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Tanzania National Water Quality Synthesis Report

By

Water Quality and Ecosystem Management Component

Edited by

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1. Executive Summary

The Water quality and Ecosystem Management Component of the Lake Victoria Environmental Management Project (LVEMP) in Tanzania for the past five years have made a considerable progress towards understanding Lake Victoria water quality and its ecosystem as well as effects of resource utilization and exploitation on the lake and its catchment. The component has been able to collect considerable amounts of data and information. In order to achieve LVEMP objectives and Water Quality and Ecosystem Management objectives, in particular, a well-coordinated analysis, synthesis and interpretation of all relevant data was required. This synthesis report documents and explain the changes that have taken place over the recent decades, and provide an overview of the present water quality status of the lake as well as identifying past changes and continuing trends that may require remedial action.

The report provides enough detailed information and spatial resolution at the regional scale to support environmental decision making in regards to possible remediation of undesirable changes that have reduced beneficial uses of Lake Victoria biological and water resources. Synthesis report was written under the guidance of an international consultant, Prof. Robert Hecky of the University of Waterloo, Canada, together with the National consultant, Prof. Mwanuzi of the University of Dar Es salaam. A number of working sessions were conducted to enable the scientists to synthesize the report.

1.1 Background

LVEMP is a comprehensive program conducted by the three countries aimed at rehabilitation of the lake ecosystem for the benefit of the 30 million people who live in the catchment, their national economies and the global community.

The overall objectives of the LVEMP is to maximize the sustainable benefits to riparian communities from using resources within the basin to generate food, employment and income, supply safe water, and sustain a disease free environment; to conserve biodiversity and genetic resources for the benefit of the riparian communities and global community and to harmonize national management programs in order to achieve, to the maximum extent possible, the reversal of increasing environmental degradation.

One of the critical Components of LVEMP concerns Water Quality and Ecosystem Management with the overall objectives of elucidating the nature and dynamics of the lake ecosystem by providing detailed information on characteristics of the waters of the lake; improving management of Industrial and Municipal effluents and assessing the contribution of urban runoff to lake pollution in order to design alleviation measures; and establishing water quality monitoring network throughout the catchment, estimating the effects of changes in land use planning on pollution loads into the lake, and developing policies and programmes to control non-point source pollution

The water quality and Ecosystem Management Component has since the inception of the Project made considerable progress towards understanding the Lake Victoria water quality and its ecosystem as well as effects of resource exploitation. The component have been able to collect considerable amounts of data and information.

The component using historical data and the data it initially collected produced an initial report in 2002, which acts as a baseline water quality status at the start of the project. The data has also been used in scientific fora within the region. But, in order to achieve LVEMP objectives in general and Water Quality and Ecosystem Management objectives in particular a well-coordinated analysis, synthesis and interpretation of all relevant data are required. This synthetic report will document and explain the changes that have taken place over the recent decades, and it will provide an overview of the present water quality status of the and continuing trends that may require remedial action. The report will provide enough detailed information and spatial resolution to support environmental decision making in regards to possible remediation of undesirable changes that have reduced beneficial uses of Lake Victoria biological and water resources.

To achieve this series of working sessions and workshops are conducted under the guidance of a national consultant and one international consultant for the region to help the scientists in the statistical analysis, synthesis and interpretation of the data so far collected by the components.

The report is divided into a number of chapters being (1) General Introduction: (2) Capacity Building: (3) Meteorology/Hydrology: (4) Non-Point Loadings: (5) Industrial and Municipal Effluents Loadings: (6) Hydraulic Conditions: (7) Lake Monitoring: (8) Sedimentation: (9) Eutrophication: (10) Pesticides and Metal Contamination: (11) Water and Health: (12) Impacts of Water Quality Change on Beneficial Uses of the Lake Victoria: and (13) Conclusion and Recommendations:

1.2 Approach to synthesis Report

All the available data and reports generated by the component since the start of the project were collected, collated, updated and reviewed. These data were used for some specific key objectives/issues as spelt as follows;

i) Update the Lake Victoria water balance and use it to determine current nutrient loads and balances of the lake,
ii) Define trends in limnology and water quality, and provide quantitative information on past, and if possible future, nutrient loading, nutrient losses and nutrient availability within the lake,
iii) Identify the sources of micro/macro nutrients promoting eutrophication in a spatially explicit manner that can guide remedial action and demonstrate how these inputs are affecting lake productivity;

iv) Summarize what is known about the presence and concentrations of contaminants in lake water and biota and, if possible, define trends in these contaminant loadings over time,
v) Describe the phytoplankton communities, their composition and their effects on beneficial uses of the lake ecosystem, in particular addressing algal bloom dynamics within the lake in relation to current and past rates of primary production
vi) Determine the trophic interrelationships of the lake's biological communities and especially address how eutrophication and food web alterations are affecting fisheries of Lake Victoria;
vii) Determine the role of lake consumers e.g. zooplankton, zoobenthos, microbes and lake flies in the ecosystem dynamics;
viii) Using the available information on the horizontal and vertical circulation of waters determine its effect on the spatial distribution of nutrients, algae, oxygen, contaminants and organisms in Lake Victoria;
ix) Integrate the WQ and Ecosystem findings with the findings of other Components of LVEMP
x) Assess effects of poor water quality on the socio economic aspect of the riparian community
xi) Use the available data as input to the LVWQ-Model to simulate the future effect of different interventions and management campaigns

The above issues were grouped and summarised in different chapters addressing specific issues as summarized here;

1) Meteorology /Hydrology chapter

- Updating an estimate of the total water balance for the lake (i.e. all discharges to and from the lake preferably on a daily basis)
- To examine if these water balances are consistent with the recent lower levels of the lake.
- River runoff from important national rivers as well as available meteorological data relevant to Lake Victoria were compiled and analysed

2) Sedimentation chapter

- Estimation sedimentation rates at inlet stations and at river mouths
- Establishment the relationship between the measured rates of sedimentation to longer term sediment accumulation.
- Assessing release of nutrients from sediments and analysis of sediment biota association for selected river mouths

3) Non-point Pollution loadings chapter

- Produce an estimate of all non-point nutrient and pollution loadings to Lake Victoria from all major rivers and the atmosphere
- Identify source distribution in relation to land-use in the catchment for management purposes with spatial resolution at least to the level of individual tributary river catchments and if possible by subcatchment.

4) Industrial and municipal loadings chapter

- Identify and quantify municipal and waste water pollution from the major cities and towns in the catchments and sub-catchment
- Identify and quantify the major pollution generated from industries in the catchment and sub-catchments including agrochemical pesticides

5) Hydraulic Conditions chapter

- Determine how the major bays/gulfs, e.g. Mwanza differ from the lake and the consequences to lake loading estimates of differential processing of tributary inputs in these shallow embayment

6) Eutrophication chapter

- Through the data collected in water Quality monitoring program to assess the state of eutrophication and spatial distribution of eutrophication effects in the lake including impacts on biota
- Assess the mechanisms by which the lake responds to increased nutrient loading
- Determine the quantitative change in lake productivity from historical conditions prior to the LVEMP project and identify any trends observed within the time of the LVEMP program

7) Lake Monitoring chapter

- Number and selection criteria,Frequency, Descriptive statistics of observations for motoring stations in the pelagic Littoral and Urban lake shores

8) Pesticides and Metal Contamination chapter

- Use of Agrochemicals, Metals esp. Mercury, and Other compounds

9) Water and Health chapter

- Water borne biological contamination and Water vectored diseases
- Identify actions that will improve the water quality of Lake Victoria to restore or maintain beneficial uses.
- Consequences of no actions being taken to water quality and helth
- Achievable water quality objectives that would maximize uses and suggest a path of actions to accomplish those objectives

10) Impacts of Water Quality Change on Beneficial Uses chapter

- What benefits and uses of Lake Victoria are negatively affected by the current water quality conditions in Lake Victoria and have they been degraded over time or is there concern for beneficial uses if trends continue
- Impact on drinking water impairment-treatment costs,Water related diseases, Food web contamination, Loss of fish habitat, Inefficient food webs, Loss of biodiversity and Nuisance macrophyte growth

1.3 LVEMP Implementation

Lake Victoria Environmental Management Project was conceived as a multidisciplinary environmental project funded by the World Bank. One of the components of LVEMP is the Water and Ecosystem Management. The component comprises of three sub-components namely In-lake Water Quality Monitoring, Management of Industrial and Municipal Waste and Management of Pollution Loading into Lake Victoria. Its objectives include;

Main objectives

- Elucidating the nature and dynamics of the lake ecosystem by providing detailed information on characteristics of the waters of the lake,
- Improving management of Industrial and Municipal effluent, and assessing the contribution of urban runoff to lake pollution in order to design alleviation measures.
- Establishing a water quality monitoring network throughout the catchment, estimating the effects of changes in land use planning on pollution loads in the lake, and developing policies and programmes to control non-point source pollution.

