Journal of Environmental Science and Water Resources
Vol. 2(7), pp. 203 - 209, August 2013

ISSN 2277 0704
2013 Wudpecker Journals

The effects of farm pesticides on water bird numbers in lake Naivasha, Kenya

[1]Kaoga J., [2]Ouma G.*, [3]Aboum P.

[1,3]School of Environmental and Earth Sciences, Maseno University, P.O Box 333, Maseno, Kenya.
[2]School of Agriculture and Food Sciences Bondo University, College P.O Box 210-40601, Bondo, Kenya.

*Corresponding author E-mail: goumaoindo@yahoo.com.

Accepted 24 May 2013

Lake Naivasha and its environs usually experience increased levels of pesticide application due to the rapid increase in acreage under flower production in the catchment. Previous studies have shown detectable levels of organo-chlorines residues; which is an indication of contamination. Organo-chlorines persist in the environment and bio accumulates in the body tissue of living organisms while, the organophosphates which have been adopted as an alternatives are highly toxic. Such occurrences are linked to the declining trends in water bird numbers witnessed earlier. The objectives of the present study were to determine pesticide residue concentrations of organophosphates and organo-chlorines and determine their effects on water bird numbers. The Lake was subjected to a cross-sectional study between the months of February to July, 2011. The sampling sites were selected on the basis of their uniqueness in the nature of discharge released into the Lake. There was no mathematical formula applied to calculate sample size, due to the discrete nature of variables. The water bird counts were recorded on Microsoft excel spread sheet and subjected to analysis while applying statistical package of social science (SPPS) using one way ANOVA at p<0.05. The study showed an upward trend in the water bird numbers while Gas Liquid Chromatography technique showed non detectable limits for the targeted analytes. These results were good signs indicative of the Lake being on its pathway to restoration to the previous state of non-contamination. The study further, recommends that the government through its enforcement agencies should continue to carry out regular inspections on the ongoing human activities in the Lake and its environs to prevent sporadic contamination and discourage any further discharge of contaminants into the Lake. Moreover, this will enable the government to generate useful information for decision making purpose as they formulate policy framework for the protection, conservation and sustainable utilization of natural resources.

Key words: Organophosphates, organo-chlorines, Gas Liquid Chromatography, contamination.

INTRODUCTION

The environmental impact of pesticides is usually big. Over 98 percent of sprayed insecticides and 95 percent of herbicides reach a destination other than target species, including non targeted, air, water, bottom sediments and food (Miller, 1998). Inappropriate application of pesticides can lead to pest resistance and kill beneficial insects. (Damalias and Illias, 2011).The factors that influence the amount of pesticides drifting away from their intended targets are chemical properties of the pesticide, its soil binding ability, its vapour pressure. Its water solubility and its resistance to being broken over time The soil factors that affect the drifting away of pesticides after application are soil texture, water retaining ability, and soil's organic matter content. (Kellog et al., 2000; Becht et al., 2005).

Water birds are very conspicuous in the landscape.

Injuries to populations of birds from environmental pollutants are indicative of environmental damage. Pesticides can affect birds through reproductive failure, egg shell thinning and breeding failures,egg hatchability and survival and survival of chicks. (Spitzer et al., 1978; Grier, 1982; Cade et al., 1971; Nisbet, 1975).) Lake Naivasha covers approximately 140 km^2 (Harper, 1993; Becht et al., 2005) and it is Kenya's second largest freshwater body that had been recognized as a site of international significance (Ramsar Wetland Conservation, 2010). It has a well known and diverse avian fauna and is an important bird area (Bennun and Njoroge, 1999).

The Lake serves as an important stop over point for water birds. Many bird species have been recorded in the site over the years and it is estimated to be at least 350 bird species of which 90 are aquatic or semi aquatic (Bennun et al., 2002). The Lake's water and its vicinity are under increased threat of losing its water birds especially, *Fulita cristata*, *Haliacetus volifer and Prionops poliolophus* which preyed on fish (CGIAR, 2010). Flower production in this catchment area has been growing at a very high rate. This is associated with high application of pesticides which are discharged with waste water which eventually ends up in the Lake.

