THE NEED FOR AQUATIC POLLUTIONS STUDIES IN KENYAN INLAND WATERS

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ABSTRACT

The need for baseline data on pollution studies to the aquatic biota of Kenyan Inland waters is of profound importance. Aware of the possible contamination of our rivers and Lakes with heavy metals, pesticides and other pollutants used around them for the control of tropical diseases and treatment of agricultural crops, a monitoring programme is necessary. For instance, aquatic plants (e.g., algae) which form part of the food of certain fish, e.g., tilapia are known to accumulate heavy metals.

Lake Victoria and other lakes in Kenya make an interesting area for studies of the accumulation of pollutants, since they form almost closed systems and, especially since these lakes are surrounded by different crops, e.g., cotton, cane sugar and coffee, and also numerous other industrial activities.

In Lake Victoria, several important fish species have declined recently, particularly tilapia, *Protopterus aethicopicus, Clarias, mossambicus,* and *Bagrus docmac* (Powell 1977). Further decline of fish species such as *Sarotherodon esculentus, Barbus, labeo, Alestes* and *Mormyrus* have been reported (Maten 1979). A total fresh weight of 26, 914 metric tonnes of fish valued at KShs. 56.7 million to the fishermen was landed around the beaches of Lake Victoria (Kenya) during 1980. This represents a decline of approximately 12% compared to that of 1979. What are the possible causes of our seemingly declining fisheries?

In essence, the limnology and environmental research programme (Onyari 1981) is proposed to try and get information on the threat of aquatic pollution to our Lakes, which provide a valuable food source and income for our people. In this discussion paper the sources and effects of several pollutants to the aquatic environment are highlighted. Further, a monitoring programme and its objectives are proposed.

Any proper and sensible exploitation of our fishery resources can only be done through scientific planning; but planning demands as a prerequisite the availability of sound scientific data. Hence this programme aims at providing the basic data upon which present and future plans can draw strategies for pollution control, resources exploitation and management.

**This paper is adapted from the Proceedings of the Workshop of KMFRI on Aquatic Resources of Kenya, July 13 - 19, 1981.*

INTRODUCTION

Kenya's total land area is 569,252 Km^2 of which 13,391 Km^2 is covered with water of which 3,831 Km^2 is occupied by the largest lake in Africa, Lake Victoria, situated in the Western part of the country. On the Southeast part of Kenya, you find the Indian Ocean with 300 neutical miles of coast line (Adero et al. 1981).

Human activity has profoundly affected streams and lakes in all parts of th world. The pollution of water resources by man's domestic waste, his industry, his agriculture and other activities is a phenomenon experienced in all parts of the world. This pollution is an inevitable accompaniment of population expansion, burgeoning industry, increasing urbanization and a surge toward a higher standard of living (Pearson 1965). The biological effects of water pollution may not only be disastrous to the surrounding water flora and fauna, but also produce more subtle changes which may upset the balance of nature in many rivers, resulting in equally disastrous effects on the piscine populations (Mawdesley-Thomas 1968).

The mechanisms of river pollution are complex, and whereas most effluents can be treated, they are seldom so innocuous as not to lead to some alterations in the receiving waters (Hynes 1963). The need for baseline data on pollution studies to the aquatic biota of Kenya lakes and rivers is therefore of utmost importance. Baseline data is prerequisite to pollution evaluation. Since even "natural" streams may show the characteristic signs of pollution, that is, "natural" pollution may also faithfully reproduce the effect of the addition of industrial pollutants to water (Hynes 1963).

Elsewhere, excessive pollution of rivers, lakes, and tidal estauaries by sewage and industrial wastes has resulted in diterioration of commercial fishing, fish kills, and injury to water fowl. The damage to water fowl results from the distruction by pollution of the feeding and breeding grounds. This may be brought about by soils, greases, foams, insecticides, and excessive depletion of dissolved oxygen by decompositing organic wastes (Camp and Meserve 1974).