Specific Objectives

- To establish periodic assessment of the physical, chemical and biological characteristics of the lake system.
- To provide details of limnological changes, model and predict their short and long-term consequences, and provide guidelines for ameliorating potentially disastrous changes.
- Provide quantitative information on nutrient loading and recycling in the lake (particularly the internal loading of sediment phosphorus); sources and mechanics of eutrophication and pollution and their effect on lake productivity (with a particular focus on ways to stabilize or reduce eutrophic status); phytoplankton communities and their composition; algal blooms and their dynamics; lake zooplankton, microbes, benthic flora and fauna, lake fly and their roles; primary production including estimation of lake carrying capacity; stratification of the lake and the increasing problem of anoxia; trophic inter-relationships; and lake paleolimnology.
- To measure temperatures in different strata, dissolved oxygen, conductivity, pH, factors affecting light penetration, water clarity, and spectral characteristics, biochemical oxygen demand levels, levels of heavy metals, pesticide residues, abundance and species composition of phyto-and zooplankton, phytoplankton primary production, and levels of B-coli and E-coli.
- (Analysis of these and other data will establish rates of change in water quality, relate these to the observed status of inputs from the catchment, estimate the effects of poor water quality on the economy of the region, and establish the basis for practicable control programme).
- To obtain data (for whole lake) on the fluxes of particulate and dissolved nutrients between the water phase and sediment, and to monitor vertical sediment profiles of dissolved and particulate nutrients (such data is an important input to the understanding of the eutrophication of the lake).
- To estimate sedimentation rate at the mouth of Simiyu River and assess the rates of release of nutrients from sediments, analyse sediment-biota associations, and compare data with soil losses from surrounding areas.

- To measure patterns of water circulation to determine the interaction between vertical and horizontal circulation components, and improve existing estimates of hydraulic retention periods in the lake.
- To develop simulation models of the dynamics of nutrients and phytoplankton which will be used to predict impacts of eutrophication control programmes and pollution intervention strategies
- To prepare inventories and classifications of all factories and industries in the catchment.
- To assess treatment of effluent before discharge and its dilution and dispersion levels in the receiving water bodies.
- To quantity pollution and nutrient flows from urban runoff.
- To identify and characterize pollution "hot spots".
- To formulate guidelines and effluent discharge standards.
- To establish training arrangements for industrialists and local authorities.
- To launch public awareness campaign, and initiate pilot treatment projects in selected municipalities and industries.
- To create "wetlands" to test tertiary treatment through filtration of industrial waste.
- To create "wetlands" to test tertiary treatment through filtration of municipal waste.
- Rehabilitation and/or extension of urban sanitary systems, which are currently discharging untreated waste directly into the lake.

In the quest to have in place a sustainable management system for water resources of the Lake Victoria basin in the environment constrained by poor economy, the Tanzania government faces the following challenges:

- Eradicating poverty through accessing clean and safe water to all people. While poverty results in environmental stress, the major cause of global environmental deterioration is an unsustainable pattern of consumption and production.
- High population growth rate. Water use is increasing in developing nations twice as fast as population growth. Thus the population boom being experienced will tax water resources that are already overstretched and unevenly distributed.
- Managing the shared water resources. Key water resource issue in Lake Victoria Basin is the presence of international river basin in a climate of weak international water law and weak regional cooperation on water quality and quantity, among the member state. Despite this, very few shared waters are jointly managed at present.
- Developing capacity for water resources management and water quality management in particular which should involve the development of capacity of institutions and scientific technical community and sensitisation of local communities to address the current and future water issues.
- Restoring the lake basin ecosystem particularly the near shore areas and rivers back to the state of the sixties and early seventies.
- Building a culture of science – based management in one of the world's poorest Nation.

1.4 General summary

The data and information available today indicate a continuing deterioration of the Lake Victoria Basin Environment. The population is increasing and the associated human activity. Poor agricultural methods are employed, overgrazing is continuing and demand for firewood is on the increase. Cultivation along the riverbanks is continuing and both untreated and partially treated municipal and industrial effluents continue to enter the lake system. Capacity to handle this condition is quite inadequate as the country belong to the poorest economic of the world. But nonetheless, the government has to ensure efforts made and the opportunities available today should not be wasted for the cost of inaction would seriously erode the economy of the lake basin and the country as a whole. Action that has begun to prevent further damage and potential misery that might follow has to be sustained.

Poverty eradiation as stated out in the millennium goals should be the entry point for minimisation of environmental degradation. The poor do not have access to electricity and thus continue cutting trees for firewood. They continue tilling the land using the same traditional poor methods including burning of bushes and cannot afford improved sanitary facilities. These lead to soil fertility loss, erosion and increased airborne nutrients resulting into nutrient over enrichment of the lake.

As the poor sanitary conditions and untreated effluents continue to introduce the pathogens into drinking water supply sources the water borne and other water related diseases continue to debilitate the people and thus drastically reducing productivity. Provision of safe and clean water, and sanitation and introduction of improved agricultural practices will reduce stress upon the environment.

Water Quality monitoring should be made an integral part of the management of Lake Victoria ecosystem. The monitoring system should be integrated Water Resources Management based, issue driven and results oriented, responsive to changes in the environment, consider the temporal and spatial variability and have a quality control system and be financially sustainable. This in turn requires development of capacity of institutions and the technical community and sensitisation of all stakeholders so to address the current and future water issues. This system will provide accurate data and information upon which informed decisions will be made, and enhanced involvement of stakeholders will increase their sense of ownership. The introduction of Integrated Water Resources Management System in Tanzania, and the opening of the Lake Victoria Basin Water Office in particular should be seen as an important milestone towards sustainable management of the Lake Victoria environment.

As pointed out earlier, shared management of the lake Victoria system is an enormous challenge. Protecting the system requires joint efforts of the riparian countries to create capacity in terms of institutional and human resources development. This will facilitate the riparian countries to enhance knowledge the lake ecosystem, and harmonize legislation and regulations so as to achieve compliance. The current efforts particularly the long term implementation of the Lake Victoria Environmental Management programme (involving Kenya, Uganda and Tanzania) should bring on board the two countries of Burundi and Rwanda in effort to address the lake water quality problems originating from these two countries.

1.5 Major findings from each chapter

1.5.1 Capacity Building

The existing Lake Victoria Environmental Management project is the first phase of a long-term program. The main objectives of the first phase are to provide the necessary information to improve management of the lake ecosystem; establish mechanisms for cooperative management by the three Lake Victoria riparian countries, and identify and demonstrate practical, self-sustaining remedies, while building capacity for ecosystem management.

To play its role of Water Quality Monitoring to address the identified critical issues namely pollution, eutrophication, inadequate data and information, and inadequate capacity for Water Quality Management, the Water Quality and Ecosystem Management Component has had to improve and strengthen its capacity in term of human resources and infrastructure. The laboratories of Mwanza, Bukoba and Musoma have been expended and rehabilitated, equipped and stocked with requisite chemicals and reagents. The field and office equipment, and both land and water transport facilities are in place. Component staff have been adequately trained at various levels including certificates (25), diplomas (6), masters degrees (6), and PhD (1). A functional basin-wide water quality-monitoring network consisting of catchment and land-based stations has been established. Decision support systems including conceptual and theoretical models have either been operationalized or are at various levels of development. These include the rainfall-discharge, erosion and nutrient yield, lake hydrodynamics and the Lake Victoria physical processes and water quality models. The Working Sessions Concept has during the project life proved to be a powerful force particularly in data quality assessment, sharing experiences, and bringing the water quality experts from Kenya, Uganda and Tanzania much closer. The experts in the World Bank Missions have always added value to the Component knowledge base. The Cleaner Production training programme for the lake basin industrialists has been appreciated as the adopted options have proved effective in reducing effluent streams in industries participating in the programme.

Since valid data are essential to assess the state of the lake system, evaluate the impact of remediation actions and for informed management decision-making, the quality assurance and control program was put in place. It involves field monitoring procedures and laboratory methods, data processing and evaluation, database management and reporting. This has resulted into a wealth of reliable data and information that has been used in the preparation of the Water Quality Synthesis report, the public awareness campaigns, and the information dissemination in general.

1.5.2 Industrial and municipal effluents loadings

Industries and urban centres (towns) represent point sources of pollution. This pollution if not well managed they can end up into the lake and pollute it especially the near shore waters. This study is aimed at identifying and quantifying municipal and industrial wastewater pollution from the urban centers and industries respectively. The magnitudes of this pollution was measured, but where reliable measurements of representative flows and concentrations were difficult to establish, professional estimates from production figures, economic turn-over, water and energy consumption by industries, and population numbers, have been used.

From 2000-2005 samples from 19 large urban centres and 31 Industries were collected and analyzed for selected water quality variables namely BOD_5, TP, TN, TSS and FC according to standard methods. From the study it is seen that the main point sources are concentrated in Mwanza City, and Musoma and Bukoba Municipalities. The total resulting municipal pollution load (Kg/day) from the urban centres of 996,108 inhabitants into Lake Victoria was found to be: BOD_5 9,998; TN 1,778; 711, TSS 6,664, and FC 6.3 x 10^{14} No./day while the resulting industrial load was found to be: BOD_5 5,201; TN 653; TP 185; TSS 4,934 and FC 1.1 x 10^{14} No./day. Urban centers contribute more pollution loading to the Lake compared to industries. They contribute 66% BOD_5; 73% TN; 79% TP; 57% TSS and 85% FC. This shows how urban growth is a threat to the Lake pollution since the urban pollution in the 1950^s were quite low as compared to the current period.

