© 2017 IJSRSET | Volume 3 | Issue 5 | Print ISSN: 2395-1990 | Online ISSN : 2394-4099
Themed Section: Engineering and Technology

Occurrence and Distribution of Organochlorine Pesticide Residues in Water and Soil Samples from Kargi Area, Marsabit County, Kenya

Vincent O. Madadi

Department of Chemistry, School of Physical Sciences, College of Biological and Physical Sciences, University of Nairobi, P. O. Box 30197-00100, Nairobi, Kenya.

ABSTRACT

This work investigated organochlorine pesticides residue levels in water and soil from Kargi area of Marsabit County, Northern Kenya. The population of Kargi has experienced high incidences of ill health conditions associated with environmental factors which has raised public concern and interest to delineate the causes. Several organic and inorganic compounds are known to cause toxicity to human health when they occur at high levels in environment, especially pesticides, polychlorinated biphenyls, polyaromatic hydrocharbons, polychlorinated dibenzo-paradioxins/furans among other organics. Inorganic chemical of concern in water include arsenic, nitrites and fluorides. The main objective of this study was to determine whether pesticides contamination in water and soil could be contributing to ill health conditions in Kargi area. We focused on organochlorine pesticides due to the fact that these were widely applied in Kenyan environment in the past, particularly in agriculture and desert locust control leading to high environmental prevalence, obsolete stocks and contaminated soils. We collected water samples in 2.5 L amber glass bottles, whereas soil was collected in aluminum foil and packed in ziplock bags. After extraction and cleanup, pesticide residues were analysed using Agilent 6890N gas chromatograph equipped with a micro-electron capture detector. Pesticide residues in water ranged from <0.001-3.370 µg/L and from <0.001-17.141µg/kg in soil. The residues in soils were approximately ten times higher than the levels measured in water. Pesticide residues detected in water samples were well below the WHO maximum limits and also below the background levels detected in other parts of the country. Therefore the residues levels measured in water and soil samples in this study could not be associated to the high incidences of ill health and cancer experienced in the region. Further sampling to compare levels in wet and dry seasons could help to establish environmental effect on water contamination.

Keywords: Marsabit, Kargi, Soil & Water quality, organochlorine pesticides residues, environmental health

I. INTRODUCTION

Pesticides have not only contributed to improving quality of life and food production[1], but also negatively affected environment and human wellbeing due to contamination and side effects to non-target organisms. In tropical countries, the hot and humid environmental conditions experienced promote development of a myriad pests and disease vectors. Therefore, economic management of crops and livestock as well as public health vector control heavily depends on use of pesticides. However, continuous application of these chemicals coupled with weak environmental management in most developing countries not only results into soil, water and air contamination but also affect other living organisms.[1] Currently agricultural and public health use of most persistent pesticides has been banned, however this has occurred after a long-term buildup of large stocks of obsolete pesticides and contaminated soils. The presence of a diverse range persistent pesticide residues in the water bodies is of concern due to their ability to bio-concentrate and bio-accumulate in the food chain, and the resulting long-term impact on ecosystem integrity. Pesticide residues have been reported widely in the global environment.[2-16] In addition a number of simulation studies and field

experiments carried out on fate and transport of pesticides in Kenyan environment showed variant levels of persistence from one region to the other explaining presence of these residues todate.[17-22]

In Kenyan environment *p,p'*-DDT, *o,p'*-DDE, *p,p'*-DDD, α-, β-, γ-HCH, aldrin, dieldrin, endrin, α & β-endosulfan, endosulfan sulphate, heptachlor, heptachlor epoxide residues have been reported at levels ranging from <0.002-0.439 µg/l in water, <0.002-65.478 µg/kg in sediments, <0.001-10.073 µg/kg in weeds and <0.001-481.178 µg/kg in fish from Lake Victoria and the Coastal environment.[5,9,23] Pesticides have been reported in regional countries such as Uganda[10] and Tanzanian[11].

The Kargi is located in Marsabit County, which is one of the semi-arid parts of Kenya with annual rainfall between 200-550 mm. The County lies in the Northern part of Kenya and covers an area of about 71,000 km^2. It borders Ethiopia to the north, Lake Turkana to the west, Samburu County to the south and Wajir and Isiolo counties to the east. Most of the county land consists of extensive plain lying between 300 m and 900 m above sea level. [24] Most of the county is arid with rocky, stony and rugged lava plains. Rainfall ranges between 200 mm and 1,000 mm per annum, and its duration, amount and reliability increases with altitude, whereby approximately 75 percent of the total land area lies below 700 m above the sea level forming low-potential rangeland. The major impediment to agriculture is lack of permanent rivers. About 60% of the households rely on boreholes, springs and wells, while the distance to the nearest water point is estimated to be 25 km. [24] The County experiences low and highly unreliable rainfall. Small scale agriculture is practiced in the foothills, lower mountain slopes and highlands, which receive moderate rainfall of about 700 mm annually. Livestock and crop production are the major economic activities in the foothills. On the other hand the highland areas like Mt. Marsabit, Mt. Kulal and Ol Donyo Mara Range receive moderate rainfall and have good soils with high potential for agricultural production. But only 0.3% (5,060 ha) of the total estimated arable area (1,582,750 ha) is under food and cash crop production mainly, with maize, sorghum, millet, beans, fruits and vegetables. It is estimated that about 2 percent of the county population is engaged in crop farming, whereas livestock keeping remains the mainstay economic activity in the region, of which cattle, goats, camels, donkeys and poultry are the majority. [24,25]

