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Occurrence of Three Pesticides in Community Water Supplies, Kenya

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In Kenya, the Pest Products Control Board (PPCB) is responsible for importation and use of pesticides in the country. Between 1985-1987, pesticides worth US $69 million (Ksh 1732.3 million) were imported into the country (Mwanthi and Kimani 1993), while between 1987-1990, a total of 31,234 tons of pesticides (PPCB 1994) were imported. Pesticides are used to control pests for crops like coffee, corn, cotton, and in public health they are used to control disease vectors such as, malaria and yellow fever carrying mosquitoes (Mwanthi and Kimani 1993).

In Canada, Frank et al. (199 1) showed that after use of pesticides in agriculture, most of the farm wells and surface waters were contaminated with organo-chlorine pesticides (OCP). Pesticide contaminants in drinking water sources were in the range of 0.05 to 0.5 ppb. Similarly, Jani et al. (1991) in Ahmedabad City, India found presence of OCP in most of the drinking water samples analyzed. Dikshith et al., in a 1990 study of pesticides in major drinking water sources in Bhopal, India, found hexachlorocyclohexane (HCH) and DDT residues in all water samples. The mean DDT residual concentration was 5794 ppb. The sum of mean concentration of p, p'-DDE and p, p'-DDD were higher than that of p, p'-DT.

In Kenya, previous studies have focused on analysis of pesticides in fish, vegetables, and human breast milk (Kanja et al. 1986; Mugachia et al. 1992). A recent study conducted by Kimani and Mwanthi (1995) in Githunguri location, Kiambu district showed that organochlorines, organophosphates and carbamates were being used all the year round. It was observed that some of the community members rinsed empty pesticide containers at the water sites. Use of pesticides and indiscriminate management of pesticide containers have potential to contaminate surface and groundwater sources in this areas.

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This study was undertaken to investigate the types of pesticides which were being used and the extent to which DDT, carbofuran and carbaryl pesticides contaminated drinking water sources in Kiaria sublocation, Githunguri location.

MATERIALS AND METHODS

The study was conducted in Kiaria sublocation, January 1994-May 1995. The sublocation is located about fifty kilometers northwest of Nairobi. It is an agricultural area, approximately 6000 ft (2000 m) above sea level. Where as coffee and tea are the principal cash crops, other crops such as, corn, potatoes, and vegetables are also grown (Mwanthi and Kimani 1993).

Seventy-two households were interviewed to ascertain the types of pesticides which then were being used by the community. Additionally, seventy-two water sites were randomly selected and numbered as sample sites. Thirty-seven of the sites were wells, while 35 were surface water sites. Seventy-two water samples were collected in a two-liter clean amber glass bottle from each site during the wet and dry seasons. Thus, a total of 144 water samples for both seasons. At least 15 ml of pesticide grade chloroform ($CHCl_3$) were added to each sample for preservation purposes. The samples were appropriately labeled, placed in two large cool boxes packed with freezer packs and immediately transported to the Kenya Bureau of Standard (KBS) laboratory and were stored in dark at 4°C until they underwent extraction.

Extraction and analysis of DDT used the American Society of Testing Material-D30867-72T, 1979 Method. One liter of water was extracted with 60 ml of ethyl-ether in hexane (15+85) mixture. The extracts were then cleaned up by florisil adsorption chromatographic technique. Fifteen gram charge of activated Florisil previously stored in an airtight container at 130°C was placed in a chromatography-Borosilicate glass column over a small layer (12.7 mm (½") of anhydrous granual Na_2SO_4. After tapping the Florisil into the column, 19 mm (¾") layer of granular sodium sulfate was added to the top. The column was then cooled and preluded with approximately 75 ml of hexane. The final extracts were each concentrated to 2 ml. All sample extracts were analyzed twice and the mean values determined.

A Varian Gas Chromatograph 3400 series fitted with a ^{63}Ni electron capture detector (ECD) was used. The GC parameters and operating conditions were as follows: column, DB-5 megabore, silica packed capillary column, length 60 m, 0.541 mm in diameter, and 1.5 µm column film thickness; temperature: column (programmed) 280°C detector 300°C injector 200°C; nitrogen-carrier gas: nitrogen flow rate of 70 ml/mm, attenuation 256; and a record chart speed of 0.3cm/min. The injection type was on the column and the injection volume was 0.5 µl. The equipment detection limit for this method was 0.002 ppb. Confirmation of species identity was performed using an alternative stationary phase column (column II) bonded with trifluoropropyl. The operating conditions were as follows: capillary column: DB 210 megabore, column length 30m, diameter.

