Insecticides, Polychlorinated Biphenyls and Metals in African Lake Ecosystems. III. Lake Nakuru, Kenya

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INTRODUCTION

Lake Nakuru is known as "The Lake of a Million Flamingos" and is famous for the large variety of birds and animals which inhabit the area. Because Lake Nakuru is a "closed system" with no outlet, it is especially vulnerable to pollution by toxic chemicals. In 1970 KOEMAN *et al.* (1972) examined the lesser flamingo (*Phoeniconaias minor*), white pelican (*Pelecanus onocrotalus*) and a cichlid fish (*Tilapia grahami*) for concentrations of insecticides and metals.

The present paper presents the results of the last of four studies on concentrations of insecticides, polychlorinated biphenyls (PCB's) and metals in African lake ecosystems. The results of the studies on the first two lakes, Hartbeespoort and Voëlvlei Dams, Republic of South Africa can be found in GREICHUS *et al.* (1977a) and the third lake, Lake McIlwaine, Rhodesia in GREICHUS *et al.* (1977b).

STUDY AREA

Lake Nakuru is typical of many of the Rift Valley Lakes in that it is a shallow, alkaline, eutrophic lake surrounded by agricultural land (Fig. 1). The lake lies entirely within the boundaries of Nakuru National Park. However the catchment area includes rich agricultural land which is subjected to insecticides and herbicides. It is situated just south of the city of Nakuru (population 50,000) which discharges its sewage effluent into the lake after treatment through a one stage digester. It covers an area of about 60 km^2 with an average depth of less than 1 m. The catchment area of 1938 km^2 includes several rivers which empty into the lake (Fig. 1). A number of fish-eating birds such as the white pelican and the white-breasted cormorant (*Phalacrocorax carbo lucidus*) were attracted to the lake after the introduction of a

Bulletin of Environmental Contamination & Toxicology,
007-4861/78/0019-0454 $1.60

small cichlid fish in 1961. The fish have flourished apparently unbothered by the lake's high alkalinity ($\triangleright$ pH 10). The lake is rich in blue-green algae (*Spirulina platensis*) which serves as the major food for the lesser flamingo.

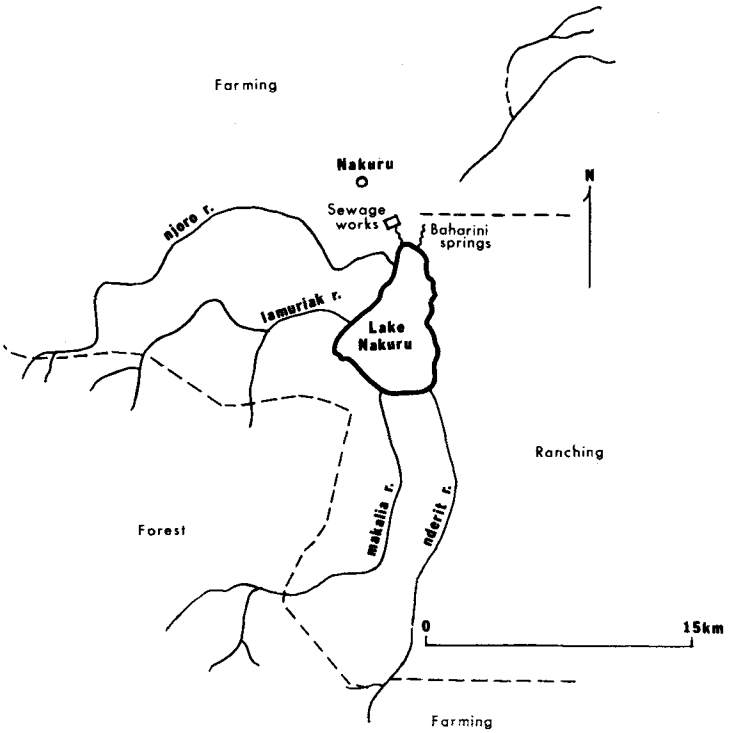

Figure 1. Lake Nakuru and catchment area.

METHODS AND MATERIALS

Samples were collected during April, 1975 and included water, bottom sediments, algae, aquatic insects (water boatmen, *Corixidae*), chironomids, and fish (*Tilapia grahami*). Unlike the studies on the other African lakes, no fish-eating birds were included as permission was not granted by the Kenyan government until it was too late for collection.

Collection and preservation of samples and methods of analysis for insecticides, PCB's and metals are described in GREICHUS *et al.*, 1977a. All samples were preserved in 10% formalin except water for metal analysis which was adjusted to a pH of < 2.0 with HNO_3. All samples were flown to the Pesticide Laboratory at South Dakota State University for analysis. Samples were analyzed for PCB's and the following organochlorine insecticide residues: lindane, heptachlor, aldrin, endrin, heptachlor epoxide, dieldrin, chlordane, endosulfan, methoxychlor, bayluseide, toxaphene, DDE, DDD and DDT. Metals included mercury, zinc, lead, arsenic, cadmium, copper and manganese. Average percent recoveries and standard deviations for samples fortified with insecticides, PCB's or metals are given in GREICHUS *et al.*, 1977a. Values for insecticides and PCB's were corrected for percent recovery, but metal values were not. In calculations of averages and totals, less than ($<$) values were included and given one-half the stated value, that is, a value of < 0.1 would become 0.05.