II. METHODS AND MATERIAL

A. Study area

Kargi is located about 89 km south of Marsabit town. It is characterized by dry climate, sporadic splash rainfall and sparse vegetation cover. Major economic activity in the area is nomadic pastoralism which is carried out majorly by men, 24 while women, children and the elderly stay at home. The main challenge to service delivery is the lack of infrastructure, low population density and limited institutional capacity for environmental management. The local communities in Kargi do not have access to safe drinking water and sanitation facilities. 26 The main sources of water in the area include shallow wells, boreholes, water pans and rain water. There are no conventional water treatment facilities in the area hence the communities directly consume raw water from the sources, which may expose them to high risks especially when the water is contaminated.27 In addition there is no adequate research data to determine the extent of water contamination and environment in general, giving room to speculations on potential causes of ill health experienced by the local communities. This study focused on determining the status of water and soil quality of Kargi area and the nearby water sources, with respect to organochlorine pesticides contamination. The sampling sites are described in Table 1 below.

B. Field sampling

Water samples (1 L each) were collected in triplicate, in amber glass bottles, from each sampling site and immediately preserved with mercuric chloride solution. The samples were stored in Coleman cooler boxes containing ice packs while in the field and during transportation to the laboratory. Once in the laboratory, the samples were immediately extracted into organic solvent and stored in a refrigerator at 4 °C prior to cleanup and analysis.

Table 1: Site Description

No.	*Site name*	*GPS location*	*Site characteristics*	*Samples*
Site 1	*Bellatrix well sites*	*N.02.70118, E.037.54083*	19 km North of Kargi town. The oil well was drilled in the late 1980's.	*Soil*
Site 2	*Wortider well*	N 02.64616, E 037.47098	The well is located at KURKUM sub-location about 18 km from Kargi town The well was dug before independence although it was later rehabilitated and a hand-pump installed by a local Church.	*Water & Soil*
Site 3	*Kargi Borehole new well*	N 02.50918, E 037.56841	The borehole is located near Kargi town. It was drilled in 2006 and after the old borehole that killed 7,000 livestock in the year 2000 was abandoned. The borehole is connected to a pump that takes water to two reservoirs for use by the public.	*Water & Soil*
Site 4	*Kargi town well*	N 02.50390, E 037.576	The well is located near the Kargi town, and the main source of drinking water. Its location is near UNICEF well that is mainly used for washing clothes.	*Water & Soil*
Site 5	*Torigeyidahar water pad (Korr)*	*N0332305, UTM 246787*	The water pan was constructed in 2008 and located between Korr town and Kargi town, 67 km from Kargi. Approximately 100 m long x 100 m wide, and 2 m deep.	*Water & Soil*

Figure 1 below shows the map of the study area where water and soil samples were collected. There are no permanent rivers in the region

.

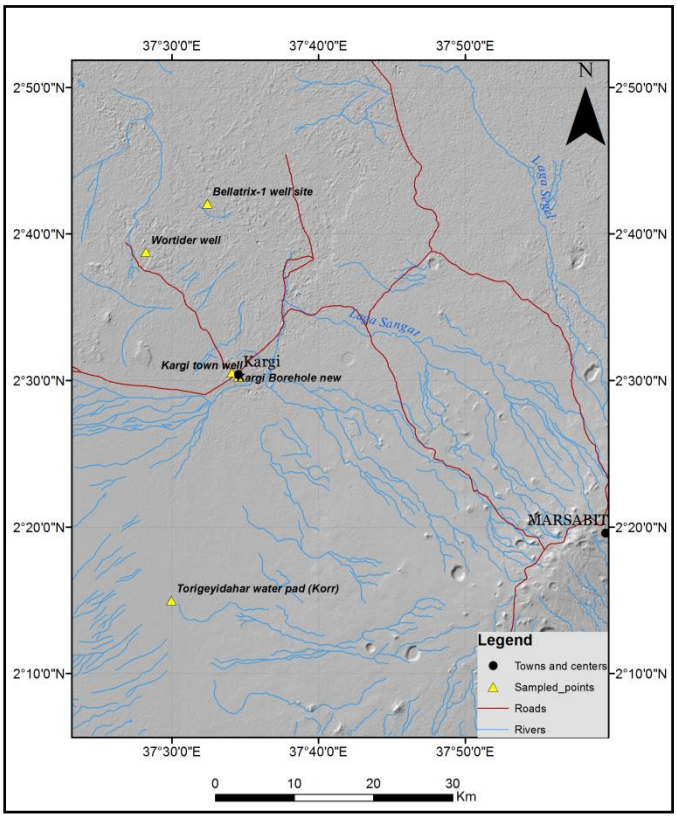

Figure 1: Map of the study area showing the sampling sites

C. Extraction and cleanup of water samples

Sample extraction was done by solvent-solvent extraction using dichloromethane. 1 L of sample was transferred into 2 L separatory funnel and treated with 50 ml of phosphate buffer (pH 7). Analytical grade sodium chloride (100 g) was added to the water and mixed thoroughly to salt out pesticides. Extraction was effected by shaking the sample with three 60