This situation calls for immediate mitigation measures that include: public awareness, developing a culture of industrial and municipal environmental compliance, construction and use of proper sanitary facilities, efficient wastewater treatment facilities, cleaner production technology and enforcement of compliance to effluent standards

This study is highly valuable as it provides pollution inventories, which can accelerate environmental compliance, by providing the information base to understand Pollution problems; identify priority options; make informed decisions; and identify opportunities for waste minimization and Cleaner Production. A database has been prepared and documented and can be used for management purposes.

1.5.3 Meteorology/Hydrology

One of the principal objectives of the Water Quality Component is to find the reasons for the changes observed in the lake water quality and ecosystem, and to identify remedial measures. To identify the reasons for the changes requires also a knowledge of the changes in the pollution loadings to the lake, which, in turn, depends on the discharges to the lake from the catchment and the atmosphere and lake outlet to River Nile i.e. hydrology and meteorological characteristics. Using these inputs the water balance of the lake is computed also this allows the calculation of loads of specific water quality variables during the estimation of non-point pollution loadings, atmospheric deposition of nutrients.

The data considered were (1) Rainfall onto, and evaporation from the lake surface (2) Discharges to the lake from all rivers and catchments around the lake and (3) Discharge from the lake into the Victoria Nile. Groundwater discharge to the lake has not been considered since in the past it was not found to be a significant parameter in the water balance. The results of analysis for stable isotopes done using samples from the Tanzania part of the harmonized Lake Victoria monitoring network indicate an insignificant interaction between groundwater and the lake.

The study found that rainfall from the selected three index stations for the long-term period and the period 2001-2004 did not show any significant changes in trend. The LVEMP period, 2001-2004, for two index stations, Mwanza and Musoma, on the eastern side of the lake indicate that there is slight increase in rainfall over the wet season and a decrease in rainfall during dry season. As for the western part of the lake, Bukoba meteorological station showed that there is no change in trend. The new LVEMP period had average rainfall. In general rainfall amount increases from east to west of the lake.

The average total basin inflows from Tanzanian portion shows a declining trend for the period 2001-2004, where flows decreased by 11% and for the long-term period 1950-2004 by 0.8%. On the Tanzanian side of the Lake, it is seen that there is downwards trend in water level, which show that on average water level is decreasing in the lake. In the recent years at Mwanza south station, it has gone down from 1141.24masl in 1998 to 1139.30masl in December 2004; that is 1.94m drop. The decrease may be due to either less inflow into the lake including rainfall falling directly over the lake surface or increased withdrawal of water for consumptive uses within the basin. The lowest level at 1139.30m was recorded in October 2004 and at the end of December 2004 the level increased to 1139.47m

1.5.4 Sedimentation

Sediments in the LVEMP context consist of the allochthonous input of suspended solids with river discharges and the autochthonous produced particulate matter in the water column and settled material on the lake bottom. The loading, transport, formation and decay of the sediments was monitored in this study programme

The sedimentation study focused on; (1) Quantification of river plumes from the major tributaries to Lake Victoria and their contribution to the nutrient cycles in the lake; (2) Quantification of settling fluxes of particulate nutrients at the offshore and nearshore monitoring stations; and (3) Quantification of the net deposition of carbon and nutrients, and the available pools of these components in the sediment at the offshore and nearshore stations.

Monitored data on sedimentation rate and settling velocities of TPP, TPN, TPC and TBSi has been analysed for the period November 2000 to March 2005. The results show that sedimentation rates are highest at the littoral stations compared to pelagic stations, but the differences are smaller than the variations in chlorophyll concentrations and secchi depths. The stochiometric composition of the settling material indicates nitrogen limitation and a non-dominance of diatoms. The differences in settling velocities indicate that the settling material consists dead and living material with a contribution of diatoms.

The suspended sediment load to the lake is estimated at 4,905.2ktons/year, with Simiyu River carrying the largest suspended sediment load estimated at about 42.3% of the total load to the Lake this is approximately 0.7mm/year.

1.5.5 LVWQ Model

From literature it has been observed that the Lake Victoria water quality has been deteriorating for a number of years. In order to understand the pollution mechanism and processes governing the lake water quality, the LVWQM model has been developed for application to the lake Victoria waters. The model is to predict the behaviour of the physical processes (water circulation and accumulation) water quality (dissolved oxygen and nutrient profiles) in the lake. Using the model will help the managers of the lake and its catchments to make wise land and water management decisions and, based on changes in lake water quality likely to arise as a result of proposed development and conservation/protection alternatives. This report presents the basis of lake water quality modelling and its application to the Lake Victoria.

Forcing functions such as hydraulic data were analyzed, temperature profiles produced, observed velocity vectors plotted and compared with existing historical data on the lake. The model was then run with a new set of the input data and the results compared with observed data at several monitoring/observation stations. Since the available model is only a framework its performance is quite satisfactory. It has reproduced measured observations reasonably well.

The model is detailed enough to simulate all processes occurring in the Lake Victoria. It has 41 state variables to simulate and out of these, 16 are phytoplankton species type. The model is designed with a bypass option thus can be made simpler, say to simulate three species of phytoplankton dominant in the lake etc. and thus quite applicable. The model does not provide the option to use the prevailing local wind conditions, which it is believed to control circulation in smaller ecosystems especially in the gulfs and the lake at large. It is recommended that the time series of hourly winds measured at all nearby stations especially at the airports be used as input to the model and that responsible scientists are trained by attaching them to the model developer for about four weeks so as to gain an in-depth model application as a management tool.

1.5.6 Eutrophication

During the LVEMP 1, the eutrophication study was carried out to establish the effects of nutrient enrichment of the lake (assess its current state); assess the mechanism by which the Lake responds to increased nutrient loadings; and provide the relevant calibration data for the lake Victoria physical processes and water quality model. This chapter presents the study results for the southern segment of Lake Victoria (Tanzania). The data set obtained for the period September 2000 through March 2005 is much more comprehensive regarding combined spatial and temporal extent than what has been the basis of former "conclusions". Generally, the offshore part of the Lake has relatively low chlorophyll-a concentrations and often measurable nutrient concentrations indicating that the primary production offshore may not be limited by nutrients but rather by light as a result of mixing depths. This implies that the ecological turnover offshore may not be significantly affected by inputs of nutrients to the lake. The near shore areas especially the hot spots such as Mwanza Speak gulfs and Mara and Rubafu bays are highly affected by eutrophication.

Some changes have been observed in the distribution, composition, abundance and biomass of plankton communities, macro-invertebrates and fishes, and the food web structure in response to the negative effects of eutrophication. The phytoplankton was as diverse in inshore as offshore and cynobacteria dominated contributing a large fraction (>50%) of total wet biomass as well as dry biomass of particulate nutrients (C, N and P). The potentially toxic cynobacteria of the genus *Microcystis* and *Anabaena*, and nitrogen fixers dominate the massive algal blooms frequently observed. The zooplankton community consisted mainly crustaceans, rotifera and to a lesser extent larvae of the stages of aquatic insects. The littoral zone was dominated by cyclopoida in terms of numbers and biomass while in the pelagic zone calanoid contributed much to biomass. Rotifera was more diverse in pelagic and littoral zones, but together with the insect larvae, their contribution to biomass was negligible. Vertically, zooplankton communities were concentrated in the bottom layers. Generally, Lake Victoria is progressively eutrophicating, and thus confirming the findings of earlier studies. Based on the OECD indicative values for trophic status of temperate lakes, the southern portion of the lake falls into highly eutrophic in the shallow sheltered zone to mesotrophic conditions in the deep pelagic zone. However, the chapter also critically evaluates the relevance of the OECD values and proposes strategies for coming up with values relevant for the tropical lakes.

1.5.7 Non Point source pollution loading

Well-documented changes have occurred to the water quality in Lake Victoria and its ecosystem. Among them, eutrophication has been observed frequently over the past two decades and is caused by numerous factors. One of the principal objectives of the WQ Components is to find the reasons for the changes observed in the lake water quality and ecosystem, and identify remedial measures. The water quality of Lake Victoria is the sum of all the inputs and outputs to and from the lake, together with the reaction of the ecosystem to these inputs and outputs. One of the sources or input to the lake is the non point sources, which have been identified to be through rivers and that which falls on the lake directly. The determination of pollution loads from the non-point sources has been limited to nitrogen, phosphorus and suspended sediment loads.

To be able to quantify these loads the study aimed at estimating all non-point pollution loadings to Lake Victoria from all major rivers and the atmosphere and also to identify source distribution in relation to land-use in the catchment. The atmospheric deposition was divided into wet deposition, washed down by the rain, and dry deposition which is the amount of nutrients deposited onto the water surface from the air during dry weather periods. For wet deposition, rainwater has been sampled and analyzed for various parameters including total-nitrogen, and total phosphorus. Due to lack of special sampling equipment for dry deposition, a simple method has been applied implying analysing the increase of nutrients in distilled water exposed in a bucket for a certain time. The total atmospheric deposition load was then calculated by summing up the wet and dry season loads. The effects of sources such as nitrogen fixation by blue-green algae on the lake and detailed assessments of the effect of landuse changes (population pressure, deforestation etc.) are not considered.