During wet season pesticides are washed into the Lake through surface run off. These have a significant threat to biodiversity and due to the fact that they cause contamination of water which interrupts the life cycles of most aquatic organisms (Furness and Greenwood, 1993). The contamination effect of DDT as a consequence of bioaccumulation and amplification through the food chain has been verified by the decreasing bird numbers (Furness and Greenwood, 1993). There have been few, if any, studies to determine the effect of pesticides on the bird population of Lake Naivasha, Kenya hence the present studies.

MATERIALS AND METHODS

The study commenced in early February 2011. Surveillance for site selection and water sampling was conducted while ensuring that the all the water samples were appropriately labelled to prevent contamination. The laboratory investigations were conducted by the Chemistry Department of Central Veterinary laboratory, Nairobi,Kenya, Water and Sewage Company laboratory, Kisumu,Kenya and Lake Victoria Water Board Services Laboratory, Kisumu, Kenya using standard methods.

Three replicates of water samples were collected monthly, 18 water samples per site, totaling 90 were prepared. Further, the water specimens for organophophates (OPs) and organo-chlorines (OCs) analysis were chilled at 4^0 C upon collection and stored at 6^0 C until extraction to prevent deterioration. The sample bottles were rinsed three times with water to be sampled before collection. The quantities of water samples collected sufficed for subsequent determinations.

The study had two treatment sites i.e. control and test sites, totaling 5. These sites were accessed using a motorboat. The water samples were collected from the side of the boat at each sampling sites. The choice of instruments used for this research depended on the variables to be analyzed, choice of location, depth, the frequency of sampling, weather conditions and the purpose of investigation.

Determinations for organo-chlorines and organophophates in the water samples were by Gas Liquid Chromatography procedures as described by Akerblom (1995) The Varian model used was equipped with ECD/NPD operating under the following conditions: Oven temperature 170^0 C for 1.5 minutes, ramp rate 15^0 per minute, oven no. II 170^0 C for 0.5, ramp rate@ 25^0 per minute to hold for 1 minute, column 3% OV 17, injector temperature 350^0 C ECD/NPD (detector type) and detector saturation below 1 (specific 0.4) in water bath.

The water samples for organo-chlorines and organophosphates pesticide residue determinations were analyzed without prior filtering so that the residue which had been adsorbed on the surface of suspended particles, especially the organic particles like humus (Ramulus, 1985) would be detected.

Unfiltered water samples (100ml), previously preserved with 10% NaCl were extracted by Liquid-Liquid Extraction (LLE) method (Akerblom, 1995). The analytes were extracted using the mixed solvent (hexane/diethylether) in the ratio 85%: 15% (Green et al., 1992) and shaken vigorously using a mechanized shaker and subsequently supernatant layers extracted. The supernatants were concentrated to 2 ml by using rotary evaporator with water bath at 50 ºC (Sieber and Notling, 1982).

Subsequently, 2 µl aliquots of both reference standards and the extracts were injected into the Gas Liquid Chromatography column, and the comparison made between the standards and the samples based on the retention times, and the total area under the peak on the chromatographs.

During the identification, the peak was not considered relevant unless it had the same peak as the standard as presented on the chromatographs. Quantification of analytes was done by using the peak heights and the internal standards method (Martens et al., 1999). The peak area of the compounds in the samples and those of the standard resulted into a ratio which was multiplied by the concentration of pesticides standard which was at 1µg /ml (ppb) (Green et al., 1992).The ecological study on water birds was carried out simultaneously and involved familiarization with the field tools which included: a chart with sufficient details and descriptions of the birds to be observed, the date, hour and prevailing weather conditions (Dale et al., 1999).

The water bird counts were based on beak modifications i.e. spear, hooked, long and flat groups respectively while using the observation check list to guide data collection process to enhance accuracy. The belts transect method was applied on an area of 100 m^2 and involved creating five imaginary lines parallel to one another at interval of 1m, 25m, 50m, 75m and 100m along the shores.

These were called transects A, B, C and D respectively. The number of water birds within a given transect were counted and an index of numbers obtained as we moved a standard route at a steady standard rate. The water bird counts were recorded on Microsoft excel spread sheet and subjected to analysis by the statistical package of social science (SPPS) using one way ANOVA at $p<0.05$. The same statistical package was applied for

Table 1. Spatial distribution and Relative Density (RD) of water birds along the shores of Lake Naivasha In 2011.