ml portions of HPLC grade dichloromethane and collecting the organic layer. Combined extract for each sample was concentrated to 1 ml using LABCONCO rotary evaporator at 40 ^{0}C and cleaned by eluting through 15 g deactivated alumina, packed in 25 cm long and 1.5 cm internal diameter glass column laced with 1 cm of activated anhydrous sodium sulphate at the bottom and on top of alumina layer to retain any moisture. The column was conditioned by eluting through 15 ml of n-hexane before transferring the sample. The sample was eluted with 165 ml of n-hexane, concentrated to 3 ml using a rotary evaporator and reduced further to 0.5 ml under a stream of nitrogen. The reduced sample was spiked with 100 µl of PCB 198 as injection reference standard before analysis.

D. Sample Analysis

Sample analysis was done using Agilent 6890N equipped with micro Electron Capture Detector. Separation was done using BPX 5 capillary column of dimensions 30 m x 0.25 mm x 0.25 µm film thickness. Confirmatory analysis was done using BPX 35 capillary column of dimensions 50 m x 0.25 mm x 0.25 µm film thickness. A temperature programme was used starting from 90 ^{0}C (hold time of 3 minutes), increased to 215 ^{0}C at 8 ^{0}C/min (hold time of 25 min), then increased to 270 ^{0}C at 5 ^{0}C/min (hold time of 5.37 min) and finally ramped to 275 ^{0}C at 5 ^{0}C/min (hold time of 18.63 min). The carrier gas was high purity helium of 99.995% and N= 6, while white spot nitrogen was used as a makeup gas. Quantification followed external calibration method using high purity pesticide reference standards mixture of 17 obtained from Ultra Scientific USA.

E. QA and QC

All sampling, extraction and analyses were conducted in triplicate to allow data verification. The samples were spiked with PCB 155 prior to extraction and PCB 198 as a syringe standard at the time of analysis to correct errors due to fluctuations in response of the ECD. Recovery tests were carried out using the reference pesticide standards to determine performance of the method. Field blanks and method blanks were incorporated to check for contamination during sampling, transportation and laboratory preparation procedures.

III. RESULTS AND DISCUSSION

The concentrations of 17 pesticides and metabolites reveal the heterogeneous nature of the sampling sites strongly influenced by diverse socio-economic activities and environmental factors. Table 1 summarises the mean concentrations of each pesticide. Endrin aldehyde, p,p'-DDT and aldrin had the highest overall concentrations in most of the sites compared to other pesticides. On the other hand, Alpha and delta –HCH, heptachlor epoxide, p,p'-DDE and endosulphan sulphate were not detected in water samples.

A. Organochlorin pesticide residues in raw water

β-HCH was the most dominant HCH isomer with occurrence of 50% in all the samples, while γ-HCH was only detected in water from one site. The mean concentrations of β-HCH ranged from <0.002-0.030 µg/l. γ-HCH recorded the highest (0.041 µg/l) level at Kargi town borehole. No HCHs were detected in water from Kargi New Borehole and Korrelle suggesting no significant contamination (Table 2). Lindane (γ-HCH) is an organochlorine insecticide and fumigant that was widely used against a wide range of insects in treatment of seeds, on crops, in warehouses, on domestic and agricultural animals as well as public health vector control of scabies and lice. HCH occurs in two formulations - technical grade HCH and lindane - whereby technical grade HCH is a mixture of different isomers: α-HCH (60-70%), β-HCH (5-12%), γ-HCH (10-15%), δ-HCH (6-10%), and ε-HCH (3-4%), whereas lindane is the γ-isomer (>99% pure) of HCH.28,29 Except in public health control of head lice, all agricultural uses have been banned under the Stockholm Convention due to their toxicity effects on human and wildlife. However its residues are still detected in environment.

Table 2. Mean concentrations of organochlorine pesticide residues in water samples from Kargi, Marsabit County (µg/L)

Water sites	α-HCH	β-HCH	γ-HCH	δ-HCH	Aldrin	Dieldrin	Heptachlor	Heptachlor epoxide	Endrin	Endrin aldehyde	*p,p*-DDT	*p,p*-DDE	*p,p*-DDD	Endosulphan1	Endosulphan II	Endosulphan sulphate	Methoxychlor
Kargi New B/H Reservoir	<0.001	<0.002	<0.002	<0.005	0.293	<0.003	<0.001	<0.001	0.021	1.302	<0.002	<0.002	<0.002	0.061	0.020	<0.002	0.320
Kargi town B/H Direct	<0.001	<0.002	0.041	<0.005	0.132	0.042	<0.001	<0.001	0.023	1.432	0.042	<0.002	<0.002	<0.001	<0.002	<0.002	<0.002
Kargi Town Well	<0.001	0.030	<0.002	<0.005	0.101	0.060	0.160	<0.001	<0.002	1.010	<0.002	<0.002	<0.002	<0.001	0.021	<0.002	<0.002
Korrolle	<0.001	<0.002	<0.002	<0.005	0.083	0.081	<0.001	<0.001	0.052	3.370	0.640	<0.002	<0.002	0.070	0.043	<0.002	0.241
Kurkum	<0.001	0.030	<0.002	<0.005	0.921	0.052	<0.001	<0.001	<0.002	1.331	0.041	<0.002	<0.002	0.041	<0.002	<0.002	0.043
Torigeyidahar Water Pad	<0.001	0.022	<0.002	<0.005	0.094	0.040	<0.001	<0.001	0.030	1.573	<0.002	<0.002	<0.002	<0.001	0.021	<0.002	<0.002
Blank	<0.001	<0.002	<0.002	<0.005	<0.004	<0.003	<0.001	<0.001	<0.002	<0.002	<0.002	<0.002	<0.002	<0.001	<0.002	<0.002	<0.002
WHO Guideline (µg/L)	-	-	2.000	-	0.030	0.030	-	-	0.600	-	1.000	1.000	1.000				20.000