The study has confirms earlier findings that the predominant source of nutrient loading to Lake Victoria is atmospheric deposition which contributes to 84 and 75% of N and P respectively, followed by catchment loads contributing about 15 and 23% of N and P of the total loads respectively. These two sources when combined indicate that non point loads accounts for 99% of N and 98%P loads to the lake..

It was observed that there is a tremendous variation in the nutrient loads and sediments of the rivers, both through space and time. For example, nitrogen and phosphorus both accumulate down a watershed as successively larger drainage areas are integrated. These two nutrients also vary significantly with the seasons. Nitrogen and phosphorus concentrations are highest in the early rainfall. This is due to factors associated with early runoffs, such as the release of nutrients stored in the soil Simiyu and Kagera Rivers. These seasonal peaks are most pronounced in the headwaters of the watershed.

1.5.8 Water quality change on beneficial uses

One of the two long-term development objectives of the Lake Victoria Environmental Management Programme (LVEMP) is to maximize the sustainable benefits to the riparian communities from using resources within the basin to generate food, employment and income, supply safe water, and sustain a disease free environment During the LVEMP implementation period 1997 through 2005, the impacts of Water Quality change on beneficial uses of Lake Victoria were investigated. The study area covered the southern Lake Victoria basin located in Tanzania. The data and information were collected through water quality monitoring in the lake, rivers, and municipal and industrial effluents, questionnaires, interviewing a wide range of stakeholders, and review of published data and data collected by health facilities and Water Supply Authorities. The results indicate increasing water quality problems and their associated negative impacts and hence unfitness of Lake Victoria waters for various uses. Pollution loads transported by rivers and municipal and industrial effluent streams are increasing and the sanitary conditions along shoreline settlements are poor. Consequently the water along the shoreline settlements were bacteriologically contaminated and the near shore areas along the urban centers of Mwanza, Bukoba and Musoma exhibited elevated BOD concentrations and feacal coliform counts.

The findings of the current study confirm the deterioration of the lake ecosystem. The lake is generally eutrophicating as algal blooms and invasive water weeds particularly water hyacinth and deoxygenation of the near bottom waters were common. The Bacteriologically contaminated waters are associated with the endemic diseases in the area, coupled with increased turbidity water treatment cost have gone up, and proliferation of water hyacinth led to loss of fish habitat and transport impediment among others. Fish kills resulting from severe anoxic near lake bottom and probably the toxic blue green algae have been reported. The water hyacinth increased the habitat for snails which are secondary hosts for bilharzias parasites. The dominance of cynobacteria, a poor food for fish has caused food limitation in the ecosystem and this may reduce fish production. As eutrophication and increased turbid river inflows are progressively putting off the light in the lake waters, fish vision is increasingly effected and hence the difficultly in selecting food and mating partners and in consequence a derease in their biodiversity. These problems are major impediments to the socio-economic well being of the Lake Victoria riparian communities and need to be addressed in order to sustain the beneficial uses of the lake and eradicate poverty.

1.5.9 Lake monitoring

To date there are several studies carried in the Lake Victoria a number of conclusions being made but most of these studies are based on either single location or single data thus not representative for the entire lake and situation. During the period September 2000 through March 2005, the Water Quality and Ecosystem Management Component in Tanzania undertook an in-lake Water Quality Monitoring in the Tanzanian part of the harmonized in-lake water quality-monitoring network designed jointly by the Water Quality and Ecosystem Management Components of the three Lake Victoria riparian states. The monitoring design involved defining of objectives, selection of monitoring stations and parameters to be monitored, and agreement on field equipment and procedures. It also involved cruise planning, and on-board training. Apart from the harmonized network, eighteen (18) impact-monitoring stations were established to determine trends and how the near-shore areas of the lake are affected by release of contaminants and other human activities carried out in the urban centres of Mwanza, Bukoba and Musoma.

This chapter provides the achievements made and challenges and problems encountered during the period in question and recommends the way forward. During the four and a half (4½) years of monitoring, a total of 16 cruises were undertaken and ……… profiles were obtained and 1688 water, 284 sediment trap, 3403 zooplankton and phytoplankton samples were collected and analysed in the laboratories of Mwanza, Bukoba and Musoma. Also since 1998, a total of 6,044 water samples have been collected from the urban impact stations and analysed in the three laboratories. The experience gained during the period has led to recommendations for improving the monitoring and research including *interalia*: retaining the current 29 stations of the harmonized network and 18 impact stations until a more complete picture of the lake is obtained; retaining the current sampling frequency and ensuring it remains interruption free for a period of one to two years so as to confirm the observed temporal variations in the state of the lake; putting in place a mechanism to sustain an efficient monitoring and research program; putting in place contingency plans for rescue operations in the event of an accident or problem; and procurement of a fast research vessel.

1.5.10 Hydraulics

One of the processes or input which is the driving force to the lake water quality changes is the hydraulic conditions of the lake. To account for this it was required to measure patterns of water circulation in selected parts of the lake in order to determine the interaction between the vertical and horizontal circulation components as well as develop simulation models of the dynamics of nutrients, phytoplankton, benthic biota, suspended sediments and dissolved pollutants. Monitoring in the selected gulfs or bay could give detailed information in a more refined situation; however the whole lake circulation is meaningful. The consequence of the lack of large scale circulations is that the spreading of pollutants from the nearshore areas to the centre of the lake during most of the year is mainly caused by dispersion and not by advection.

Since the ADCP to measure the currents/circulation is not yet available study of the hydraulic conditions is based on the measurements of vertical water temperature profiles at the lake monitoring stations. These data were established by the water quality component for the period from September 2000 to March 2005 Current/velocity variations are simulated by the Lake Model.

Based on the available monitored data of temperature, it can be concluded that, for most of the year, there does not seem to be any recognisable, large-scale horizontal circulation pattern in Lake Victoria. However, it is possible that strong winds in July - Aug (the cause of the total vertical mixing) could cause large scale circulations.

1.5.11 Water quality and Health conditions

Thus, during LVEMP I, an attempt was made to establish the water quality-health relationship in the Lake Victoria basin through water quality assessment, and collection of data and information on waterborne contamination and water vectored diseases. From 2001 to 2004, water quality monitoring along the near shore areas of the urban centers of

Mwanza, Bukoba and Musoma, and rapid assessment of water quality and sanitary conditions along the shoreline settlements were carried out. Information on the common water related diseases associated with poor water quality were also collected through literature search and interviewing personnel working with dispensaries, hospitals, and health centres, as well as district and regional health headquarters. The near shore areas along the urban centers of Mwanza, Bukoba and Musoma exhibited elevated faecal coliform counts, thus indicating high faecal pollution. The study has also shown that the sanitary conditions of the shoreline settlements were poor and hence presented a local public health issue. In addition, water quality and inadequate sanitary facilities data indicated positive correlation with waterborne diseases. The common waterborne diseases associated with the observed conditions include cholera, typhoid, dysentery, diarrhoea, intestinal worms, and amoebiasis. Bilharzia is endemic in the southern and the eastern parts of the lake, where the local customs and nature of the shoreline favour its prevalence. The prevalence of Malaria and HIV/AIDS diseases as well as the status of algal toxins and its associated problems in Lake Victoria are also discussed. Furthermore, recommendations aiming to address the water quality-health related issues and areas for further research are presented.

1.5.12 Pesticides and Metal contamination

Since the activities associated with metal and pesticide contamination of the environment are increasingly carried out in the Lake Victoria basin, the Lake Victoria Environmental Management Project (LVEMP) has since 2000 through 2005 attempted to identify sources and contaminant “hotspots” through rapid assessment of metal concentration levels in water, biota, sediments, and the atmosphere. A review of literature and a pilot study on micro-pollutants with reference to pesticides in the River Simiyu catchment and Magu bay in the Speke gulf, as well as inventory of agrochemicals used in the Lake basin, were undertaken.

The studies have concluded that generally, at present the mining activity in the Lake basin has had no impact on levels of heavy metals in the Lake System. Also to a great extent, it is now apparent that neither fish nor humans are at risk from increased levels of heavy metals particularly mercury in the lake basin. Mercury concentrations in most fish species are generally lower than the WHO maximum allowable concentration of 500 ng/g ww in edible fish parts. In sediments, the concentration of As is less than 6 $\mu g\ g^{-1}$ dw and Cd is below 1.9 $\mu g\ g^{-1}$ dw. Although not extensively used in the River Simiyu catchment, the organo-chlorine pesticides such as dichloro-diphenol-trichloroethane (DDT) and hexachlorocylcohexane (HCH) were frequently detected in water samples. Agricultural areas of the upper catchment contributed significantly to the sources of contamination during high flows in April 2003. The estimated pesticide average daily load during high flows (100 m^3/s) was 4.3 kg/day. Three organo-chlorine pesticides namely DDT, HCH, and Endosulfan with concentrations ranging between zero and 2 $\mu g/l$ were detected in surface water samples from Speke gulf. The elevated concentrations appeared during the rain season in April 2003 when river discharge was high. This suggested that the high contaminant loads were associated with increased Simiyu river discharge to the Speke gulf.