Statistics on fish catches, both commercial and sport, have often been used to show that pollution is the cause of declining catches. Fisheries statistics, indeed are valuable tools in assessing the effects of pollution, but they must be complete and must be considered along with other factors in order to avoid unreliable conclusions (Tellefson 1961). In some parts of the world, the tonnage of commercially important fish has been reduced drastically over the past 50 years. This has been attributed to the more desirable fish species being unable to spawn in the grossity polluted tributaries (Beetin 1965). In Lake Victoria, several important fish species have, similarly been showing a declining trend.

Scientific literature is replete with reports of studies of the aquatic environment and its inhabitants. Fish are usually employed as sensitive indicators of toxic pollution. The dissolved oxygen (DO) is of utmost importance to aquatic life, since it determine whether or not the water can sustain a desirable variety of aquatic organisms (Ethan 1970). Fairly high levels (i.e., 5.0 mg/l) of oxygen are required to maintain a desirable population of organisms, including the aerobic bacteria that consumes waste material in the wate. Low levels of DO (i.e. 1.0mg/l) mark the transition to an aerobic conditions which are often denoted by odours of organic sulfides, blackening of the water and destruction of desirable fish species and many other aquatic organisms. (Ethan 1970).

Fish depend upon dissolved oxygen for respiration, and they will smother and die with an inadequate supply. Under actual stream conditions, a fish must maintain its position against the current, find, pursue and catch its food, avoid its enemies, and reproduce (Tarzwell 1957). All these activities require oxygen in such amounts that oxygen levels at which the fish can just survive are unsatisfactory. Generally, fry and younger fish have a higher metabolic rate and require more oxygen than adults. Because of increased activity and their physiological condition, fish require more oxygen at the spawning season (Tarzwell 1957)

The oxygen requirements of fish are affected by the temperature and pH of the water as well as its carbon dioxide and dissolved soilds content. The oxygen uptake of any species of fish increases two or threefold with each 10°C increase in temperature. On the other hand, high carbon dioxide concentrations interfere with the ability of fish to utilize DO, as do high and low pH values (Camp and Meserve 1974).

For a well-rounded warm-water fish population, the DO must not be below 5 ppm for more than eight hours of any 24 hour period, and at no time should it be below 3 ppm. For instance, salmonoid fish are not usually found where DO is less than 4 to 5 ppm, and its eggs and fry require a minimum of 6 ppm (Tarzwell 1957, 1958). However, warm-water species can live for considerable periods during cold weather at DO levels of 1 to 2 ppm (Tarzwell 1958).

Studies done, indicate that the turbidity of water must be very high (20,000 ppm or more) to be directly harmful to fish (Tarzwell 1957). Consequently game fish which feed by sight are at a disadvantage in muddy waters when competing with Catfish and with Carp, buffalo, and Suckers, which employ a suction type of feeding. Since algae, are the basic food materials for aquatic life, turbidity indirectly affects fish production by reducing nest-building and spawning areas (Tarzwell 1957).

Further, pH values from 5 to 8.5 have not been shown to be detrimental to fish. However, pH values below 5 and above 9 seriously affect the abilities of some fish to extract oxygen from the water. It is no surprise, therefore, that streams carrying acid coal-mine wastes are not inhabited by fish (Tarzwell 1957). Generally, in more productive streams, the pH is in the range of 6.5 to 8.5

The presence of dissolved salts in water influences the toxicity of certain substances. The presence of calcium ions in solution will appreciably reduce the toxic effects of heavy metals such as lead and Zinc. High concentrations of Sodium, Calcium and Magnesium prevent the toxic effects of heavy metals probably by complex formation mechanism. For instance, 1 mg/1 lead in a soft water is rapidly fatal to fish, but in a hard water of say 150 mg/l calcium hardness, 1 mg/1 of lead may not be harmful (Oporor, undated)

According to annual reports of the United States Public Health Service on the effects of pollution the greatest number of fish were killed by industrial wastes, followed closely by agricultural poisons. Domestic sewage and wastes from mining operations were other major causes. Of the agricultural poisons, the most frequently reported causes were rotenone, DD7, 2, 4-D, and endrin, whereas, cyanide and metallic ions were the principal causative agents in industrial wastes (Camp and Meserve 1974).