Heptachlor recorded occurrence of 16.67% in water samples with the highest concentration of 0.160 µg/L recorded in samples from Kargi town well (Table 2). Heptachlor (1,4,5,6,7,8,8-heptachloro-3a 4,7,7a - tetrahydro-4,7-methano-l H-indene) is a contact organochlorine pesticide that was widely used in the control of soil insects and termites, but its global production and use has been banned under the Stockholm Convention due to environmental persistence and potential toxicological effects on human and wildlife. The technical grade heptachlor consists of 70% heptachlor, 22% trans-chlordane and 5% nonachlor.30 Under environmental conditions, heptachlor undergoes transformation into heptachlor epoxide which is more persistent than the parent

compound. Low occurrence of both heptachlor and heptachlor epoxide suggest no significant use of the compound in the region.

Aldrin registered 100% occurrence in the samples with concentrations ranging from 0.083 µg/L to 0.921 µg/L. On the other hand the levels of dieldrin ranged <0.003 µg/L to 0.081 µg/L. The highest concentrations of aldrin were measured at Kurkum (0.921 µg/l) and Kargi new borehole with concentration of 0.293 µg/L (Table 2). Aldrin ((1R,4S,4aS,5S,8R,8aR)-1,2,3,4,10,10-Hexachloro-1,4,4a,5,8,8a-hexahydro-1,4:5,8-dimethanonaphthalene) and dieldrin ((1R,4S,4aS,5R,6R,7S,8S,8aR)-1,2,3,4,10,10-Hexachloro-1,4,4a,5,6,7,8,8aoctahydro-6,7-epoxy-1,4:5,8-dimethano naphthalene) were widely used in the past as insecticides for soil-dwelling pests and for the protection of wooden structures against termites, and as insecticide against insects of public health concern. However, the use of the two compounds has been banned in the country due to their deleterious effects on human health and environment. While in the environment, aldrin breaks down slowly by oxidation to dieldrin accounting for the prolonged detection in environmental samples. The metabolite, dieldrin, has equally slow degradation rate with an estimated half-life of 5 years in temperate regions. In the tropics, both oxidation and dissipation rates of dieldrin are faster, whereby volatilisation alone is reported to contribute to over 90% disappearance of the compound within 1 month.31 Endrin(1,2,3,4,10,10-hexachloro-6,7-epoxy-1,4,4a,5,6,7,8,8aoctahydro-1,4-endo,endo-5,8-dimethano-naphthalene) is a broad-spectrum foliar insecticide that acts against a wide range of agricultural pests, but also used as a rodenticide. It is known to transforms into endrin ketone and endrin aldehyde when released in environment. The concentration of endrin in water ranged from <0.002 to 0.052 µg/L, with occurrence of 66.67%. On the other hand, endrin aldehyde was recorded at 100% occurrence in the water, with concentration ranging from 1.01 to 3.37 µg/l.

The concentrations of endosulphans in this study ranged from <0.001 µg/L to 0.07 µg/L for endosulphan 1 and from <0.002 µg/l to 0.043 µg/L for endosulphan 2. The concentration of endosulphan sulphate was < 0.002 µg/L in all water samples. Endosulphan (6,7,8,9,10,10-hexachloro-1,5,5a,6,9,9a-hexahydro-6,9-methano-2,4,3-benzodio-xathiepin-3-oxide) is an organochlorine insecticide belonging to the cyclodiene group and is one of the pesticides that was widely applied in the control of pests on vegetables, cotton and fruits.32 Technical grade endosulphan is a 2:1 to 7:3 mixture of the α- and the β-isomers. Both α-and β-endosulphan can be oxidized to endosulphan sulphate via biotic metabolism. The metabolite is of comparable toxicity like the parent compounds but two to three times more persistent. Further degradation of the three compounds leads to formation of endosulphan diol which is more hydrophilic but less toxic. Whereas the use of endosulphans in agriculture has been banned under the Stockholm Convention, the residues are still widely detected due to persistence and widespread environmental contamination.

Dichlorodiphenyltrichloroethane (DDT) and metabolites analysed in this study included p,p' DDT, p,p'-DDE and p,p''-DDD. DDT was formerly worldly used in agriculture for the control of insect pests on cotton, potatoes and fruits and in public health to control malaria, typhus, body lice and other disease vector diseases. But its agricultural and other uses were banned in most countries in 1970s and 80s due to its toxicological effects on human health and environment. Currently, its application is limited to indoor spraying for malaria control. In this study p,p'-DDT recorded occurrence of 50% in the water samples with concentration range from <0.002 to 0.640 µg/L. p,p'-DDE and p,p'-DDD were both not detected in water samples.