Artisanal gold mining utilizing mercury in extracting gold from its ore remains a potential source of mercury pollution, and the contribution of the identified pesticide residues from the Simiyu catchments to Lake Victoria is significant This emphasizes the urgent need for establishing the status of pesticide contamination in other Lake Victoria tributaries, and calls for efficient pesticide and mercury monitoring and research programmes for both pesticide users and artisanal gold miners in effective application of agrochemicals and efficient ways of gold extraction respectively. Although large-scale commercial miners using cyanide in the production the effluent discharge is zero, it is important to ensure that their systems are closely monitored.

1.5.13 Impacts Of Water Quality Change On Beneficial Uses Of Lake Victoria

During the LVEMP implementation period 1997 through 2005, the impacts of Water Quality change on beneficial uses of Lake Victoria were investigated. The study area covered the southern Lake Victoria basin located in Tanzania. The data and information were collected through water quality monitoring in the lake, rivers, and municipal and industrial effluents, questionnaires, interviewing a wide range of stakeholders, and review of published data and data collected by health facilities and Water Supply Authorities.

Water quality parameters analyzed by LVEMP included nutrients especially phosphorous and nitrates, phytoplanktons and zooplanktons. Some species of phytoplankton like algae produce complex organic compounds, which can cause tastes and odours. They can form a mat on surfaces resulting in clogging or binding of the filter. Some algae produce slime in their outer layers causing slippery surfaces and bad odours. Colour can be caused by the by-products of algae of all types and usually indicates taste and odour problems. Algae can cause the corrosion of concrete or metal structures. As algae grow and die they can bring about changes in the characteristics of the water, which can interfere with the treatment processes. This was evidence from the cost of water treatment cost experience by MWAUWASA. Some algae species present in Lake Victoria are toxic like the blue-green algae thus poisoning fish and livestock. Also, *Anabaena* and *Anacystis* which can cause skin problems and hay fever respectively are also observed in Lake Victoria waters.

From the analysis impacts that were identified includes; 1)drinking water impairment leading to high treatment costs; 2)appearance/outbreak of water related diseases which in a way reduce the workforce and increased medical bills; 3)food web contamination leading to bioaccumulation in higher trophic levels; 4)loss of fish habitat due to increased pollution/eutrophication; 5)inefficient food webs resulting from occurrence of other dominance species which are not easily ingestible by lower and or middle trophic levels; 6)loss of biodiversity and proliferation of unmanageable macrophytes such as water hyacinth.

These impacts are major impediments to the socio-economic well being of the Lake Victoria riparian communities and need to be addressed in order to sustain the beneficial uses of the lake and eradicate poverty.

1.6 Recommended Actions

1. To capture fully seasonal variations of the Lake Victoria ecosystem at least one year of continuous monitoring should be implemented during LVEMP II there after the frequency can be revised to once every three or four months throughout all of the years

2. Basic and contracted research should remain a component during the LVEMP II so that the results are scientifically justified and published

3. Enhance or put in place: legislative, regulatory, and compliance enforcement.

4. Educate, train, and raise awareness for stakeholder

5. Sustain the attained capacity during LVEMP 1through a timely maintenance of the infrastructure and put in place the staff retention scheme to minimize “greener pasture” migration.

6. Employ or establish the GIS/data base/information management so as to keep record of all the data gathered

7. Pilot projects that are aiming at reducing pollution to the lake should be implemented; for example catchment managements and urban sanitation management, etc

8. Mapping the lake area quality against fish abundance thus study the environmental influence on fish ecology

9. Emphasis should be put on measurement of lake circulation (ADCP should be made available to all countries) so that the lake hydrodynamic can be studied as this is the major driving force for pollutants and fish migration

10. Some studies on global and micro climate change should be conducted to determne their possible role in the reduced and declining lake levels.

11. Multi-purpose management of Owen falls and other consumptive use of Lake Victoria waters should be embedded in an ecosystem approach to lake management to ensure optimum results for the beneficial uses of the lake

12. Proper lake management can not be achieved only by water quality monitoring but also require simulation/modeling of possible interventions and meterorological processes, thus a need for training in modeling especially hydrodynamic and quality modeling

13. More studies on hot spot areas and establish the levels of pollution from industries and municipalities in the near shore areas include also hazardous pollutants not only

eutrophication causing parameters. Lake water and fish heavy metal, pesticides and fungicides pollution/contamination

14. Study the role of sediment in transportation of pollutants from the catchment via the river up to the lake and the role of land use in determining rates of erosion, transport and nutrient yield

15. More studies on algal toxin and their effect to health are required

16. In view of the vulnerability of planktons to environmental degradation, future research efforts should emphasize on regular monitoring of the communities in response to water quality changes –these are the major food for the fish and inputs to models that can predict fish production.

17. Conduct social economic studies of water quality of the lake in relation to health and beneficial uses Beneficial uses of lake water include

-Domestic, Agricultural, and Industrial water
-Energy generation
–Tourism -Aquatic life
-Transport
–Recreation
-Waste Disposal
-Cooperation
-Regulating climate

Efforts should be made to put a monetary value for each of these beneficial use and their impacts on lake ecosystem be established.

18. Once water quality objectives are set, then a strategic action plan should be developed by the commission for pollution reduction to meet those objectives and a monitoring program put in place to evaluate progress.

Lake Victoria Environmental Management Project (LVEMP) Tanzania National Water Quality Report:

GENERAL INTRODUCTION CHAPTER

INTRODUCTION

Background:

LVEMP is a comprehensive program conducted by the three countries aimed at rehabilitation of the lake ecosystem for the benefit of the 30 million people who live in the catchment, their national economies and the global community.

The overall objectives of the LVEMP is to maximize the sustainable benefits to riparian communities from using resources within the basin to generate food, employment and income, supply safe water, and sustain a disease free environment; to conserve biodiversity and genetic resources for the benefit of the riparian communities and global community and to harmonize national management programs in order to achieve, to the maximum extent possible, the reversal of increasing environmental degradation.

One of the critical Components of LVEMP concerns Water Quality and Ecosystem Management with the overall objectives of elucidating the nature and dynamics of the lake ecosystem by providing detailed information on characteristics of the waters of the lake; improving management of Industrial and Municipal effluents and assessing the contribution of urban runoff to lake pollution in order to design alleviation measures; and establishing water quality monitoring network throughout the catchment, estimating the effects of changes in land use planning on pollution loads into the lake, and developing policies and programmes to control non-point source pollution

The water quality and Ecosystem Management Component has since the inception of the Project made considerable progress towards understanding the Lake Victoria water quality and its ecosystem as well as effects of resource exploitation. The component have been able to collect considerable amounts of data and information.

The component using historical data and the data it initially collected produced an initial report in 2002, which acts as a baseline water quality status at the start of the project. The data has also been used in scientific fora within the region. But, in order to achieve LVEMP objectives in general and Water Quality and Ecosystem Management objectives in particular a well-coordinated analysis, synthesis and interpretation of all relevant data are required. This synthetic report will document and explain the changes that have taken place over the recent decades, and it will provide an overview of the present water quality status of the and continuing trends that may require remedial action. The report will provide enough detailed information and spatial resolution to support environmental decision making in regards to possible remediation of undesirable changes that have reduced beneficial uses of Lake Victoria biological and water resources.

To achieve this series of working sessions and workshops are conducted under the guidance of a national consultant and one international consultant for the region to help the scientists in the statistical analysis, synthesis and interpretation of the data so far collected by the components.

The report is divided into a number of chapters being (1) General Introduction: (2) Capacity Building: (3) Meteorology/Hydrology: (4) Non-Point Loadings: (5) Industrial and Municipal Effluents Loadings: (6) Hydraulic Conditions: (7) Lake Monitoring: (8) Sedimentation: (9) Eutrophication: (10) Pesticides and Metal Contamination: (11) Water and Health: (12) Impacts of Water Quality Change on Beneficial Uses of the Lake Victoria: and (13) Conclusion and Recommendations:

Bio-Physical, demographic and economic characteristics of the catchment

Freshwater is a basic natural resource, which sustains life and provides for various social and economic water needs. In its natural state, water is an integral part of the environment whose quantity and quality determine how it can be used (MoWLD, 2002). Since it is the basis for all living ecosystems and habitats and part of an immutable hydrologic cycle, it must be respected if development of human activity and well being is to be sustainable. On the whole, Tanzania has sufficient surface and groundwater resources to meet most of its present needs. However, differences in topography, rainfall pattern and climate account for the existing variations in the availability of it in different parts of the country (MoWLD, 2004). Hydrologically, the country is divided into five major drainage systems namely the Indian Ocean Drainage Basin system, the Internal Drainage of Lake Eyasi, Natron and Bububu Depression Complex, the Internal Drainage System of Lake Rukwa, the Atlantic Ocean Drainage and Mediterranean Sea Drainage System. These systems are divided into nine river and lake basins for ease of management of the country's water resources on a River Basin basis (MoWLD 2002). With Lake Victoria falling under the Mediterranean Sea Drainage System. According to the Draft National Water Sector Development strategy of June 2002, Tanzania will face a water stress ($<1700m^3$/cap.year) by the year 2024. It further states that Lake Victoria, and River Kagera and Mara, which, are trans-boundary and form part of the Lake Victoria basins are some of the most abundant surface water resources in the country.