Extraction and analysis of carbofuran and carbaryl applied the EPA 632 Method (Pressley and Longbottom, 1982). One liter of water sample was extracted three times with 60 ml of dichloromethane and the extract was made up to 10 ml in methanol. Knauer HPLC equipment Model 5500 equipped with ultraviolet wavelength monitor; octadecyl; Pickering (C_{18}) column phase bonded to 5µ spherical silica; 15 cm column length; 4.6mm column diameter; and 5µm column film thickness was used. The operating conditions for analyzing the carbofuran and carbaryl were: mobile phase (50% methanol+50% water); flow rate 0.3 ml/ml; detector wavelength 254nm; detector sensitivity 0.04 AUFS; chart speed 0.25 cm/min; attenuation 32. The injection volume was 20µ1 and the column was maintained at an ambient temperature. The exact concentration for each pesticide was calculated as described in the ASTM-D30867-72T, 1979 method, section 14.1.1.

RESULTS AND DISCUSSIONS

This study interviewed 72 households in Kiaria sublocation and all conceded to have been using or had used 8 different types of pesticides during January 1994-May 1995. Table 1 gives the distribution of the 8 types of pesticides which were then being used by the community and their known chronic health effects. Ambush® (cypermethrine), malathion, dithane, carbofuran and antracol were used by over 57% of the community members. The least used pesticides were, sevin (carbaryl), red copper, lybacid® and DDT. Overall, most of the pesticides were used as insecticides while very few were used as acaricides. The majority of these pesticides have potential to cause chronic health effects, which include, immune suppression, or immunotoxicity, carcinogenicity and mutagenicity (Briggs 1992).

Out of the 72 water sites sampled in both dry and wet seasons, 18(25%) of the sites had detectable levels of DDT, its isomers and its metabolites or the carbofuran and carbaryl. Although it is illegal to use DDT unless authorized by the Kenya government, it is likely that a proportion of community members were illegally using DDT or else the DDT levels found in the drinking water sites were a carryover from the past legal spraying activities, or due to its persistent nature in the environment.

During the wet season, runoffs from agricultural land are potential sources of pollution for both surface and ground water sources. Table 2 indicates the status of pesticides levels in 72 sampled sites in wet and dry seasons. Sites with no detectable pesticides were each assigned a concentration level equal to % minimum detectable limit (Keith 1991). There were 14 sites with detectable DDT in the wet season and lof the same sites was positive in the dry season. The mean concentration of each DDT-isomers and two of its metabolites in surface and ground water sources ranged from 0.00335 ppb to 0.00449 ppb, with a total DDT mean concentration of 0.00310 ppb during the dry season. On the other hand, during the wet season, the mean concentration for the same pesticide ranged from 0.0010 ppb to 0.02582 ppb with a total DDT mean concentration of 0.0103 ppb. Evidently, the mean concentration in the wet season was significantly higher ($p = 0.007$) than in the dry season. The difference could be due to storm runoffs, release of DDT residues bound to soil particles and infiltration of pesticide residues into ground water sources (Menzer 1991). The DDT concentrations in both surface and ground water sites of this study are consistent with DDT levels found in drinking water sources in United States of America and elsewhere. Concentrations ranging from 0.005 ppb to 0.316 ppb have been detected in USA storm waters (Kolpin et al. 1996), while elsewhere, levels ranging from 0.006 ppb to 0.008 ppb have been detected in storm waters (Makepeace et al. 1995; Dikishith et al. 1990).

Only one site per season was found to have carbofuran pesticide above the minimum detection limit. Concentration levels for each site in dry and wet seasons were 102.12 ppb and 36.35ppb respectively. Sites with no detectable pesticide were assigned a concentration level equal to ½ minimum detection limit. The mean concentration of carbofuran among the 72 sites, both in surface and ground water was 2.500 ppb, while during the wet season, the mean concentration was 1.59 ppb. The mean concentrations are slightly below the detection limit because only one site per season was positive and all other sites with no detectable pesticides were assigned the relevant concentration factor equal to % the detection limit. Difference in the mean concentrations for carbofuran between the seasons was not statistically significant, $p = 0.54$. These findings tend to agree with a similar study conducted in the Philippines (IRRI 1992) where the carbofuran levels in ground and surface water ranged from 0.15 to 1.15 ppb. Kimbrough and Litke (1996) found concentrations ranging from 0.03 ppb to 1.2 ppb in surface and ground water, in the U.S.A. Concentration levels of up to 300 ppb have been detected in Canadian surface waters (Trotter et al. 1989) and levels as high as 50000 ppb in in various parts of USA water sources (Nigg et al. 1990).

A different site for each season had carbaryl pesticide. In wet season one site had 9.99 ppb, while in dry season another site had 6.71 ppb. Considering sites with no detectable pesticides were each assigned a concentration equal half the minimum detection limit, it apparent that carbaryl mean concentration level was higher in wet season(0.326 ppb versus 0.281 ppb) than in dry season (Table 2). The seasonal mean concentration difference was not statistically significant, $p = 0.78$. However, the higher mean concentration in wet than dry season suggests the seepage effect, the haphazard disposal of the pesticide empty containers which could account for increased pollution in wet season. Other factors could be accidental spills and contaminated water from cattle dips which could be washed to water sources during the wet season.

