Assessment of Pollution and Prediction of Environmental Risks of Organochlorine Pesticide Residues on Aquatic Communities in Lake Naivasha, Kenya

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ABSTRACT

Anthropogenic activities in the Lake Naivasha catchments pose serious environmental threats to sustainable freshwater ecosystem management. The future of the lake hangs on the balance of economic exploitation and sustainable watershed conservation. The current growth experienced in the chemical intensive flower industry, human settlements and power generation have led to chemical pollution, wetland reclamation and increased water abstraction volumes, which threaten the existence of the water body. Chemical drift during spray and washing of agrochemicals during the rainy season add the chemicals to water bodies. This study reports the findings of an environmental pollution assessment and environmental risks assessment posed by organochlorine pesticide residues and their metabolites in the Lake Naivasha basin during the period between 2008 and 2009. The objective of the study was to assess environmental pollution in reference to heavy metals, organochlorine pesticides in Lake Naivasha basin and to predict environmental risks of organochlorine pesticides on aquatic communities. Primary data was acquired through interviews, observations and sample whereas secondary data was obtained from published information. The data was analyzed statistically at $p = 0.05$ confidence level using significant T-Test, ANOVA and Dixon's test. The concentrations of lead (Pb), cadmium (Cd), nickel (Ni), zinc (Zn), copper (Cu), *p, p'*- DDT, *p, p'*- DDE, *p, p'*- DDD, heptachlor, heptachlor epoxide, lindane, aldrin, dieldrin, endosulfan and methoxychlor in water column and three fish species; Tilapia, *(Oreochromis leucosticus),* Common carp, *(Cyprinus carpio)* and Mirror carp, *(Cuprinus spectacularlus)* from Lake Naivasha, Kenya were determined. The contaminants were chosen due to their toxicity to aquatic life and persistence. Lake bed sediments were also analyzed for the concentrations of Pb, Cd, Zn, Ni and Cu. Fishnet caught fish samples were bought from fishermen while still alive and identified by the Kenya Marine and Fisheries

Research Institute (KEMFRI) staff whereas sediment and water samples were collected from 10 sampling sites in the basin. Water, fish and sediment samples for heavy metal analysis were wet oxidized and the concentrations determined using Flame Atomic Absorption Spectrophotometry (AAS). Edible portions of fish were homogenized and extracted with High Pressure Liquid Chromatography (HPLC) grade dichloromethane and cleanup with Florisil, the concentrations were determined using Varian CP 3800 Gas Chromatograph equipped with Electron Capture Detector. The mean heavy metal concentrations in sediments (in µg/g) ranged within 38.81 - 118.42 (Ni), 34.58 - 70.22 (Zn), 18.18 - 60.25 (Pb), 1.13 - 2.66 (Cu) and 0.74 - 3.66 (Cd) respectively these were higher than those found in fish. The mean heavy metal concentrations in fish (µg/g) ranged between 13.39 – 14.63 (Ni), 7.31 – 9.32 (Zn), 1.49 – 1.56 (Pb), 0.27 – 0.36 (Cu) and 0.13 – 0.44 (Cd) respectively. The order of bio-concentration of the metals in fish are *C. spectacularlus>C. carpio>O. leucosticus* respectively. The heavy metal concentrations in the water column (total content, mg/L) ranged between 0.81 - 1.92 (Zn), 0.08 - 0.45 (Ni), 0.01 - 0.36 (Pb), 0.004 - 0.04 (Cd), and 0.001 - 0.01 (Cu) respectively. The study shows that the Lake bed is contaminated with Cd, moderately contaminated with Ni and Pb, but not contaminated with Zn and Cu. Pearson's correlation coefficient at $p = 0.05$ revealed negative correlation between heavy metals and Secchi depth indicating that the metals are adsorbed on suspended particulate matter. Naivasha Town, River Malewa and Flower farms were found to be important sources of heavy metal contamination in the Lake. Organochlorine pesticides were detected in fish (wet weight, µg/Kg); methoxychlor was most predominant ranging within Below Detection Limit (BDL) - 28.87, BDL - 7.26 for *p, p'*- DDT, 0.14 - 6.69 for *p, p'*- DDE, BDL - 21.13 for *p, p'*- DDD, 0.41 - 4.19 heptachlor and BDL - 0.22 for heptachlor epoxide. Low concentrations (ng/L) were detected in the water column; heptachlor ranged within 455.5 - 6762.23, 33.95 - 100.11 for

heptachlor epoxide, 42.55 - 305.97 for aldrin, 48.93 - 11.58 for dieldrin, 6.13 - 405.57 for *p, p'*- DDT, 37.82 - 498.03 for *p, p'*- DDE, 26.72 - 42.9 for *p, p'*- DDD, 10.12 - 69.89 for lindane, 16.15 - 1932.1 for methoxychlor, 16.02 - 1025.25 for endosulfan sulfate, 34.84 - 271.7 for endosulfan II and 20.1 - 77.28 for endosulfan I. The measured exposure concentrations of endosulfan and methoxychlor in the water column were analyzed with a modified version of the PERPEST model version 2.0 to predict the environmental risks of methoxychlor on aquatic communities in the Lake. The modified PERPEST model predictions were consistent with experimental data for concentrations of 0.3 – 50 µg/L and 2.0 – 75 µg/L for methoxychlor and endosulfan respectively. The modified model could not be applied on the measured exposure concentrations of endosulfan which fell below the optimal range. The prediction shows that the most affected aquatic communities are insects, microcrustacea and rotifers. The research findings indicate that; (i). The lake bed is contaminated with cadmium, nickel and lead (ii). The heavy metal and pesticide concentrations in the water column and fish are within those recommended by WHO/FAO for freshwaters, (iii). Consumption of fish from the lake does not pose any risk to the consumers with respect to methoxychlor, *p, p'*- DDT, *p, p'*- DDE, *p, p'*- DDD, heptachlor and heptachlor epoxide, Cd, Pb, Cu Zn and Ni (iv). Flower farms, River Malewa and the Naivasha Municipal Council are important sources of contaminants, (v). Though organochlorine insecticides are only targeted to insects, they were found to have adverse effects on other aquatic communities, (vi). Formulated endosulfan was the most used organochlorine pesticide in the catchment, (vii). Endosulfan was found to pose environmental risks on insects, rotifers, macrocrustacea and microcrustacea. (vii). Water abstraction was unregulated and unsustainable (vii). Geochemical processes are important sources of heavy metals in the lake (viii). The current ecological changes experienced in the lake today are due to human activities in the lake. The

study recommends that the economic activities in the catchment area be controlled and regular surveillance/monitoring of the pesticides and other contaminants can be carried out.