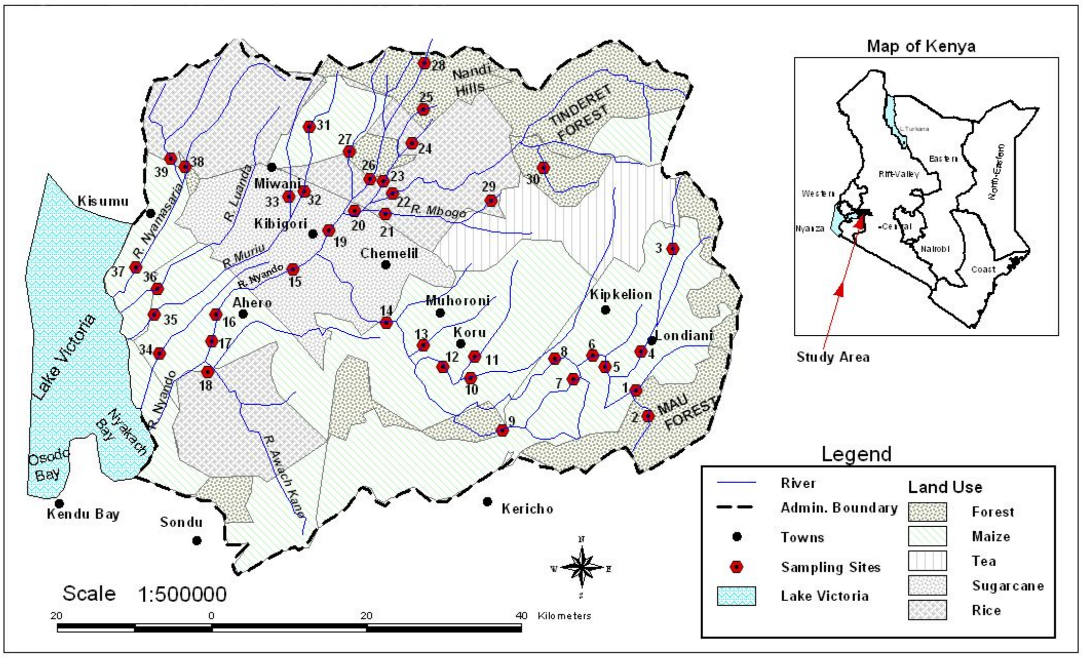

Figure 1: Map of River Nyando drainage basin showing sampling sites.

Questionnaire: Survey of agrochemicals used in the River Nyando catchment

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 adults…….. 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**
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.