Lake Victoria is the largest equatorial lake with about 6% of its surface lying in the northern hemisphere and 94% in the Southern hemisphere. It is the second largest fresh water lake in the world with an area of about $69{,}500km^2$ (Akiyama *et al* 1997, LVEMP 2002) and has the largest freshwater fishery in the world. It has a shoreline of about 3,450 km, and its terrestrial catchment (Figure 1) covers about $197{,}500km^2$ (LVEMP 2002). Part of the catchment lying in Tanzania (Figure 2) has a total area of $115{,}400m^2$

(LVBWO 2002). The lake is shallow with a mean depth of 40m. Precambrian granites and gneisses are the oldest rocks outcropping in the lake region (older than 600 million years) often, however, they are covered by sedimentary rocks of the Nyanzian series. The later are mainly composed of metasediments, banded ironstones, and acidic and basic volcanics. Fresh dolerites, laterites and early lakebeds made up of a series of the young rocks in the lake Victoria basin with age ranging from Palaeozoic (old) to Kainosoic (recent). The most recent (youngest) being Mbuga, alluvium and some young lakebeds of Kainosoic age *(Brokonsult AB, 1978).* The various rock formations in the basin show some variability in their capacity to yield water (McCann.1972). Significant volumes of water are obtained from fractured or fissured zones. Major rivers flowing into the lake include Kagera in the west, Magogo-Moame, Mbarageti, Grumeti, Mori and Mara to the east. Kagera and Mara are Transboundary Rivers. Kagera drains the mountains of Rwanda and Burundi and Mara enters the country from Kenya. Generally, July is the coolest month and the warmest month is variable and fluctuates in the period between October and February. Rainfall varies considerably per season with maxima in March through May and November through December. The human population within the lake basin is about 30 million and is increasing at a rate of about 4.5% per annum. The lake is a resource shared by the three countries of Kenya (6%), Tanzania (51%) and Uganda (43%). The area of the lake that lies in Tanzania is 35,720km^2 (MLHSD 2000).

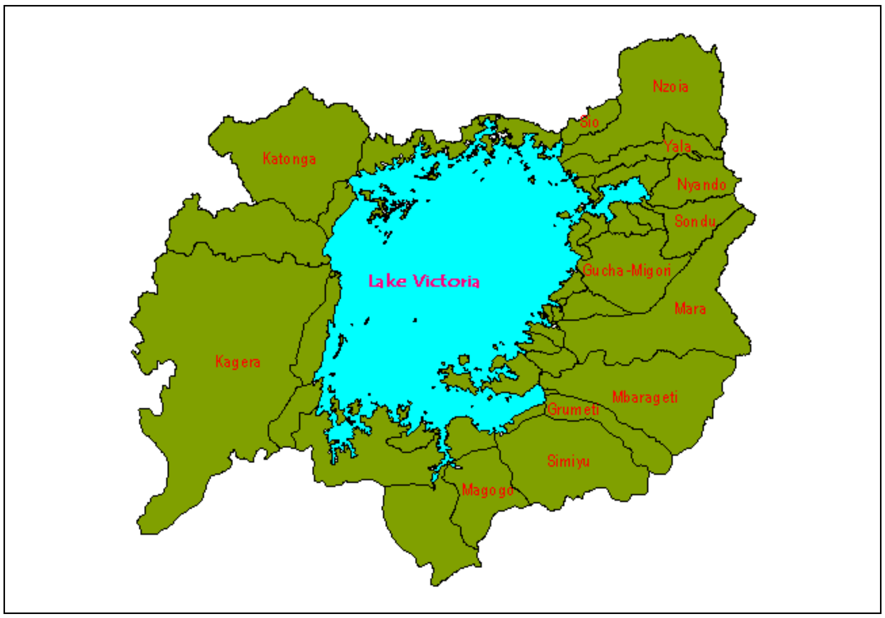

Figure 1: Lake Victoria basin Sub-catchments

Lake Victoria is an economically important water resource in the region. It is a major source of water for domestic and industrial purposes and supports a valuable fishery that supplies fish protein to East Africa as well as other parts of the world. It is estimated that the annual landing of the lake fishery is 500,000 metric tones valued at US$ 600 million locally with exports estimated at US$ 217 million in 2001. The lake is also an avenue for transport and is increasingly becoming a tourist destination due to sport fishing, scenic beauty and wildlife of the area. The Owen Falls hydroelectric power plant that supplies electricity to Uganda, Kenya, Tanzania and Rwanda is located at the lake's outlet to the White Nile in Jinja, Uganda.

Figure 2: Basin Districts: Tanzania side

However, the lake ecosystem has changed with time. Increasing population and socio-economic activities like agriculture, industrial and urban establishment, fisheries etc., have brought about deforestation and overgrazing, and hence soil erosion, increased domestic and industrial waste discharges, greater use of pesticides and destruction of wetlands. These activities have resulted in pollution and excessive nutrient enrichment in the lake (eutrophication). As a result, algal blooms (excessive growth of algae) are more frequent, turbidity of the water is increasing, fish stocks are decreasing and biodiversity has declined. The lake ecosystem was also seriously impacted on by the water hyacinth.

The State Of Lake Victoria Environment Before 1997

Lake Victoria ecosystem has increasingly degenerated since early 1960s both in water quality and its fishery. These changes were driven by high population increase and their associated activities and economic development. The activities resulted in increased flows of pollutants and nutrients to the lake and its tributaries leading to pollution, sedimentation and eutrophication of the lake and public health problems. The lake has also since 1980s been invaded by the water hyacinth which presented a big challenge to environmental managers through chocking of waterways and intakes and interrupting the fishery. These in combination with other problems in turn resulted into decline in biodiversity, dominance of toxic algal species and increased water borne and other water related diseases.

WATER POLLUTION

During the period, it was observed that some of the rivers and streams feeding the lake and the near -shore areas were particularly polluted by raw and partially treated municipal and industrial effluents, contaminated urban surface runoff, and the unsanitary conditions of the shoreline settlements. These introduced into the lake increased coliforms of faecal origin, oxygen demanding organic substances, heavy metals such as chromium, lead and mercury and pesticides. Also some inflow of residues from the use of chemical herbicides and pesticides in some areas in the lake catchment, and specialized industries such as gold mining, were viewed as potential sources of heavy metal and pesticides pollution. The small-scale gold mining activities in Mwanza and Mara regions increased and the use of mercury in recovery of gold posed potential contamination of waterways (leading to the lake). The increased faecal contamination of the near shore lake waters was associated with increased cases of water-borne and other water related diseases including diarrhoea, intestinal worms, cholera, typhoid and dysentery. Proliferation of water hyacinth also increased the habitat for the biomphilaria snails, which are the host for schistosoma responsible for bilharzias.

The lake water quality problems discussed above arose in the watershed and not in the lake. They were actually a result of increased population pressure and the associated increased human activity. It was observed that populations of urban areas along the lake were growing at an estimated 6 percent per annum or more, and rural areas near the lake shore were experiencing in-migration which was causing faster growth of their populations (World Bank 1996).

The population pressure was, in particular contributing to the existence of pollution “hot spots” where there was heavy localized degradation of water quality in the lake, from human waste, urban runoff, and effluent discharges from industries for example in Mwanza, Musoma and Bukoba. In addition, it was observed that there were some inflow of residues from the use of chemical herbicides and pesticides in selected agricultural operations in the lake catchment, and specialized industries such as gold mining, which were potential sources of localized areas of heavy metals. The population pressure also contributed to the inflow of nutrients into the lake, which were responsible for algal build-up, oxygen depletion, and to proliferation of water hyacinth infestation.

Since the level of fertilizer uses in agricultural areas around the catchment was generally low, the main rural source of the nutrients was obviously soil erosion, which released nitrogen and phosphorus held in the natural soil profile. In many instances such nutrients are not available to agriculture, but are released by chemical changes once the soil is washed into the lake (World Bank 1996). In urban areas and shoreline settlements, the main sources of nutrients were human wastes especially from raw and partially treated sewage and the obtaining unsanitary conditions. For example raw municipal effluents were directly discharged into the lake (Kirumba bay) via Mirongo River at a rate of about 2500-3000m^3/s per day during the period Mwanza sewage treatment system was inoperative for more than ten years (Rutagemwa 1997).

Figure 5: Raw municipal effluent discharging into the Mirongo River (in Mwanza) before closure of the by-pass

High population growth coupled with poverty and lack of appropriate agricultural methods also increased pressure on land and natural resources in general. The poor farmers resorted to cultivating in areas with steep slopes, riverbanks, forests and wetlands. These activities contributed to increased soil erosion and thus increased sedimentation of the lake. Overgrazing and deforestation also contributed significantly to soil erosion. Deforestation is mainly due to clearing of land for agriculture, and the rising need for timber used for construction and wood fuel for cooking, and smoking fish.