Fish are, particularly sensitive to low concentrations of insecticides. Chlorinated compounds, including DDT, endrin, dieldrin, BHC and toxaphene, constitute the group most toxic to fish (Webb 1962). According to experimental studies of sublethal exposures of fish to organic phosphorous insecticides for periods upto 24 hours, fish brain enzyme, *Acetylcholine esterase* (AchE), is inhibited with concentrations of 0.1 mg/1 (ppm) or less depending upon the compound and the fish species (Weiss 1959).

DDT and other related chlorinated hydrocarbons are fat soluble and are accumulated and stored in organs rich in fatty substances, e.g., adrenais, castes, and thyroid, in the liver and kidneys, and in the fat of the large protective mesenteries that enfold the intestines. An intake of as little as 0.1 ppm in the diet results in storage of about 10 to 15 ppm, an increase of 100 - fold or more (Carson 1962). Evidence of aerial dispersion of pesticides, other than by direct air-spraying applications have been reported (Cohen at al, 1962). It has further been demonstrated that long distance movement of pesticide-laden particles are also possible (Cohen and Pinkerton 1966).

Quite a large number of potentially harmful metals and elements are known pollutants. Heavy metals are very rapidly trapped in biological systems and many accumulate in the sediments. Aquatic plants (e.g., algae) are also known to accumulate heavy metals (Bukenyi 1979). The heavy metals in solution are highly reactive, hence their trace level concentrations. A lot of Swedish lakes are reported to have high mercury levels (Ginsbugr et al. 1974). Spot checks on specific elements are, therefore, necessary on fish caught in suspect areas. The elements of most concern are "cumulative poisons" i.e, those that cause injury to health through progressive and irreversible accumulation in the body as a result of ingestion of repeated small amounts. Hence analysis of some heavy metals of current major concern as potential aqueous polluters will be considered. These include mercury, cadmium, lead, selenium and arsenic.

The effects of potentially toxic materials is normally determined by their action on fish as demonstrated by some form of bioassay experiments. The procedure involves the use of a seiles of dilutions of the suspected material to which test fish are exposed under standard conditions. The prescribed measures of toxicity is the median tolerance limit (TLm), often referred to as 50% lethal dose (LD50). This is the concentration of material under test at which 50% of the test fish are able to survive for a specified period of exposure (usually 48h or 96h).

SOURCES OF POLLUTION

Today, Kenyan inland surface waters are threatened by pollution and eutrophication. Three major sources of pollution, namely domestic/urban wastes, agricultural wastes and industrial wastes will now be considered.

DOMESTIC AND URBAN WASTES'

The discharge of domestic sewage with varying degrees of treatment into lakes and rivers may lead into major qualitative and quantitative changes in the biota. The water may become a health hazard, uninhabitable by desirable fish or aesthetically unpleasant. The symptoms of stress in fresh water bodies caused by loading with treated or untreated seawge are outlined below (UNESCO 1972).

1. Low dissolved oxygen levels caused by biological oxidation of organic matter and increased concentrations of refractory organic matter in this water.

2. Stimulation of algae growth and shift of algal type to obnoxious blue greens. This may lead to large accumulations of algae, often characterized with massive production of floating algal scums. Later as these decompose, DO levels will be lowered.

Thus sewage loading is accompanied by structural changes in ecosystem components in addition to contributing towards the total input of organic and inorganic materials to freshwater bodies. In a municipal sewage of medium strength, the total solids content may amount to about 800 mg/ l of which about 300 mg/ l is suspended and about 500 mg/ l is colloidal and dissolved. About two thirds of the suspended solids are organic and the remainder are mineral. The organic matter is about 50% carbohydrate, 40% nitrogenous matter and 10% fat.

When organic matter is added to a stream, it is immediately attacked by bacteria, which breaks it down to simpler substances, and in so doing uses up oxygen. Sewage being well inoculated with bacteria and adequately supplied with a wide range of compounds, gets broken down relatively easily. However, some materials, notably wood pulp are very poor bacterial foods and are decomposed very slowly. These will normally exert a lower oxygen demand, but for a longer period of time (Hynes 1963). The biological oxygen demand (BOD) of a sample of sewage, industrial waștes of polluted water is a measure of the concentration of decomposable organic matter in the sample.