Summary of responses

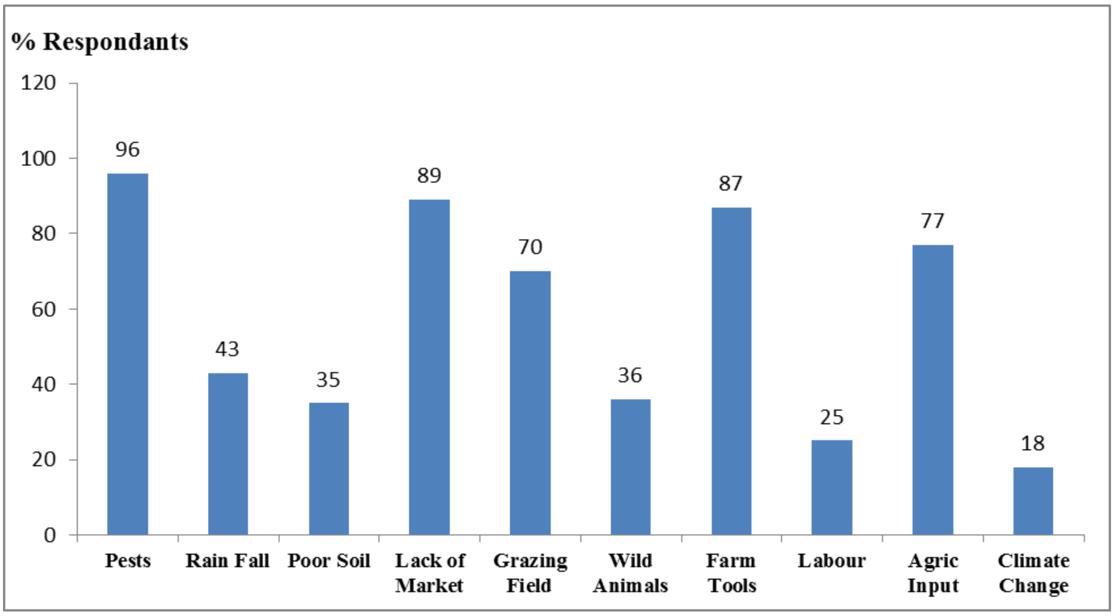

Figure 2: Problems encountered by the farmers in River Nyando catchments area

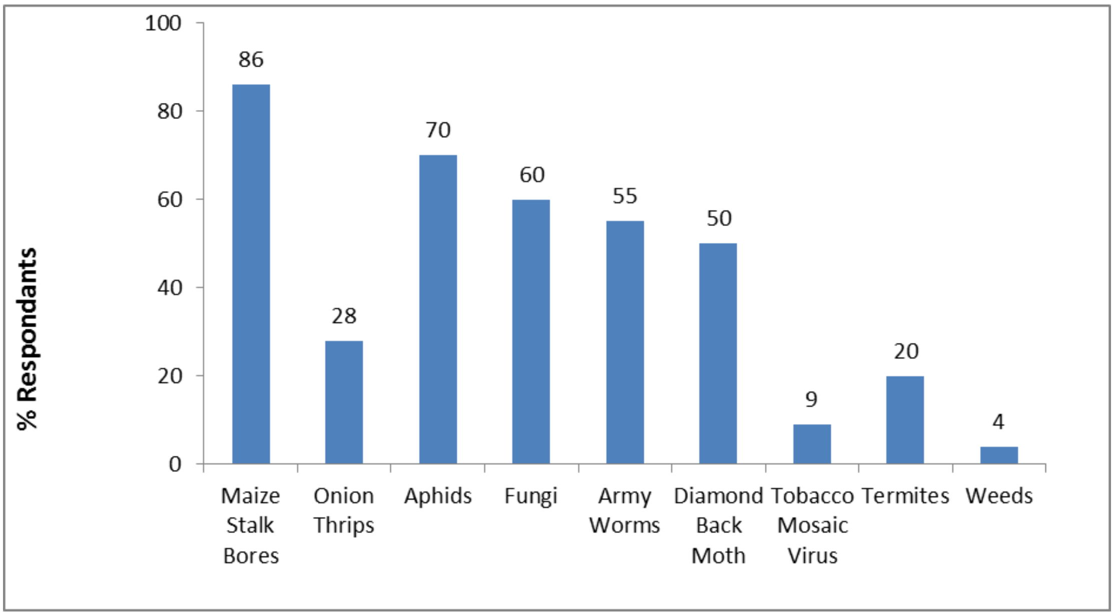

Figure 3: Major pests in River Nyando catchments area

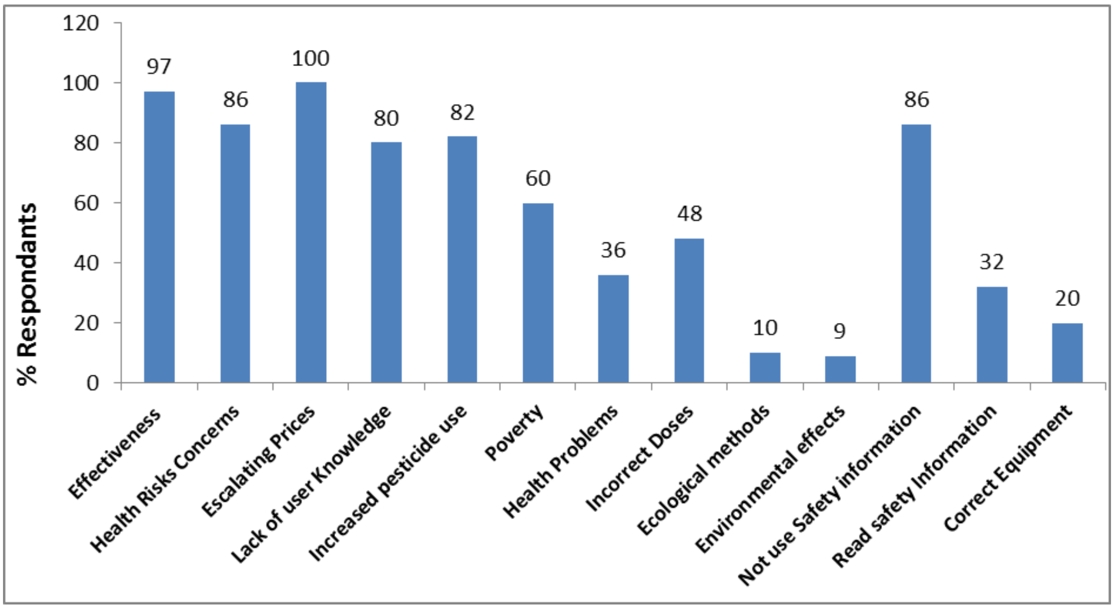

Figure 4: Farmers' knowledge and attitude towards pesticide usage