In squatter areas, inadequate facilities to handle solid and liquid waste and storm water led to pollution of the lake and its tributaries. To date the main sanitary facilities available in these areas are pit latrines, which are usually shallow and rudimentary.

Figure 6: A Rudimentary pit latrine in a squatter area in Igogo ward (Mwanza)

During rainy seasons these latrines overflow and their contents are transported by the surface runoff to rivers and streams and ultimately to the lake. Since it has been a common habit for some of the squatter communities to direct their wastewaters into watercourses, the streams and rivers flowing through these areas were observed to be under stress.

Eutrophication

In lake Victoria, eutrophication has been the result of increased inflow of nutrients particularly nitrogen and phosphorus. During the period under review, the concentration of phosphorus rose markedly in the deeper lake waters and nitrogen in the near shore areas. Stimulated by these nutrients algal growth increased (figure 4) five fold and its composition shifted towards domination by heterocystous blue-green cynobacteria (Hecky 1993). This led to, decline of transparency from 5 meters in the early 1930s to one meter or less for most of the year in the early 1990s (Mugidde 1993). Apart from the massive blooms of algae dominated by the potentially toxic blue green variety the water hyacinth, absent as late as 1989 begun to choke important waterways and landings (World Bank 1996). The waterweed (water hyacinth) mostly infested the relatively shallow sheltered bays and gulfs receiving high nutrient loads from the catchment.

Figure 4: Typical Algal Blooms in Mwanza Gulf.

Increased algal growth caused de-oxygenation of water, increased sickness for humans and animals drawing water from the lake, clogging of water intake filters, and increased chemical treatment costs for urban water supplies (World Bank 1996). Apart from the near-total loss of deepwater species, the de-oxygenation of the lake bottom posed threat even to fish in shallower portions of the lake, as periodic up welling of hypoxic water caused massive fish kills. (Ochumba 1998, Ochumba & Kibaara 1989). Although the causes of eutrophication were known, the rates of enrichment, its sources and its numerous effects in the Lake Victoria basin were not well quantified.

The state of Lake Victoria environment before 1997 mainly stems from the fact that the country's ability to plan, implement and evaluate water quality management activities in a realistic manner had been relatively weak. Since there was no comprehensive water quality-monitoring programme in place during the period, the information on the situation explained above was based on scanty data collected by local and international researchers mostly on *ad hoc* basis. Most of the research was undertaken in the Northern sector of the lake in Uganda and Kenya and only a few were carried out in Southern sector of the lake (Tanzania). But nonetheless, we should be very thankful to the early European, American and the few east African scientists whose work during the period under review has farmed a springboard for the future work aiming to sustainably address the lake Victoria ecosystem problems. As Hecky (1993) rightly said, we are indeed fortunate at Lake Victoria received the attention of some excellent limnologists and fisheries scientists in the 1950's and 1960's.

Although the Water Utilization Act of 1974 had been amended in 1981 to address the water quality issues, its implementation remained ineffective. Additionally, there had been no efforts to involve the communities in effective co-management of the water resources. Considering the UN Millennium Development Goal of ensuring environmental sustainability by 2015, the country on its partner lake Victoria riparian states have a big task ahead. Under the goal, the UN member states have pledged to integrate the principles of sustainable development into country policies and programmes; reverse loss of environmental resources and reduce by half the proportion of people without sustainable access to safe drinking water and sanitation (MDG 2005). The National Water Policy (MoWLD 2002) recognizes the rationale for Integrated Water Resources Management while the National Environmental Policy (VP 1997) seeks to provide the framework for making fundamental changes that are needed to bring environmental considerations into the mainstream of decision making in Tanzania.

LVEMP IMPLEMENTATION

Lake Victoria Environmental Management Project is multidisciplinary environmental project funded by the World Bank. One of the components of LVEMP is the Water and Ecosystem Management. The component comprises of three sub-components namely In-lake Water Quality Monitoring, Management of Industrial and Municipal Waste and Management of Pollution Loading into Lake Victoria. Its objectives include;

Main objectves

- Elucidating the nature and dynamics of the lake ecosystem by providing detailed information on characteristics of the waters of the lake,
- Improving management of Industrial and Municipal effluent, and assessing the contribution of urban runoff to lake pollution in order to design alleviation measures.
- Establishing a water quality monitoring network throughout the catchment, estimating the effects of changes in land use planning on pollution loads in the lake, and developing policies and programmes to control non-point source pollution.

Specific Objectives

- To establish periodic assessment of the physical, chemical and biological characteristics of the lake system.
- To provide details of limnological changes, model and predict their short and long-term consequences, and provide guidelines for ameliorating potentially disastrous changes.
- Provide quantitative information on nutrient loading and recycling in the lake (particularly the internal loading of sediment phosphorus); sources and mechanics of eutrophication and pollution and their effect on lake productivity (with a particular focus on ways to stabilize or reduce eutrophic status); phytoplankton communities and their composition; algal blooms and their dynamics; lake zooplankton, microbes, benthic flora and fauna, lake fly and their roles; primary production including estimation of lake carrying capacity; stratification of the lake and the increasing problem of anoxia; trophic inter-relationships; and lake paleolimnology.
- To measure temperatures in different strata, dissolved oxygen, conductivity, pH, factors affecting light penetration, water clarity, and spectral characteristics, biochemical oxygen demand levels, levels of heavy metals, pesticide residues, abundance and species composition of phyto-and zooplankton, phytoplankton primary production, and levels of B-coli and E-coli.
- (Analysis of these and other data will establish rates of change in water quality, relate these to the observed status of inputs from the catchment, estimate the effects of poor water quality on the economy of the region, and establish the basis for practicable control programme).

- To obtain data (for whole lake) on the fluxes of particulate and dissolved nutrients between the water phase and sediment, and to monitor vertical sediment profiles of dissolved and particulate nutrients (such data is an important input to the understanding of the eutrophication of the lake).
- To estimate sedimentation rate at the mouth of Simiyu River and assess the rates of release of nutrients from sediments, analyse sediment-biota associations, and compare data with soil losses from surrounding areas.
- To measure patterns of water circulation to determine the interaction between vertical and horizontal circulation components, and improve existing estimates of hydraulic retention periods in the lake.
- To develop simulation models of the dynamics of nutrients and phytoplankton which will be used to predict impacts of eutrophication control programmes and pollution intervention strategies
- To prepare inventories and classifications of all factories and industries in the catchment.
- To assess treatment of effluent before discharge and its dilution and dispersion levels in the receiving water bodies.
- To quantity pollution and nutrient flows from urban runoff.
- To identify and characterize pollution “hot spots”.
- To formulate guidelines and effluent discharge standards.
- To establish training arrangements for industrialists and local authorities.
- To launch public awareness campaign, and initiate pilot treatment projects in selected municipalities and industries.
- To create “wetlands” to test tertiary treatment through filtration of industrial waste.
- To create “wetlands” to test tertiary treatment through filtration of municipal waste.
- Rehabilitation and/or extension of urban sanitary systems, which are currently discharging untreated waste directly into the lake.

In the quest to have in place a sustainable management system for water resources of the Lake Victoria basin in the environment constrained by poor economy, the Tanzania government faces the following challenges:

- Eradicating poverty through accessing clean and safe water to all people. While poverty results in environmental stress, the major cause of global environmental deterioration is an unsustainable pattern of consumption and production.
- High population growth rate. Water use is increasing in developing nations twice as fast as population growth. Thus the population boom being experienced will tax water resources that are already overstretched and unevenly distributed.
- Managing the shared water resources. Key water resource issue in Lake Victoria Basin is the presence of international river basin in a climate of weak international water law and weak regional cooperation on water quality and quantity, among the member state. Despite this, very few shared waters are jointly managed at present.

- Developing capacity for water resources management and water quality management in particular which should involve the development of capacity of institutions and scientific technical community and sensitisation of local communities to address the current and future water issues.
- Restoring the lake basin ecosystem particularly the near shore areas and rivers back to the state of the sixties and early seventies.
- Building a culture of science – based management in one of the world's poorest Nation.

CONCLUSION

The data and information available today indicate a continuing deterioration of the Lake Victoria Basin Environment. The population is increasing and the associated human activity. Poor agricultural methods are employed, overgrazing is continuing and demand for firewood is on the increase. Cultivation along the riverbanks is continuing and both untreated and partially treated municipal and industrial effluents continue to enter the lake system. Capacity to handle this condition is quite inadequate as the country belong to the poorest economic of the world. But nonetheless, the government has to ensure efforts made and the opportunities available today should not be wasted for the cost of inaction would seriously erode the economy of the lake basin and the country as a whole. Action that has begun to prevent further damage and potential misery that might follow has to be sustained.

Poverty eradiation as stated out in the millennium goals should be the entry point for minimisation of environmental degradation. The poor do not have access to electricity and thus continue cutting trees for firewood. They continue tilling the land using the same traditional poor methods including burning of bushes and cannot afford improved sanitary facilities. These lead to soil fertility loss, erosion and increased airborne nutrients resulting into nutrient over enrichment of the lake.