Groups	1		2		3		4		5		Total	
	Popn	RD %	Popn	RD%	Popn	RD%	Popn	RD%	Popn	RD%	Popn	RD%
Stout and Spear shaped	1226	7.5	1326	8.1	1178	7.2	1046	6.4	1138	7.0	5914	36.3
Hooked shaped	1204	7.4	1364	8.4	1280	7.8	1127	6.9	1080	6.6	6055	37.1
Stout and Long shaped	525	3.2	672	4.1	483	3.0	393	2.4	449	2.8	2522	15.4
Flat and Hooked shaped	373	2.3	401	2.5	338	2.1	488	3.0	242	1.5	1842	11.3
Total	3328	20.4	3763	23	3279	20.1	3054	18.7	2909	17.8	16333	100

Note:*sites 1, 2, 3, 4, 5 representing: Elsamere conservation centre, crescent island lagoon, Karuturi flower farm inflow, sewage inflow and river Malewa inlet in that order.

Table 2. Abundance, distribution and relative density (rd) of the water birds recorded along the shores of lake Naivasha in 2011.

Months	Site 1	Site 2	Site 3	Site 4	Site 5	Total
Feb	502	586	493	455	424	2460
RD	3.1%	3.6%	3.0%	2.8%	2.6%	15.1%
March	518	596	509	466	446	2555
RD	3.2%	3.6%	3.1%	2.9%	2.7%	15.6%
April	530	604	545	479	477	2635
RD	3.2%	3.7%	3.3%	2.9%	2.9%	16.1%
May	554	645	545	513	481	2738
RD	3.4%	3.9%	3.3%	3.1%	2.9%	16.8%
June	578	645	570	538	574	2905
RD	3.5%	3.9%	3.5%	3.3%	3.5%	17.8%
July	646	708	637	603	574	3168
RD	4.0%	4.3%	3.9%	4.0%	3.5%	19.4%
Total	3328	3763	3279	3054	2909	16333

Note:*sites 1, 2, 3, 4, 5 representing: Elsamere conservation centre, crescent island lagoon, Karuturi flower farm inflow, sewage inflow and river Malewa inlet in that order.

other determinations in this study.

RESULTS AND DISCUSSION

The study observed that the birds were not confined to any one particular site but the abundance varied with Crescent Island Lagoon recording the highest counts as shown in Table 1.There was an upward trend in water birds numbers from commencement to termination of the study. This was a reflection of the ecological transition in the character of the Lake as a result of the intervention measures by the government and stake holders in Table 2.

Water bird abundance and distribution along the shores of Lake Naivasha

Many bird species have been recorded in Lake Naivasha and its environs over the years and it is estimated to be at least 350 bird species of which 90 are aquatic or semi aquatic (Bennun et al., 2002). According to Furness and Greenwood, (1993) the assessment of abundance and distribution of water birds was an independent way of monitoring aspect of environment pollution. Surveillance on the habitat through regular counts generated data for comparison. The present findings were in agreement with Clark et al. (1989) who reported an abundance of waterfowl (around 35,000 individuals). However, the habitat serves as an important stop over point for water birds with more than 80 species regularly recorded during censuses.

Our study observed that the Lake and its environs supported diverse water bird community and serves as an important area for conservation of migratory, vagrant and resident water birds agreeing with Harper et al. (1990) who reported that the habitat is rich in birds. Similar observations were made by Otieno et al. (2004);

Bennun and Njoroge (1992).

Spatial abundance and distribution of water bird numbers

The organo-chlorines pose the greatest threat to water birds since their long-term use leads to their accumulation in the environment (IPCS, 2005). The present study focused on water birds with to evaluate the changes in the ecological character of the Lake and its environs. The effects of these changes could be seen on the adjustments in their population, for instance, the reduction in water birds numbers was an indication of underlying environmental problems (Bennum et al., 2002).

Our study reported that water birds were not confined to any one particular site but established that the nature of impurities discharged off shores could have influenced and restructured the Lake's ecology. This is in agreement with observation made by Harper and Muchiri (1986) who reported that the ecology of Lake Naivasha and its environs was ever changing and the increase in water bird numbers was indicative of its recovery.