Methoxychlor (C16H15Cl3O2) is an organochlorine insecticide used for the control of livestock parasites and a variety of pests on ornamentals, fruits and vegetables. Due to persistence in environment, the use of methoxychlor in Kenya was banned in 1984.33 In the current study methoxychlor residues were recorded in 50% of water samples with concentration between <0.002 µg/L to 0.320 µg/L.

Figure 2 shows the comparison of pesticides residue levels in water from different sites. Endrin aldehyde was the highest followed by γ-HCH, aldrin and p,p'-DDT.

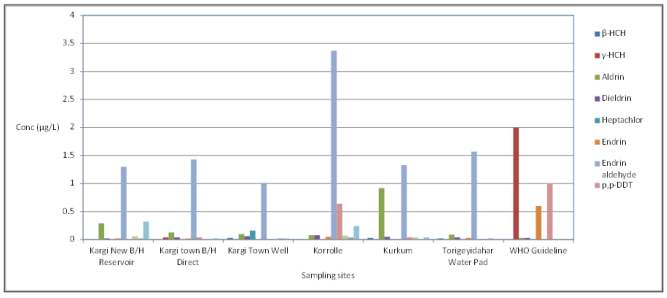

Figure 2. Comparison of pesticide residue levels in water from different sites

B. Organochlorine pesticide residues in soil

OCP residues in soil samples were higher than in water samples in the order of 1 to 10 times (Table 3). That was partly attributed to high hydrophobic nature of these compounds and therefore high tendency to adsorb on soil organic matter. Among the HCHs in soil, α-HCH recorded the highest concentration followed by β-, δ- and γ- HCH. The concentration of α-HCH ranged from <0.001 µg/kg to 10.430 µg/kg measured from soils from Kurkum. Similarly the highest level of γ-HCH was measured in soils from Kurkum site (1.652 µg/kg). The highest concentration of β-HCH was measured in soil samples from Bellatrix well sample D (4.840 µg/kg) and Kurkum (4.60 µg/kg). Occurrence of HCHs varied from one isomer to the other with α- and γ-HCH recording the highest (88%) followed

by δ (77%) and β-HCH at 55%.

Table 3: Organochlorine pesticide residues in soil from Kargi area (µg/Kg)

Soils sites	α-HCH	β-HCH	γ-HCH	δ-HCH	Aldrin	Dieldrin	Heptachlor	Heptachlor epoxide	Endrin	Endrin aldehyde	*p,p*-DDT	*p,p*-DDE	*p,p*-DDD	Endosulphan1	Endosulphan II	Endosulphan sulphate	Methoxychlor
Kargi Well	2.242	2.663	0.913	7.150	0.620	0.581	0.912	0.071	0.813	4.714	3.923	0.430	0.452	0.234	0.301	0.643	3.010
Torigeyidahar Water Pad	1.001	3.061	0.110	1.461	0.682	0.662	2.671	0.110	0.781	6.891	6.471	0.402	0.371	0.161	0.232	0.741	3.721
Kurkum	10.430	4.601	1.652	1.383	1.800	0.604	1.091	0.073	0.860	13.250	9.540	0.354	0.514	0.113	0.261	1.000	3.100
Korrolle	1.944	1.732	0.441	1.280	2.533	0.640	0.773	0.071	0.801	5.672	9.192	0.162	0.262	0.102	0.190	1.600	3.602
Kargi Borehole	<0.001	<0.002	0.112	0.661	3.452	0.750	7.013	0.250	0.472	9.574	7.061	0.471	0.470	0.120	0.273	0.661	4.943
Ballatrix A	9.132	<0.002	<0.002	<0.005	<0.004	<0.003	0.960	<0.001	<0.002	<0.002	<0.002	<0.002	<0.002	<0.001	<0.002	<0.002	<0.002
Ballatrix B	0.713	<0.002	0.113	1.052	0.191	<0.003	0.563	0.032	0.562	1.182	<0.002	0.170	0.241	0.182	0.211	0.742	<0.002
Bellatrix C	0.681	<0.002	0.161	0.790	0.170	<0.003	0.451	<0.001	0.070	<0.001	<0.002	0.153	0.183	0.134	0.100	0.544	0.091
Bellatrix D	8.510	4.840	0.100	<0.005	3.990	0.731	<0.001	<0.001	0.812	17.141	<0.002	<0.002	0.300	0.290	0.214	0.632	6.310

Aldrin concentration in soil ranged from <0.004 µg/kg to 3.990 µg/kg, while dieldrin levels varied from <0.003 to 0.750 µg/kg. The percentage occurrence of aldrin was 77% while dieldrin recorded 66.7% occurrence in soils. Bellatrix D and Kargi Bohore sites recorded the highest levels of aldrin and dieldrin in soil samples.