Generally, the geographical location of some of the sites could have contributed to pollution by the three pesticides from point and non-point sources. For instance, $^{13}/_{18}$ (70%) of all the positive sites were on flat landscape (investigator's observation). Consequently, 10 (out of 13) sites were subject to pollution because they were unprotected from storm runoffs and other possible causes of pollution such as, animals, humans and wind.

Table 1. Distribution of pesticides used by the community, January 1994-May 1995 (N=72)
Source: Briggs 1992

Pesticide Name	Principle Use	Number Who Used	Known Chronic Health Effects
Malathion	I	66 (91.7%)	suspect mutagen and teratogen; immune suppressor; gastrointestinal inflammation; allergic reaction; delayed neurotoxin
Dithane (mancozeb)	F	64 (88.9%)	No known effect
Antracol (propineb)	F, I, H	57 (79.2%)	carcinogen; goitrogen; pituitary enlargement
Ambush (cypermethrine)	I	68 (94.4%)	mutagen; immunotoxin
Sevin (carbaryl)	I	33 (45.8%)	suspect carcinogen and mutagen; decreased fertility
Copper-oxychloride	F	11 (15.3%)	irreversible eye damage
Lybacid (fenthion)	I, A, AV	1 (1.4%)	suspect carcinogen and embryo toxin; neuromuscular dysfunction; delayed neurotoxin
Furadan (carbofuran)	I, A, N	58 (80.6%)	suspect mutagen; immunotoxin
DDT[+] (anofex)	I	NA	cumulative carcinogen; mutagen; fetotoxin; immunotoxin; liver damage; decreased fertility hormone; embryo toxin

[+]= used in the past but not at study time, NA= Not applicable
I= insecticide, F= fungicide H = herbicide, A= acaricide, AV= avicide
N= nematocide

Table 2. Status of pesticide levels in 72 sampled sites in wet and dry seasons January 1994-May 1995

Pesticide Type	Number of Sites with Pesticides	Mean Concentration (ppb)	Range (ppb)	SD
DRY SEASON				
p, p′ DDT	1 (1.4%)	0.00432	0.001-0.02400	0.02817
o, p′ DDT	1 (1.4%)	0.00356	0.001-0.1850	0.02168
p, p′ DDE	1 (1.4%)	0.00335	0.001-0.1700	0.01992
p, p′ DDD	1 (1.4%)	0.00449	0.001-0.2520	0.02958
Total DDT	1 (1.4%)	0.00310	0.0010-0.2520	0.02048
Carbofuran	1 (1.4%)	2.500	1.100-102.12	11.9100
Carbaryl	1 (1.4%)	0.2806*	0.1900-6.7100	0.7684
WET SEASON				
p, p′ DDT	14 (19.4%)	0.02582	0.00100-0.5000	0.07630
o, p′ DDT	10 (13.4%)	0.01260	0.00100-0.17200	0.03406
p, p′ DDE	9 (12.4%)	0.00706	0.00100-0.09300	0.01933
p, p′ DDD	0 (0%)	0.00100*	<0.001-0.00100	0.000
Total DDT	14 (19.4%)	0.01034	0.00100-0.500	0.04117
Carbofuran	1 (1.4%)	1.590*	1.1000-36.3500	4.154
Carbaryl	1 (1.4%)	0.326*	0.1900-9.9860	1.154

Detection Limits: DDT its isomers and metabolites = 0.002 ppb, carbofuran = 2.2 ppb, carbaryl = 0.37 ppb.

Total number of sites with detectable total DDT = 14.

Total number of sites with detectable carbofuran and carbaryl = 4.

* Levels below detection limit (DL) due to the sites which had non-detectable pesticides.

Note: Sites with non-detectable pesticides were each assigned ½ the DL concentration.

The Kenya government has not yet established maximum contaminant limits (MCLs) for pesticides in drinking water. Because of lack of such MCLs, the mean concentration level for each pesticide assayed was compared with the World Health Organization (WHO) and the United States Environmental Protection Agency (USEPA) established MCLs. The mean concentration for any of the three pesticides did not exceeded either the WHO nor the USEPA MCLs. However, when each individual site concentration levels were considered, carbofuran exceeded the WHO MCL of 5 ppb by 20 times. Carbofuran also exceeded USEPA MCLs of 40 ppb by 2½ times in dry season and WHO MCL by 7% times in wet season. Pesticide concentration levels exceeding the MCLs are of public health concern because individuals who drink water from these sites risk developing chronic health conditions cited in Table 1.

In order to alleviate the pollution, protection and monitoring of the water sources is very important. In addition, adoption of an Integrated Pest Management (IPM) approach would be the best long term solution to minimizing the water pollution.

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