Our study reported that Crescent Island Lagoon had the highest numbers of water birds (Table 2). Similar observation was made from surveys carried out by Earth watch, (Earth watch 1992).and was attributed to its open and more expansive shoreline. In addition, the area had incorporated areas of flooded or floating vegetation with grassy shores around it making it easy for the water birds to access the open areas behind the papyrus fringe where the wading birds were observed. Moreover, Maclean, (2001) reported that certain East African bird species that were almost entirely restricted to Papyrus (*S. molesta)* had been observed to provide food, nesting, preening, protection, and roosting sites, among many other benefits, to invertebrates, avians and fish (Taylor, 1984). Similarly, Njuguna, (1992) reported that these plants provided habitats for invertebrates and juvenile fish.

The mouth of River Malewa had the least numbers of water birds (Table 1). This may be attributed to the continuous interference by human activities along its shorelines resulting in ecological changes witnessed especially on the northern off shores of the Lake (Bennun et al., 2002).

Furthermore, the present study observed that the site was inhabited with water birds mostly feeding on invertebrates, amphibians and microscopic algae which were most affected by any slight environmental changes. For instance, the north was devoid of most natural vegetation while the remnants of the original forest existed only in small patches, and cultivation often extended right down to stream level (Kitaka et al., *2*002). Further, the present study observed a significant rise in the number of water birds off shore at the flower farms.

Temporal abundance and distribution of the water bird numbers

Pesticide residues are passed on along the food chain to the tertiary consumers, through dietary exposure. The study focussed on water birds due to their advanced levels on the food chain and longer life span thus an ideal bio-indicator of ecological changes of the habitat (Furness and Greenwood, 1993) in order to integrate their population density to the effects of the environmental stress over time.

According to Connell, (1997) application of organochlorine (OCs) pesticides can reach high concentrations in the tissues of predators which occupy advanced levels along the food chains through biomagnifications. Similarly, Nowak, (1995) reported that bioaccumulation rates depended on factors such as exposure concentrations as well as time. The present study observed a gradual rise in water bird numbers from the study initiation in the month of February to its completion in July, 2011.

This agrees with Barasa et al. (2006) who reported an upward trend in water bird numbers relative to the years before. This may have been due to the fact that habitat biodiversity and abundance appear strongly linked to the strength of contamination. (Harper et al., 2002; Boar et al., 2002).

However, our study reported that the adjustments were gradual, where water birds were able to respond to the new changes taking place on this particular ecosystem (Henderson and Harper 1992). This was reflected in the upward trends on the water bird numbers across the five sampling sites. We also observed that water bird composition changed as conditions changed with some groups relatively responding faster to the changes than others. For instance, the fish eagle population in the Lake's riparian habitat showed an upward trend following a two year ban in fishing in the Lake (Otieno et al., 2004). In addition, considerable pressure has been alleviated as a result of net mesh-size regulations, particularly for the bass fishery (LNRA, 1999). Similarly, Njunguna, (2002) reported that the government had imposed a temporary ban on fishing in 2001.

The piscivorous water birds especially the hooked stout and spear shaped group increased relatively faster in comparison to the other groups of water birds. This was attributed to their feeding habits where by healthy fish population attracted a variety of fish eaters' e.g. long tailes, great cormorants, fish eagles, pied kingfisher, watch back and herms.

Moreover, following the introduction of exotic crayfish in 1970 (Harper et al., 2002) and common carp in 2001 (Brecht et al., 2005), common carp numbers increased substantially by 2010. (LNAFR, 2010). There has been drastic decline in the use organophosphates and organochlorides following their ban in most developed countries. (US Geological Survey, 2005).