Heptachlor residues in soil were higher in samples from Kargi town borehole (7.013 µg/kg) followed by Torgeyidarh which recorded 2.671 µg/kg. Bellatrix D did not show contamination by both heptachlor and heptachlor epoxide, while for sites Bellatrix A and C no heptachlor epoxide residues were detected. Endrin residues in soil were lower than endrin aldehyde suggesting contamination due to old sources of the compounds or deposition from the atmosphere. The levels of endrin ranged from <0.002 to 0.860 µg/kg while endrin aldehyde ranged from <0.002 to 13.250 µg/kg. Heptachlor epoxide registered lower occurrence at 66.67% compared to endrin which recorded 88.89% in the soils. Among p,p'-DDT, p,p'-DDE and p,p''-DDD, the p,p'-DDT recorded the highest concentration of 9.540 µg/kg at KurKum site followed by 9.192 µg/kg at Karolle. The highest level of p,p'-DDE in the soil was 0.47 µg/kg recorded at Kargi borehole. On the other hand, p,p'-DDD levels ranged from <0.002 to 0.514 µg/kg.

Endosulphan sulphate recorded the highest levels among the endoslphans with concentration ranging from <0.002 to 1.600 µg/kg, whereas endosulphan 1 was the lowest with levels ranging from <0.001 to 0.290 µg/kg. Endosulphan 2 which is relatively more stable in the environment compared to endosulphan 1 recorded concentrations between <0.002 to 0.301 µg/kg. The highest levels of endosulphans were detected in soils near Kargi well, Torigeyidahar and Balletrix D. The occurrence of the three compounds was greater than 88.89% which was considered relatively high compared to the heptachlors which fall in the same group of drin pesticides. The residues of methoxychlor ranged from <0.002 µg/kg to 6.310 µg/kg measured at Balletrix well

A and Ballextric well C respectively. The occurrence was 77.77% suggesting relatively high prevalence.

C. Discussion

Contamination of pesticides residues has been a acandidate of suspecion among the Kargi local communities for a long period of time but limition of adequate data to delineate the extent and magnitude of contamination has remained the major bottleneck to management activities. Pesticides residues in the samples from the area were generally lower than those detected in samples collected from other parts of the country.5,6,7,8 & 9 However, among all the pesticide residues analysed, there was a clear evidence that the soils contained higher residue levels compared to the water samples.

Although the pesticide residues measured in water were significantly lower than WHO maximum permissible residue levels for drinking water,34 their longterm impact may be of significance due to their high potential of biomagnification through the food chain. Earlier studies conducted elsewhere reported OCP residues at higher trophic level organisms like birds where α-HCH, γ-HCH, β-HCH, aldrin, heptachlor, heptachlorepoxide, endrin, dieldrin, p,p'-DDD, p,p'-DDE and p,p'-DDT were detected in varying concentrations, in three different birds species of Lake Nakuru, Kenya.35 High prevelance of p,p'-DDE (95.5%) and α-HCH (66.4%) was reported in the same study.

Most of the pesticides detected in water samples have also been reported in rivers and lake samples within the country, however, at higher concentrations than the ones reported here. For instance while investigating the pesticide residues in the drainage basin of Nyando River in the sugarcane belt that constitutes part of Lake Victoria catchments, Getenga and coworkers12 reported 10 different organochlorine pesticides in water samples, α-BHC, β-BHC, lindane, endosulfan, heptachlor, aldrin, heptachlor epoxide, dieldrin, endrin and methoxychlor. They reported concentrations of pesticides, with α-BHC concentrations ranging from 113-691 µg/l, β-BHC (7-46 µg/l), lindane (27-1,240 µg/l), heptachlor (6-70 µg/l), aldrin (3-89 µg/l), heptachlor epoxide (2-5 µg /l), endosulphan (BDL-10 µg/l), dieldrin (1-96 µg/l), endrin (BDL-31 µg/l) and methoxychlor (BDL-40 µg/l).
Several pesticides with high potential of bioaccumulation effects were detected in soil samples in this study. However the study results are limited by the fact that it was conducted over a short period of time. Further investigation of pesticide residues is required to track down the trend and sources of these pesticides in the region. Therefore, in addition to addresssing challenges associated with water contamination, there is need to consider chemicals management issues related to transport from contaminated sites and atmospheric depostion due to high volatility of the OCPs. The findings of this study, therefore, show the need to impose stricter regulations on management of contaminated soils and routine monitoring of transport and deposition of pesticides residues in environment.
This study has shown that several peristent organic pollutant pesticides occur in detectable quantities in Kargi area. Potential sources could be attributed to atmospheric deposition and residues from past applications in the country. The pesticide residues detected in water samples from Kargi area had considerably lower concentration compared to levels measured in lakes, rivers and marine water others regions in the country, 7,8,9 however bioaccumulative properties of these compounds allow them to build up in the food chain and causing risk to human. Therefore consideration of biota matrices could provide additional information on the levels of these pesticides in the food chain.

IV. CONCLUSION

The pesticide residue levels in soil and water samples were significantly low compared to background levels detected in other parts of the country. It is unlikely that pesticide residues measured from the outlined sampling sites visited could be the cause of any great concern to the health of the communities. Sampling during wet and dry season could help to establish the environmental changes in concentration of the contaminants. It is noted that the field trip was carried out in the month of October which represent the dry moths. Further studies could benefit if the samples are collected across the four seasons encountered in the country. It is possible that during this the pesticide residues were higher due to depositions from the atmosphere.