AGRICULTURAL WASTES

Today, fairly large amounts of insecticides, herbicides and fertilizers are used in Kenya. Large amounts of DDT and other pesticides are used by the public health bodies for the control of disease such as maralia, sleeping sickness and river blindness.

Pesticides are also used in agriculture, especially on coffee plantations and in cotton growing areas. The vast plantations of sugar-cane in western Kenya also make much utility of fertilizers. Widespread use of inorganic fertilizers may cause an increase in the nutrient level of run-off water, particularly nitrates, which may contribute towards unwanted production of certain algae in the receiving waters.

The biocides used in agriculture and forestry find their way into the aquatic environment by drift or run-off. The latter may be enhanced by irrigation. By products of agriculture, e.g., silage, effluent and wastes from dairies and pig and poultry farms may be discharged into streams (UNESCO 1972). Insecticides applied on land may cause destruction or decimation of aquatic invertebrate populations, and may accumulate in the food chains to poison fish, birds and humans.

Herbicides emanating from the land may destroy the aquatic plants which for the basis of food chains of direct or indirect significance to man.

INDUSTRIAL WASTES

The appearance of new synthetic compounds such as poly-chlorinated biphenyls (PCB) and changes in distribution, concentration and form of naturally occuring substances, e.g., zinc and cyanides in the environment due to the disposal of industrial wastes has led to increased and differential mortality of populations, impairment of reproduction and disruption of species composition and balance (UNESCO 1972)

Industrial effluents comprises of several pollutants. including heavy metals, some of which are extremely toxic. Table 1 shows the general distribution of heavy metals in particular industrial effluents (Stumm and Morgan 1970). Industrial effluents which contain only chemical reducing agents, e.g., ferrous salts or sulphides, take up oxygen by purely chemical action. They do this repidly exerting what is sometimes known as immediate oxygen demand (Hynes 1973).

The chlor-alkali industry is the largest consumer of mercury, which is the most serious polluter of the aquatic environment. Consumption of fish containing high levels of methyl-mercury can have serious consequences, as demonstrated in the Minamata and Niigata disasters in Japan (Wfrei 1975). In Kenya, we have reasonable industrial establishments manufacturing a wide spectrum of goods, e.g., sugar, textile and paper. Furthermore, new ones are coming up, e.g. the molasses industrial complex which will produce power alcohol (ethanol) besides other products such as citricK acid, vinegar, dry and fish baker's yeast, sulphuric acid, methane, oxygen and gypsum.

OTHER POLLUTANTS

The sugar, paper and coffee industries are major pollutants in Kenya. Unfortunately, no serious restrictions are in force as concerns control of their effluents, which are normally discharged almost at will into waterways. I will now address myself to other inorganic compounds that are potential threats to the ecosystem balance in Kenya. These include, flourspar, cement, asbestos and calcium flouride. The flouride ion is formed by dissolution of flourspar. When its concentration exceeds 0.8 ppm in drinking water, it will affect the bone systems of all animals, making them soft. It will even hydrolyse most peptide bonds. The ultimate result of flouride poisoning is death (Wandiga 1980). On the other hand, the high particulate emission from cement and absestos are objectionable because of their effect on the respiratory systems.

The insecticide, toxaphene is a chemical currently used in cattle dip tanks for control of ticks on cattle. Toxaphene is an organochlorine insecticide which acts on the nervous system, with symptoms depending on exposure, varying from slight behavioural and growth pathology to death. If carelessly handled and accidentally allowed to spill into streams it may result in great mortalities of fish and other inhabitants of the aquatic regime.

MONITORING PROGRAMME

Ideas about pollution indicator species are almost as numerous and diverse as are the people concerned with them. These range from the simplistic quest for an all purpose aquatic "canary" that will warn of pollution to the complex mathematical models of community interrelationships. Indeed, no one index or model can be depended upon to describe a community completely. Rather a balance of many techniques incorporating studies on species compositions, population sizes and physico-chemical environments to which they are exposed, must be employed (Hart et al. 1974)

The species and media appropriate for sampling and analysis must be carefully selected. Species of which individuals move over considerable distances, either for feeding or on migration, may give information difficult to interpret as the pollutants may not have been ingested in the area in which the specimens were collected. Ideally, freshwater fish which remain in the lake over a complete life-span or invertebrate which move relatively short distances should furnish information relevant to their local environments.