Table 3. Levels of organo-chlorines residue concentration across the five sampling sites in lake Naivasha during the wet and dry season in 2011

Organochlorine	Wet season	Concentration ppb	Dry Season	Concentration ppb
Endo sulfan	Malewa	Not detected	Malewa	Not detected
	Sewage	Not detected	Sewage	Not detected
	Karuturi	Not detected	Karuturi	Not detected
	Crescent	Not detected	Crescent	Not detected
	Elsamere	Not detected	Elsemere	Not detected
Lindane	Malewa	Not detected	Malewa	Not detected
	Sewage	Not detected	Sewage	Not detected
	Karuturi	Not detected	Karuturi	Not detected
	Crescent	Not detected	Crescent	Not detected
	Elsamere	Not detected	Elsemere	Not detected
Aldrin	Malewa	Not detected	Malewa	Not detected
	Sewage	Not detected	Sewage	Not detected
	Karuturi	Not detected	Karuturi	Not detected
	Crescent	Not detected	Crescent	Not detected
	Elsamere	Not detected	Elsemere	Not detected
Dieldrin	Malewa	Not detected	Malewa	Not detected
	Sewage	Not detected	Sewage	Not detected
	Karuturi	Not detected	Karuturi	Not detected
	Crescent	Not detected	Crescent	Not detected
	Elsamere	Not detected	Elsemere	Not detected
DDT	Malewa	Not detected	Malewa	Not detected
	Sewage	Not detected	Sewage	Not detected
	Karuturi	Not detected	Karuturi	Not detected
	Crescent	Not detected	Crescent	Not detected
	Elsamere	Not detected	Elsemere	Not detected

Table 4. Levels of organophosphates residue concentrations across the five sampling sites in lake Naivasha during wet and dry season in 2011.

	Organophosphate	Wet season	Concentration ppb	Dry Season	Concentration ppb
1	Nemacur	Malewa	Not detected	Malewa	Not detected
		Sewage	Not detected	Sewage	Not detected
		Karuturi	Not detected	Karuturi	Not detected
		Crescent	Not detected	Crescent	Not detected
		Elsamere	Not detected	Elsamere	Not detected
2	Orthene	Malewa	Not detected	Malewa	Not detected
		Sewage	Not detected	Sewage	Not detected
		Karuturi	Not detected	Karuturi	Not detected
		Crescent	Not detected	Crescent	Not detected
		Elsamere	Not detected	Elsamere	Not detected
3	Durban	Malewa	Not detected	Malewa	Not detected
		Karuturi	Not detected	Karuturi	Not detected
		Crescent	Not detected	Crescent	Not detected
		Crescent	Not detected	Crescent	Not detected
		Elsamere	Not detected	Elsamere	Not detected
4	Diazol	Malewa	Not detected	Malewa	Not detected
		Sewage	Not detected	Sewage	Not detected
		Karuturi	Not detected	Karuturi	Not detected
		Crescent	Not detected	Crescent	Not detected
		Elsamere	Not detected	Elsamere	Not detected
5	Fenitroth-ion	Malewa	Not detected	Malewa	Not detected
		Sewage	Not detected	Sewage	Not detected
		Karuturi	Not detected	Karuturi	Not detected
		Crescent	Not detected	Crescent	Not detected
		Elsamere	Not detected	Elsamere	Not detected

According to Jeffrey et al. (1981) similar measures had been taken earlier for instance, lindane was restricted for seed dressing only despite it being relatively biodegradable and less persistent (Tanabe et al., 1993) while aldrin and dieldrin were restricted to termite control in the building industry (PCPB, 1998).

The pesticides residue levels of the targeted analyses of organo-chlorines (OCs) and organophosphates (OPs) in water samples from Lake Naivasha were below detection limits during both dry and wet season (Table 3 and 4). These findings could have been attributed to the improved environmental conditions following the ban and restrictions on these groups of pesticides. Furthermore, the study reported the great effort and determination put in place by the government and diverse stakeholders in the Lake and its environs. Therefore, the targeted analytes were neither environmental nor human health hazards since their concentrations did not pose any threat.

Furthermore, the region experienced high solar radiation with its effects felt throughout the year in the tropics (Lalah et al., 2001). This could have contributed to the irradiation of Dichlorodiphenyl trichloroethene (DDT) since solar irradiation enhanced its volatilization and mineralization in the soil (Lalah, 1993). Kale et al. (1999 reported that tropical environments shortened. Dichlorodiphenyl trichloroethene (DDT) half-life to about 5 years.