V. ACKNOWLEDGEMENT

The authors acknowledge the Government of Kenya for facilitating the field trip to collect the samples from the Greater Marsabit.

VI. REFERENCES

[1]. Anju Agrawal, Ravi S. Pandey, Bechan Sharma, (2010) Water Pollution with Special Reference to Pesticide Contamination in India. J. Water Resource and Protection, 2010, 2, 432-448.

[2]. Marc Lamers, Maria Anyusheva, Nguyen La, Van Vien Nguyen and Thilo Streck, (2011) Pesticide Pollution in Surface- and Groundwater by Paddy Rice Cultivation: A Case Study from Northern Vietnam. Clean – Soil, Air, Water, 39 (4), 356–361.

[3]. Karimi, Fatemeh, Moattar, F.; Farshchi, P., Savari, A. and Parham, H., (2012) ERA: Suitable Method for Estimation of Ecological Effects of Pesticide Contamination on Aquatic Species. Journal of the Persian Gulf (Marine Science). 3 (8) 67-73.

[4]. Shailesh T., Z. P. Patel , D. S. Mutkule and A. M. Kakde, (2013) Pesticide Contamination in Food: A Review. IOSR Journal of Agriculture and Veterinary Science (IOSR-JAVS) e-ISSN: 2319-2380, p-ISSN: 2319-2372.Volume 6, Issue 1 (Nov. - Dec. 2013), PP 07-11.

Getenga Z. M., Kengara F. O. & Wandiga S. O., (2004) Determination of organochlorine pesticides in soil and water from river Nyando Drainage System Within Lake Victoria Basin, Kenya. Bull. Environ. Contam. Toxicol 72 (2): 335-342.

[5]. Gitahi S.M., Harper D.M., Muchiri S.M., Tole M.P. & Ng'ang'a R. N., (2002) Organochlorine and pesticide organocphosphorus concentrations in water, sediment, and selected organisms in Lake Naivasha (Kenya). Hydrobiologia 488 (Developments in Hydrobiology 168).

[6]. Wandiga S.O., (2001) Use and distribution of organochlorine pesticides. The future in Africa. Pure Appl. Chem. 73 (7): 1147–1155.

[7]. Wandiga S.O., Yugi, M.W., Barasa M.W., Jumba I.O. & Lalah J.O., (2002) The distribution of organochlorine pesticides in marine samples along the Indian Ocean Coast of Kenya. Environmental Toxicology, 23. 1235-1246.and Socio-economic Status, Trends and Human Vulnerabilities. UNEP/PASS Report. Pp. 61-76.

[8]. Wandiga, S.O., P. O. Yugi, M. W. Barasa, I. O. Jumba, and J. O. Lalah, (2002) The distribution of organochlorine pesticides in marine samples along the Indian Ocean Coast of Kenya. Environmental Toxicology 23: 1235-1246.

[9]. Wasswa, J., Kiremire, B. T., Nkedi-Kizza, P., Mbabazi, J. And P. Ssebugere, (2011) Organochlorine pesticide residues in sediments from the Uganda side of Lake Victoria. Chemosphere 82: 130–136.

[10]. Mwevura, H., O. C. Othman, and G. L. Mhehe, (2002) Organochlorine pesticide residues in waters from the Coastal area of Dar ES salaam and their effect on aquatic biota. Tanz. J. Sci. 28(2): 117-130.

[11]. Getenga, Z. M., F. O. Kengara, and S. O. Wandiga, (2004) Determination of organochlorine pesticides in soil and water from river Nyando Drainage System Within Lake Victoria Basin, Kenya. Bull. Environ. Contam. Toxicol., 72 (2): 335-342.

[12]. Osoro EM, Wandiga S.O, Abongo DA, Madadi V O and Macharia J W. (2016) Organochlorine Pesticides Residues in Water and Sediment from Rusinga Island, Lake Victoria, Kenya. . IOSR-JAC. 9 (9): 56-63. EISSN: 2278-5736.

[13]. Debora Atieno Abong'o, Shem. O. Wandiga, Isaac O. Jumba, Paul J. Van den Brink P, Betty B. Naziriwo, Vincent O. Madadi and Godfrey A. Wafula, Peter Nkedi- Kizza, , Kylin Henrik, (2015) Occurrence, abundance and Distribution of Benthic Macro-invertebrates in the Nyando River Catchment, Kenya. Africa Journal of Physical Sciences, 40(4) 373-392.

[14]. Abong'o Debora Atieno, Wandiga Shem Oyoo, Jumba Isaac Ogangu, Van den Brink Paul J., Naziriwo Betty Bbosa, Madadi Vincent Odongo and Wafula Godfrey Angoe, Kylin Henrik, Nkedi-Kizza Peter, (2015) Organochlorine pesticide residue levels in soil from the Nyando River Catchment, Kenya. Africa Journal of Physical Sciences, 2(1) 18-32.