A further important consideration in the choice of species for monitoring is that sufficient individuals must be available for sampling at the required time, without having significant influence on the total population. In practice, in order to obtain a reasonably accurate estimate of the mean level of contamination in any one population, a large number of individuals must be sampled.

The collected samples must be truly representative of the environment under consideration. This is aimed at achieving the goals of the monitoring study. Therefore the sites, techniques and frequency of sampling and the size and number of samples must allow the analytical results to be statistically evaluated and replicated at a later time for confirmation.

A "biotic index" based on the macro-invertebrate fauna has been proposed (Beak 1965). Six distinct stages in the change from a normal fauna to no fauna, corresponding with increasing degrees of pollution and relative "biotic index" and fisheries potential are displayed in table 2.

With these ideas in mind, a monitoring programme has been suggested to Kenyan waters of Lake Victoria. These are outlined in figure 1. The pollution indicators to be employed are fish, invertebrates and water criterion. Fish species used by the surrounding population as a source of protein will be chosen as an important link in the food chain and as an indicator for the degree of pollution of the lake. particularly to be of interest will be the riverine fish species. Such a general survey may also unfold possible aerial fallout from distant sources of pollution.

In determining admissible pollution, determination of both physico-chemical properties of Lakes Victoria, Naivasha, Turkana and rivers on both the eastern and western part of Kenya will be embarked on. The usual parameters employed in water pollution studies, e.g., dissolved oxygen, pH, conductivity, BOD and chemical oxygen demand (COD) will be monitored routinely at the suggested stations (figure 1). Other physico-chemical parameters, e.g., colour, turbidity, hardness, alkalinity, nitrates, phosphates, sulphates, chloride, flouride, sodium, potassium, iron, manganese, calcium and magnesium will also be considered.

The content, distribution and accumulation of heavy metals and pesticides in Lake Victoria, and its effluent rivers is little known in our country. Fish will be used in this monitoring programme, and later plankton, invertebrates and bottom sediments analysis will be considered. An exhaustive working plan has been proposed (Onyari 1981). This has been divided into five phases as follows:

1. Determination of physico-chemical and biological pollution indices in among others Lakes Victoria, Naivasha, Turkana and Nakuru including their effluent rivers.
2. Evaluation by bioassays of the toxicity to tilapia species and other endangered fish species of industrial and municipal effluents.
3. Determination of the concentration of mercury and other heavy metals in lake Victoria and all other Kenyan Lakes.
4. Determination of pesticides (e.g., DDT) residues in among others, Lakes Victoria, Naivasha, Nakuru and Baringo.
5. Determination of the nutritive values, e.g., fats and proteins of various species of fish from, among others, Lakes Victoria, Turkana, Naivasha.