Similarly, Esser et al. (1975) concurred that herbicides decomposed faster under the influence of radiation. Therefore, photo-degradation was an important dissipation pathway for these pesticides.The present study reported efforts by stakeholders to replace organochlorine (OCs) and organophophates (OPs) with alternative pesticides with a shorter half life. This observation was in agreement with Getenga et al. (2000) who reported that stakeholders were adopting new alternatives to organochlorine (OCs) and organophophates (OPs). They reported that organo-chlorines (OCs) were under restriction by authorities.

Conclusion

The study reported an upward trend in water bird numbers and targeted analytes of organo-chlorines and organophosphates were undetected. The study concluded that the various interventions by the government and stakeholders through implementation of conservation efforts in Lake Naivasha catchment area were fruitful despite the dynamics of this ecosystem. It is recommended that the monitors the farming activities around Lake Naivasha to reduce any pesticidal contaminations.

REFERENCES

Akerblom, M (1995). Guidelines for environmental monitoring of pesticides residue for the SADC region. SADC/ELMS, Monitoring techniques, Series 3 Lesotho.

Boar R, Harper DM, Everard M, Hickley P (2002). Lake Naivasha, Kluwer Academic Publishers, Netherlands.

Becht R and Harper DM (2002). Towards an understanding of human impact upon the hydrology of the Lake Naivasha. Review Hydrobiologia tropical 21:127-134.

Bennun LA, Nasirwa O, Owino AO, Oyugi JO (2002). Trends in water bird numbers in Southern RiftValley of Kenya, NMK, Ornithology Department, Nairobi.

Bennun L, Njoroge P (1999). Important Bird Areas in Kenya. Nature Kenya, Nairobi.

Barasa FM, Mandindou I, Mulwa R, Kanyanya E, Ngari A, Kinga E, Njehia S, Ndonye P, Siele J, Kele JM, Misila S, Wanyiri M, Buckley P (2006). Kenya Important Bird Areas status and trends.

Cade TJ, Liner JL, White CM, Roseeau DG, Swartz LG (1971). DDE Residues and Egg Shell Changes InAlaskan Falcons and Hawks.Science 172:955-957

Connel DW (1997). Basic concepts of Environmental Chemistry. Springer, A.M Ijmuiden, The Netherlands, 560p.Marco and Kishimba-levels of pesticides and metabolites in water. 88.

Damalas CA, Illias GE (2011) Pesticiide Exposure ,Safety Issues and Risk Assessment Indicators.International of Environmental Research and Public Health, 8 (5):1402-1409

Dale AZ, Donald AT, David JP (1999). Birds of Kenya and northern Tanzania, Helm publishers, London.

Earthwatch (1992). Lake Naivasha bird survey.

Esser O, Herbert G, Dupius C, Vogel G, Macro J (1975). Hebicides; Chemistry, degradation and mode of action, P.C. Keaney D.D. Kaufmann (Eds), Marcel Dekker, Newyork, 129-208.

Furness RW, Greenwood JJD (1993). Birds as monitors of environmental change, Chapmall and Hall.

Green AE Clesceri, LS and Eaton, AD. (1992).Standard methods for examination of water and waste water, 18th Edition, American Public Health Association,APHA (Edited).

Grier JW (1982) Ban of DDT and Subsequent Recovery of Reproduction In Bald Eagles,Science 218:1232-1235.

Harper DM, Muchiri SM (1987). The ecology of Lake Naivasha, Kenya: Introduction and historical review. In Harper, D.M., (ed) studies on Lake Naivasha ecosystem, 1982-84. Final report to the Kenya Government, May 1987. University of Leicester.

Harper DM, Mavuti KM, Muchiri SM (1990). Ecology and Management of Lake, Naivasha, Kenya, in relation to climatic change, alien species introduction and agricultural development. Environmental conservation 17: 328-335.