[15]. Debora Atieno Abong'o, Shem Oyoo Wandiga, Isaac Ogangu Jumba, Vincent Odongo Madadi and Henrik Kylin, (2014) Impacts of Pesticides on Human Health and Environment in the River Nyando Catchment, Kenya. Best: International Journal of Humanities, Arts, Medicine and Sciences (BEST: IJHAMS) ISSN(E): 2348-0521. 2(3) 1-14.

[16]. Getenga, Z. M., J. I. O. Jondiko, S. O. Wandiga, E. Beck, (2000) Dissipation Behaviour of Malathion and Dimethoate Residues from soil and

Their Uptake by Garden Pea (Pisum sativum). Bull. Environ. Contam. Toxicol., 4: 359-367.

[17]. Getenga, Z. M., and F. O. Kengara, (2004) Mineralization of Glyphosate in Compost-Amended soil under controlled conditions. Bull. Environ. Contam. Toxicol., 72 (2): 266-275.

[18]. Wandiga, S. O., D. M. K. Ongeri, L. Mbuvi, J. O. Lalah, and I. O. Jumba, (2002) Accumulation, Distribution and Metabolism of 14C-1,1,1-Trichloro-2,2-,BIS(p-Chlorophenyl)ethane(p,p-DDT) Residues in a model Tropical marine Ecosystem. Environmental Toxicology 23:1285-1292.

[19]. James K. Mbugua, Antipas Kemboi, Immaculate N. Michira, Vincent O. Madadi, Mark F. Zaranyika and Geoffrey N. Kamau (2014) Adsorption of Atrazine pesticide by sediment and soil samples: Effect of Equilibration Time on the Freundlich Parameter (n). International Journal of BioChemiPhysics, 22: 31-41.

[20]. James K. Mbugua, Immaculate N. Michira, Stanley M. Kagwanja, Vincent O. Madadi, Mark F. Zaranyika and Geoffrey N. Kamau (2012) Adsorption of 2,4,5,6-tetrachloroisophthalonitrile (Chlorothalonil) by Nairobi River Sediments: Adsorption characteristics and related thermodynamic Data. International Journal of BioChemiPhysics, 20: 25-37.

[21]. Getenga, M. Z., Madadi O. V., and S. O. Wandiga, (2004) Studies of degradation of 2,4-D and metribuzin in soil under controlled conditions. Bull. Environ. Contam. Toxicol. 72(3): 504-513.

[22]. Madadi, V. O., (2005) Chemodynamic studies and assessment of pesticide residues in Lake Victoria catchtment area for Rivers Sio and Nzoia. M.Sc. Thesis, Department of Chemistry, University of Nairobi.

[23]. County Government of Marsabit, (2013) County Government of Marsabit County Integrated Development Plan, 2013-2017. County Government of Marsabit, Republic of Kenya.

[24]. Kuria, S.G., R.G. Wahome, C.K. Gachuiri and M.M. Wanyoike (2004) Evaluation of forages as mineral sources for camels in western Marsabit, Kenya. South African Journal of Animal Science, 34 (3) 180-188.

[25]. Shivairo RS, Shivoga WA, Mbaria JM and JK Kumba, (2014) Acute borehole poisoning in livestock in Kargi, Marsabit, Kenya: A Case Report. Advances in Life Science and Technology, 24: 1-3.

[26]. Shivoga, W. and D.L. Coppock, (2003) For pastoralists the risk may be in the drinking water: The case of Kargi, N. Kenya. Research Brief 03-03-PARIMA. Global Livestock Collaborative Research Support Program. University of California at Davis. 4 p.

[27]. Bintein, S. and Devillers, J., (1996) Evaluating the environmental fate of lindane in France. Chemosphere 32(12):2427-40.

[28]. Cornacoff, J.B., Lloyd, D., Lauer, R.V., House, A.N., Tucker, L.M., Turmond, J.G., Vos, P.W. and Dean, J.H., (1988) Evaluation of the immunotoxicity of b-hexachlorocyclohexane (β-HCH). Fundam Appl Toxicol 11:293-99.

[29]. Deichmann W.B., (1981) Halogenated cyclic hydrocarbons. In: Patty's Industrial Hygiene and Toxicology, 3rd rev. ed., Vol. 2B, G.D. Clayton and F.E. Clayton, Eds. John Wiley and Sons., Inc., NY. p. 3603-3769.

[30]. WHO, (1989) Aldrin and dieldrin. World Health Organization, International Programme on Chemical Safety (Environmental Health Criteria 91). Geneva, Switzerland.

[31]. Jalili S. H., Ilkhanipour M., Heydari R., Farshid A.A. & Salehi S., (2007) The Effects of Vitamin E on Endosulfan - Induced Oxidative Stress in Rat Heart. Pakistan Journal of Nutrition 6 (4): 375-380.

[32]. PCPB, (2017) Banned pesticides in Kenya. Available from URL:http://www.pcpb.or.ke/bannedproducts/BANNED%20PESTICIDES%20IN%20KENYA.pdf. Accessed 10 July 2017.

[33]. IUPAC, (2003) Regulatory Limits for Pesticide Residues in water. Pure Appl. Chem. 75(8): 1123-1156.

[34]. Ormerold S.J. & Tyler S.J., (1993) Birds as indicators of change in water quality. In greenwood, J.J. and R.W. Furness (eds.) Birds as Monitors of Environment Change. Chapman and Hall, London: 179-216.