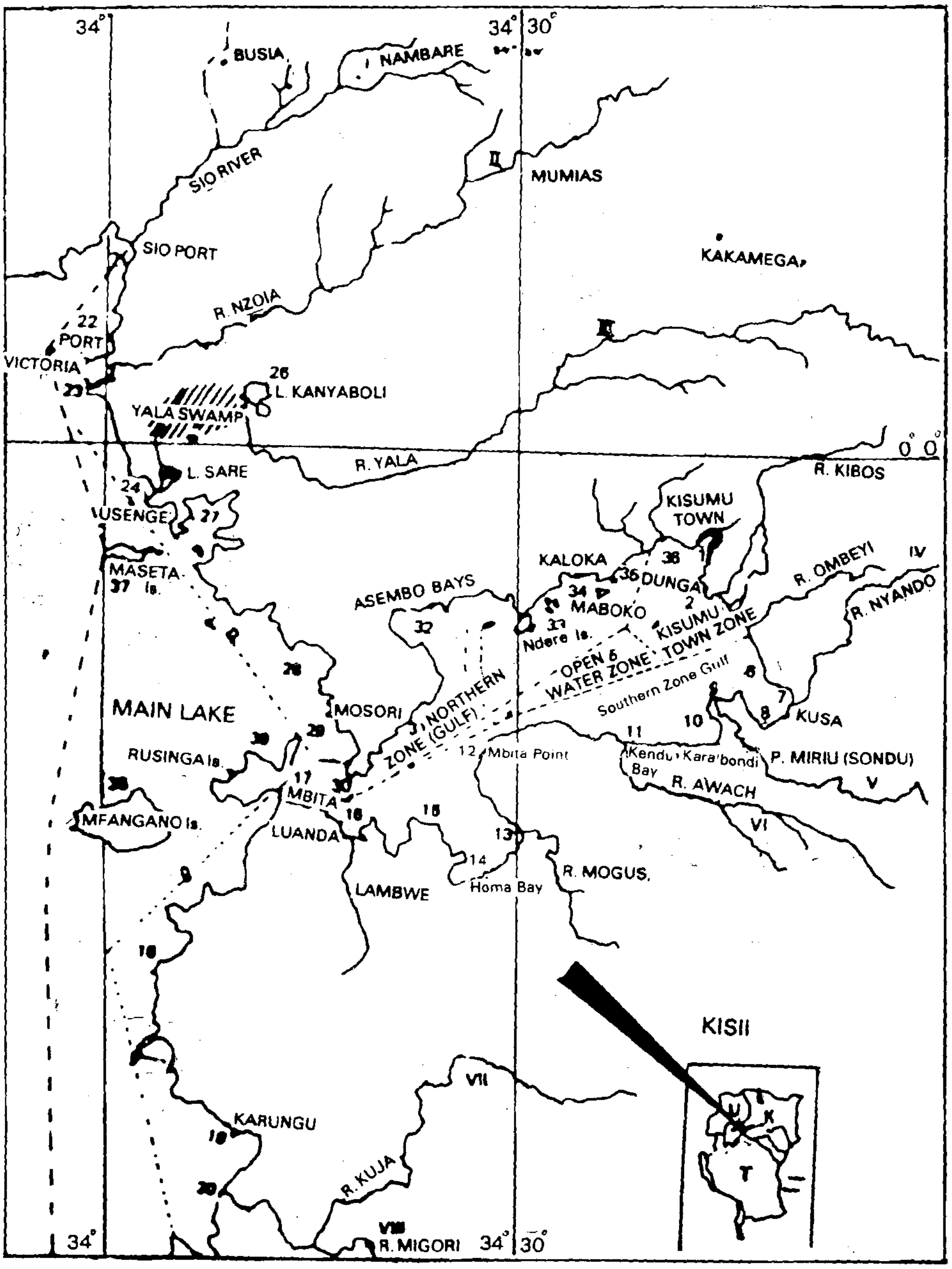
OBJECTIVES

The limnology and environmental research programme will look into the causes and nature of aquatic pollution in Western Kenya. It further aims at providing basic baseline data on water quality characteristics upon which future levels of pollution will be guarded against. Pollutants and their effects on aquatic organisms (plankton, benthos and fish) will be studied and remedial action will be recommended where possible. The progremme intends to:

1. identify the sources and nature of common pollutants, and advise on its preventation;
2. assess the acceptability of industrial wastes for lake and river disposal;
3. determine toxicity values of urban, and agricultural industrial pollutants;
4. study the likely short-term biological effects of the pollutants on fish;
5. establish the present composition and degree of purity (water quality) of Kenyan rivers and lakes, so as to provide baseline data upon which future studies can be compared to;
6. determine the nutritive values, quality of Kenyan fish species with regard to marketibility, particularly for local and export purposes; and

7. postulate same explanations for the declining trend of some fish species in Lake Victoria.

Fig. 1. Sampling areas in Kenya waters of Lake Victoria.



LIMNOLOGY AND ENVIRONMENTAL RESEARCH PROGRAMME 1:250000

DISCUSSION

Today, pollution has relatively not reached any alarming proportions in Kenya, despite the alarming and very often exaggerated reports by our national newspapers. Ideally, therefore thorough baseline chemical and biological studies should be done, for purposes of establishing standards upon which subsequent detection and monitoring of aquatic pollution can be based on. Phase one of the proposed research programme has already been launched. Preliminary observations on aquatic pollution has been in progress and routine monitoring still continues. These studies cover in part pH, colour, turbidity, iron, total hardness, total alkalinity, conductivity, dissolved oxygen, flouride, phosphate, nitrates and sulphates.