Harper D (1993). Publications on the ecology of Lake Naivasha and Hell's gate national park,1984-91 plus recent unpublished reports of work at the Lake and parks, 1991-92 ecology unit, department of zoology,

university of Leicester, U.K.
Harper DM, Mavuti KM (2004). Lake Naivasha, Kenya. Ecohydrology to guide the management of tropical protected area. Ecohydrol., 4:287-305.
Henderson IG, Harper DM (1992). Birds distribution and habitat structure of Lake Naivasha, Kenya. Afri. J Ecol., 30: 223-232.
IPCS (2005). Inventory of IPCS and other WHO pesticide evaluations and summary of toxicological evaluations and summary of toxicological evaluations performed by joint meeting of pesticide residue (JMPR) through 2002.The international programme on chemical safety. Geneva: World Health Organisation; 2005.
Kellog RL, Nehring R, Grube A, Gross DW, Plotkin S (2000) Environmental Indicators of Pesticide Leaching and Run-off From Farm Field.U,S Department of AgriculturalandNatural Resources Conservation Service.Retrieved on 2007-10-03.
Kitaka N, Harper DM, Mavuti KM (2002). Phosphorus inputs to Lake Naivasha, Kenya, from its catchment and the tropic state of the Lake. Hydrobiologia 488 (Development in hydrobiology 168: 73-80.
Lake Naivasha Annual Fisheries Report, 2010.
Lalah JO, Kiagwara PN, Getenga ZM, Mghenyi JM, Wandiga SO (2001). The major environmental factors that influence rapid disappearance of pesticides from tropical soils in Kenya. Toxico. Environ. Chem., 81:161-197.
Lalah JO, Yugi PO. Jumba IO, Wandiga SO (2003). Organochlorine pesticide residues in Tana and Sabaki rivers in Kenya. Bull Environ Contam Toxical.2003; 71; 298-307.
Maclean I (2001). The effects of habitat degradation on papyrus. *Ceperius papyrus* Lake Avian communities: Implications for identifying areas for conservation. PhD Thesis University of East Anglia.
Martens D, Schramm KW, Kettrup A (1999). Standard operation procedures for the determination of chlorinated hydrocarbons in sediments, suspended solids and surface waters: In: On the presence of polychlorinated organic compounds in the Liao River and the Yangste river in eastern China, Gawlik BM, Platzer B, Muntau H (Eds). European Commission EVR-Report 18702 EN Ispra, 21-28.
Miller JC, Miller JM (1998). Statistic for analytical chemists, pp. 75-112, West sussex, England: Ellis and Horwood.
Nisbet ICT (1975) Ecological Magnification. Technol. Rev., 3-4: 6-8
Njunguna SG (1992). Floating aquatic weeds in Kenya. In Crafter SA, Njunguna SG, Howard GW (eds), wetlands of Kenya.pp 85-90. IUCN Gland, Switzerland.Earthwatch/Leicester final report to GOK 1987.
Nowak B, Goodsell A, Julli M (1995). Ecotoxicology., 4:363 Yebiyo, B.T. MSc. Thesis, university of Nairobi.
Nowak B (1995). Arch. Environ. Contam. Toxicol., 30:195.
Otieno N, Mwangi S, Bunnun L, Musila S, Mulwa R, Kiragu A (2004). Important bird areas status.
Pest Control Products Board (2010). A statutory organisation of government pest control product Act, Cap 346) Daily Nation, viewed 16th September.
Pest Control Product Board (1998). List of pest control products provisionally registered by pest control products board for use in Kenya (Revised June, 1998). PCPB. Nairobi.
Ramsar Wetland Conservation (2010).
Ramsar Wetland Conservation Awards (1999).
Ramulus SUS (1985). Chemistry of insecticides and fungicides, second Edition, Oxford and IBH publishing CO. New Dehli, India.
Sieber JH, Notling G (1982). Anaysenmethod zur bestimmung von pyrethroiden nachrichtenblatt deut flanzzenscutzd.Eugen Ulmer Verlag, Stutgard,166-170.
Spitzer PR, Risebrough RW, Walker W, Hernandez R, Poole A, Puleston D, Nisbet IC (1978). Productivity of Sprays In Connecticut-Long Island Increase as DDE residues Decline Sci., 202:333-335
Tanabe S, Subramanian AN, Ramesh A, Kumaran PL, Miyazaki N, Tatsukawa R (1993). Persistent organochlorine residue in dolphins from the bay of Benghal, south India. Mar. Pollut. Bull., 26:311-316.
Taylor C (1984). The feeding ecology of the African Lily trotter at Lake Naivasha, Kenya.
U.S. Geological survey (2005). Organo-chlorines in streambed sediment and Aquatic Biota U.S.