RESULTS AND DISCUSSION

Insecticides and PCB's

No samples from the Lake Nakuru ecosystem had levels of lindane, heptachlor, heptachlor epoxide, aldrin, endrin, chlordane, endosulfan, methoxychlor, bayluseide or toxaphene above the minimum analytical levels for this laboratory. The most prevalent residue was DDE followed by DDD, dieldrin and DDT (Table I). No water or bottom sediment samples had any discernible insecticide residues except a sediment sample collected at the inlet of a sewer from the city of Nakuru. This sample had 0.01 ppm of DDE and 0.02 ppm DDD. Plankton, chironomids, water

TABLE 1

Average Concentrations of Insecticides and Polychlorinated Biphenyls in the Lake Nakuru Ecosystem

		ppm (ug/g)[a]					
Description	No.	DDE	Dieldrin	DDD	DDT	Total Insecticide	Total PCB
Waters	10	<.0001	<.0001	<.0001	<.0001	<.0002	<.001
Bottom Sediments	10	<.001	<.001	<.001	<.001	<.002	<.02
Plankton	1[b]	0.05	0.03	0.02	0.02	0.12	<.5
Chironomids	1[b]	0.02	<.01	0.02	0.01	0.06	0.59
Water Boatmen	1[b]	0.02	<.01	0.02	0.01	0.05	0.52
Fish	10[c]	0.02	0.02	0.01	<.01	0.05	<.5

a - All samples analyzed on a dry weight basis except water.
b - Each sample consists of a composite collected from all over the lake.
c - Each sample consists of a composite of 10 fish ranging from 5.4 to 9.6 g. Ten composite samples were analyzed.

boatmen and fish had residues of DDE and DDD. No dieldrin was detected in chironomids and water boatmen and no DDT was found in the fish. KOEMAN *et al.*, 1972 reported only residues of DDE and dieldrin in the same species of fish collected from Lake Nakuru. Although the values in this study are reported on a dry weight basis, it is possible to estimate the wet weight value of DDE and dieldrin to be about 0.003 and 0.005 ppm, respectively. The highest values reported by KOEMAN *et al.*, 1972 were 0.002 and 0.0024 ppm, respectively for DDE and dieldrin. Fish from Lake Nakuru had lower levels of average total insecticide residues than did sun-dried fish from the northern end of Lake Tanganyika which ranged from 0.69 to 2.04 ppm of DDE + TDE + DDT (DEELSTRA *et al*, 1976).

Only chironomids and water boatmen had levels of PCB's higher than the minimum analytical levels (Table 1). The pattern of PCB's more closely resembled those of Aroclor 1254 than those of Aroclor 1260 (Monsanto Chemical Co., St. Louis, MO). In general Lake Nakuru had lesser amounts of insecticides and PCB's in all types of samples analyzed, except water, than did Hartbeespoort and Voëlvlei Dams in the Republic of South Africa (GREICHUS *et al*, 1977a) or Lake McIlwaine in Rhodesia (GREICHUS *et al*, 1977b).

Metals

Average concentrations of metals in Lake Nakuru are given in Table II. In general levels of arsenic, manganese, lead, zinc and mercury did not appear unusual when compared to these metals in Hartbeespoort or Voëlvlei Dams in the Repbulic of South Africa (GREICHUS *et al*, 1977a) or to Lake McIlwaine, Rhodesia (GREICHUS *et al*, 1977b). Levels of cadmium in water, chironomids, aquatic insects, and fish were higher in Lake Nakuru than in the other three African lakes. It was noted that bottom sediments from the Nakuru sewage inlet were higher in cadmium (0.46 ppm) than the other two areas, Nsoro River inlet (0.16 ppm) and Nderit River inlet (0.17 ppm). KOEMAN *et al.*, 1972 reported fish in Lake Nakuru as having 0.086 ppm arsenic, 1.6 ppm copper, 19 ppm zinc, no detectable cadmium and 0.016 ppm mercury. Converting the values in this study to an approximate

TABLE II

Average Concentrations of Metals in Lake Nakuru Ecosystem

ppm (ug/g)[a]

Metal	Water	Bottom Sediment	Chironomids	Insects	Fish[b]
No. Analyzed	3	3	Composite	Composite	3
Arsenic	0.006	35.	7.5	0.14	1.80
Cadmium	0.021	0.27	0.19	0.45	0.26
Copper	0.002	6.2	4.6	11.	10.
Manganese	0.024	550.	78.	12.	19.
Lead	0.005	34.	1.3	0.82	0.84
Zinc	0.049	140.	61.	70.	110.
Mercury	$<$.001	$<$.05	0.26	0.16	0.22

a - All samples analyzed on a dry weight basis except water.
b - Each sample consists of a composite of 10 fish ranging from 6.4 to 8.6 g. Three composite samples were analyzed.

wet weight value gives 0.33 ppm arsenic, 1.8 ppm copper, 20 ppm zinc, 0.05 ppm cadmium, and 0.04 ppm mercury. Although the fish in this study had higher copper concentrations than fish in the three African lakes in the previous studies, the levels in this study agree closely with those reported by KOEMAN *et al.*, 1972. Metals in Nakuru fish fell within ranges given for cadmium, lead and zinc for fish collected from the San Antonio Bay (SIMS and PRESLEY, 1976) but were higher in copper, mercury and arsenic. However some fish from the U.S. Southeast Coast (WINDOM, 1972) had as high or higher average levels of cadmium, copper, lead, zinc and arsenic than the average values for Nakuru fish.

In general concentrations of insecticide residues and PCB's in the Lake Nakuru ecosystem do not appear at present to be a pollution problem. This is probably also true for the metals but it is difficult to distinguish between naturally occurring concentrations and those introduced by man.

ACKNOWLEDGEMENTS

The authors wish to thank the personnel of the Baharini Wildlife Sanctuary who assisted us with this study. The hospitality of John and Sandy Hopcraft was greatly appreciated by the Greichus family during their stay in Kenya.

This paper was approved for publication by the Director of the South Dakota Agricultural Experiment Station as paper No. 1524 of the journal series.

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