Whereas, the analysis of chemical pollutants in Kenya has been carried out by several parties, the results of most of these analyses, however, are unknown. Of late the threat to the Lake Nakuru ecosystem by the production of copper-oxy-chloride has been greatly exaggerated. Analysis of the Lake Nakuru water (Wandiga 1980) reveals that the concentration of copper (2-8 mg/1), a major inorganic poison is far below the threshold limit. Likewise, pesticide studies have been done for several species of birds and fish of this lake. The results obtained for DDT, DDE, DDD, dieldrin and endrin, range from 0.001 mg/g to 0.64 mg/g (Koeman et al. 1972). Subsequent analyses of Chlorinated pesticides residue in cope pods (Lovelula spp.) reveal low concentrations of DDT (0.003 mg/g) and DDE (0.007 mg/g). The analysis of algae and mud samples from the same lake gave no detectable DDT or DDE (Wandiga 1980).

In Lake Victoria, analysis of one sample of bass (fish) by the University of Stockholm indicates the presence of a wide range of chlorinated hydrocarbons in the lake. The results (in ppb) obtained were DDT (0.02); BHC (0.06); Heptachloroepoxide (0.07); Aldrin (0.04); Dieldrin (0.13); HCB (0.03); PCB (0.04) (Jensen and Odhiambo 1977). These results indicate the need for further and more intensified monitoring as discussed in the monitoring programme (figure 1).

There is need for biological and chemical studies to be carried out on River Nzoia in particular, to evaluate the direct effects of the pulp and paper mill wastes on its resources. The paper industry has a history full of dead rivers all over the world. In the United States, this industry is credited with the death of most rivers in the Tennessee and Mississippi valleys, although credit must be given to the same industry for the research it has done in improving its own technology (Wandiga 1980). Those of you who have paid a visit to Pan African Paper Mill factory, situated in Webuye will probably remember the stench around the town. The "awful stench" is mainly sulphur dioxide which interracts with the moisture in the air to form sulphurous and sulphuric acids. These chemicals all irritate the respiratory systems and at higher concentrations may gradually cause death (Wandiga 1980). Hence this area provides a target priority area for research into the nature of the discharges and their effects on the entire ecosytem.

Kenyan living marine and inland water resources may face the danger of extreme depletion if pollution and physical alteration of the water is allowed to take full effect. Athi River offers an excellent example of the rapid deterioration in water quality of lotic aquatic systems in tropical Africa due to industrialization and urbanization. The results of the physico-chemical analysis and examination of the macro-fauna and riverine flora describe a river unable to cope up with the heavy pollution load from the city of Nairobi and its upper reaches (Njuguna and Gaudet 1979).

The construction of dams along a river will normally be accompanied by a number of changes within the river, which may affect the fisheries in several ways (Okedi et al. 1974).:

1. The river flow will be interrupted in the dam sites and the dam wall becomes an obstacle to fish movements, making it difficult for fish to reach their breeding grounds.

2. Creation of lake environment above the dam with its new flooded habitat and the destruction of the breeding grounds.

3. Separation of fish populations into those below and above the dam.

4. Changes in physico-chemical characteristics of the water, this depending upon the flooded area, water depth, decomposition, temperature and rainfall regimes. The physico-chemical changes may ultimately affect the flora and fauna in the system.

5. The new habitat (lake) may eliminate old fish species or modify their habits or may support an entirely different plant and animal communities.

6. Disturbance of the entire food chain dynamics which the aquatic inhabitants had established, i.e, breakdown (collapse) of the natural ecosytem feeding pattern.

Several rivers in Kenya are reported as being potential sources for local power supply. The potential energy of the Tana, calculated from rainfall and elevation is reported as 15,3000 million kWh a year of which about 2,700 million kWh can usefully be exploited; a small station (2,000 kW) on the Kurja; and feasibility for the development of a five megawatt station at Broderick falls on the River Nzoia (Fadel 1979). However, in the construction of these and other dams, the decision makers should not overlook the possible effects enumerated above on the ecosystem, many of which may be irreversible in the long run.

In recent years the insecticide, toxaphene commonly used in cattle dip tanks has been responsible for fish and bird mortalities.

In August 1978 a large number of fish were reported dying in the Hluhluwe river in Natal, South Africa, due to pollution by toxaphene from a cattle dip tank (Brooks and Gardner 1980). Hence, we in Kenya ought to exercise caution in its use and handling to avoid such undesirable consequences.

Perhaps one of the sources of great concern in Kenya is the pollution of the water systems by spillage of the human wastes into the waterways. it is reckoned that schistosomiasis (bilhaeziasis) and to a lesser extent leishmaniasis remain two of the major health problems in the tropics. In Kenya, it is estimated that one out of every five peoplde suffers from schistosomiasis (Wandiga 1980).

Narrowing up, observations of changes in plankton, invertebrates and fish communities are necessary in evaluating the impact of enrichments on our aquatic environment. If we are aware of the usual seasonal succession, diversity and species interrelationships, any subsequent modifications of the ecosystem will be readily detectable.

Considerable damage has been done to Italian lakes by combined discharges of sewage and industrial wastes including synthetic textile works. Some of these lakes are now eutrophic to a high degree. Fish losses have been reported in Lake Balaton (Hungary) due to a discharge of a pesticide. Whereas, in the south of Norway, the waters have low mineral content 1.5 mg CaO to 4.0 mg CaO/1 and acid rain water derived from atmospheric pollution in northern European countries is thought to have caused the pH values to fall to harmful levels (Holden and Lloyd 1972). Consequently we in Kenya must know with much greater certainty what we are doing to the aquatic environment and the degree and extent to which it is being damaged in order to properly understand their effects on our fisheries. These pollution studies and limnological studies will greatly enhance the management and developement of Kenyan inland fisheries.

Table 1 General distribution of heavy metals in particular industrial effluents.

Industrial effluents	As	Cd	Cu	Fe	Hg	Pb	Ag	Zn
General Industrial & Mining	—	—	X	X	—	X	—	X
Plating	—	X	X	—	—	X	—	X
Paint products	—	—	—	—	—	X	—	—
Fertilizers	—	X	X	X	X	X	—	—
Insecticides/Pesticides	X	—	X	X	X	—	—	—
Tanning	X	—	—	—	—	—	—	—
Paper products	—	—	X	—	X	X	—	X
Photographic	—	—	—	—	—	—	X	—
Fibers	—	—	X	—	—	—	—	
Printing/Dyeing	—	—	—	—	—	X	—	—
Pipe corrosion	—	—	X	—	—	X	—	—
Chlor-alkali and pulp mills					X			

Note: X = Presences
— = Absence
no information

Table 2: Biotic index: Index of water pollution based on the study of the biota

Biotic Index	Pollution Status	Type of macro-invertebrate community	Fisheries potential
8	Unpolluted	Sensitive, facultative and tolerant predators, herbivores, filter and detritus feeders all represented, but no species in excessively large numbers.	All normal fisheries for type of water well developed.
5 or 4	Slight to moderate pollution	Sensitive predators and herbivores reduced in population density or absent. Facultative predators, herbivores and possibly filter and detritus feeders well developed and increasing in numbers as index decreases.	Most sensitive fish species reduced in numbers of missing
3	Moderate pollution	All sensitive species absent and facultative predators (Hirudinae) absent or scarce. Predators of family pelopiinae and herbivores of *Tindipe didae* present in fairly large population densities.	Only coarse fisheries maintained
2	Moderate to heavy pollution	Facultative and tolerant species reduced in numbers if pollution toxic, if organic few species insensitive to low oxygen present in large numbers.	If fish present only those with high toleration of pollution
1	Heavy pollution	Only most tolerant detritus feeders (Tubificidae) present large numbers.	Very little, if any fishery.
0	Severe pollution usually toxic	No macro-invertebrates present	No fish

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