As the poor sanitary conditions and untreated effluents continue to introduce the pathogens into drinking water supply sources the water borne and other water related diseases continue to debilitate the people and thus drastically reducing productivity. Provision of safe and clean water, and sanitation and introduction of improved agricultural practices will reduce stress upon the environment.

Water Quality monitoring should be made an integral part of the management of Lake Victoria ecosystem. The monitoring system should be integrated Water Resources Management based, issue driven and results oriented, responsive to changes in the environment, consider the temporal and spatial variability and have a quality control system and be financially sustainable. This in turn requires development of capacity of institutions and the technical community and sensitisation of all stakeholders so to address the current and future water issues. This system will provide accurate data and information upon which informed decisions will be made, and enhanced involvement of stakeholders will increase their sense of ownership. The introduction of Integrated Water Resources Management System in Tanzania, and the opening of the Lake Victoria Basin Water Office in particular should be seen as an important milestone towards sustainable management of the Lake Victoria environment.

As pointed out earlier, shared management of the lake Victoria system is an enormous challenge. Protecting the system requires joint efforts of the riparian countries to create capacity in terms of institutional and human resources development. This will facilitate the riparian countries to enhance knowledge the lake ecosystem, and harmonize legislation and regulations so as to achieve compliance. The current efforts particularly the long term implementation of the Lake Victoria Environmental Management programme (involving Kenya, Uganda and Tanzania) should bring on board the two countries of Burundi and Rwanda in effort to address the lake water quality problems originating from these two countries.

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CAPACITY BUILDING

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ABSTRACT

The current Lake Victoria Environmental Management project is the first phase of a long-term program. The objectives of the first phase are to provide the necessary information to improve management of the lake ecosystem; establish mechanisms for cooperative management by the three Lake Victoria riparian countries, and identify and demonstrate practical, self-sustaining remedies, while building capacity for ecosystem management.

In order to undertake the above tasks sustainably, the project had to build capacity in terms of manpower infrastructure and equipments, and chemical for use in the laboratories. The project financed/facilitated vehicles and boats; laboratory and field equipment; laboratory chemicals and reagents; renovation of offices, laboratories, and monitoring stations; training and workshops; technical assistance; personnel costs, and operation and maintenance expenditures; construction of artificial wetlands; feasibility studies and structures for sanitation; training, workshops, and demonstrations, books and subscriptions to journals and construction of rain gauge stations.

The laboratories of Mwanza, Bukoba and Musoma have been expended/rehabilitated, equipped and stocked with requisite chemicals and reagents. The field and office equipment, and both land and water transport facilities are in place. Component staff have been adequately trained at various levels including certificates (25), diplomas (6), masters degrees (6), and PhD (1).

A functional basin-wide water quality-monitoring network consisting of catchment and land-based stations has been established. A number of decision support systems including conceptual and theoretical models have been either operationalized or are at various levels of development. These include the rainfall-discharge, erosion and nutrient yield, lake hydrodynamics and the Lake Victoria physical processes and water quality models. The Working Sessions Concept has during the project life proved to be a *powerful force particularly* in data quality assessment, sharing experiences, and bringing much closer the water quality experts from Kenya, Uganda and Tanzania. The experts in the World Bank Missions and consultants and collaborators and local communities have always added value to the Component knowledge base. The Cleaner Production training programme for the lake basin industrialists has been appreciated, as the adopted options have proved effective in reducing effluent streams in industries participating in the programme. Since valid data are essential to assess the state of the lake system, evaluate the impact of remediation actions and informed management decision-making, the quality assurance and control program was put in place in collaboration with Kenya and Uganda Water Quality Management Components. It involves field monitoring procedures and laboratory methods, data processing and evaluation, database management and reporting. This has resulted into a wealth of reliable data and information that has been used in the preparation of public awareness campaigns, and information disseminated, and this Water Quality Synthesis report.

INTRODUCTION

The Water Quality and Ecosystem Management Component is one of the eight (8) components of the Lake Victoria Environmental Management Project (LVEMP) implementing the long-term development objectives of the LVEMP carried out under a Joint Project Agreement of September 10,1996 covering Kenya, Tanzania and Uganda. These are to: maximize the sustainable benefits to riparian communities from using resources within the basin to generate food, employment and income, supply safe water, and sustain a disease free environment; and conserve biodiversity and genetic resources for the benefit of riparian countries in particular and the global community in general. The current project is the first phase of a longer term programme whose aims are as outlined above and its objectives are to provide the necessary information to improve management of the lake ecosystem; establish mechanisms for cooperative management by the three Lake Victoria riparian countries; and identify and demonstrate practical, self-sustaining remedies, while simultaneously building capacity for ecosystem management (WB, 1996). Implementation of the Programme required a large investment in form of capacity building. According to the World Bank staff appraisal report for the Lake Victoria Environmental Management Project (June, 1996) it had been estimated that 42 percent of the project cost was to be directed towards capacity building. The project consists two broad sets of activities. The first set of activities are designed to address specific environmental threats, and has taken place in a series of selected **pilot zones**. The second set of activities, has focused on improving information on the lake and building capacity for more effective management and has been **lake-wide** in scope.

It has been providing governments with the necessary skills, information, technical and financial resources for water quality management. It has been building technical capacity to promote, assist and coordinate the various initiatives within the regional framework and helping design a comprehensive set of national policies and strategies based on lessons learned from field experience.

In the pilot zones it had been planned that the project has among others the following in an integrated way: develop groundwater resources; reduce sediment and nutrient flow, especially phosphorus into the lake, reduce faecal colifrom and municipal nutrient output into the lake; and regulate industrial effluent. Among the **lake-wide** actions the project would was to: assess and measure sources of nutrients causing eutrophication; measure fisheries-trophic state interactions; model and monitor lake circulation; define and measure the contaminant threat, harmonize regulation and legislation; monitor recovery and impact; and build institutional capacity. The project was to support among others the following activities; management of lake pollution and water quality, including strengthening and harmonizing national regulatory and incentive frameworks and enforcement capabilities, and establishing a lake-wide water quality monitoring system, improvement of research and information base for pollution control and water quality, pilot investments in industrial and municipal waste management, and priority waste management investments; management of land use in the catchment, including improvement of research and the information base for pollution loading from the catchment; support for institutions for lake-wide research and management, and pollution disaster contingency planning. In line with the above, the Water Quality and Ecosystem Management Component objectives are to elucidate the nature and dynamics of the lake ecosystem by providing detailed information on characteristics of the waters of the lake; improve management of Industrial and Municipal effluents, assess the contribution of urban runoff to lake pollution in order to design alleviation measures; and estimate the effects of changes in land use planning on pollution loads in the lake, and develop policies and programmes to control non-point source pollution. These fall under three sub-components namely in-lake Water Quality Monitoring; Industrial and Municipal Waste Management; and Management of Pollution Loading. The inlake Water Quality Monitoring consist of a core project namely Management of Eutrophication, two pilot projects, Sedimentation Studies and Hydraulic Conditions in Lake Victoria, and a Model of Water Circulation and quality in the lake designed to help manage the problems. The core project aimed to establish periodic assessment of physical and chemical characteristics of the lake system.

In order to undertake the above tasks sustainably, the project had to build capacity in terms of manpower infrastructure and equipments, and chemical for use in the laboratories. The project financed/facilitated vehicles and boats; office, laboratory and field equipment; laboratory chemicals and reagents; renovation of offices, laboratories, and monitoring stations; training and workshops; technical assistance; personnel costs, and operation and maintenance expenditures; construction of artificial wetlands; feasibility studies and structures for sanitation; training, workshops, and demonstrations, books and subscriptions to journals and construction of rain gauge stations.

METHODOLOGY

Training and facilities need assessment were carried out before the capacity was though of. As mentioned earlier, during the first phase of LVEMP, implementation efforts focused on collection of information and data and capacity building for efficient knowledge acquisition for management purposes. This called for rehabilitation/construction of water laboratories and offices, procurement of requisite laboratory and office equipment, chemicals, reagents and other consumables; development/rehabilitation of monitoring stations and making available both land and water transport facilities and communication systems; training of Component staff at various levels at various training institutions; on the job training through consultants and collaboration with other institutions; and interaction with communities, and sensitizing them on issues related with water quality management.

RESULTS AND DISCUSSION

Building of the capacity to undertake tasks pertinent to water quality management focused on personnel development, laboratory and field infrastructure, monitoring network and databases, and conceptual and theoretical models.

Personnel

Given the level of tasks to be undertaken, the required expertise, and the diversity of areas pertinent to water quality management, training at various levels ranging from short courses to Master and PhDs were arranged. The master's degrees focused on Water Resources Management, Water Quality Management and Environmental Science and Technology. The short courses included general water and wastewater analysis, nutrient analysis, and quality assurance and quality control, algal taxonomy, and environmental auditing.

Other member of staff undertook training courses in computing at different training institutions. A summary of staff trained under the project is given in table 01. One scientist is still pursuing a

Doctorate Programme on Modelling of Micronutrients and is expected to complete the studies early next year (2006).

Table 01: Summary of Component staff trained and corresponding training levels:

Course	Number trained
PhD	1
Masters	6
Diploma	7
Short Courses	21

On-board training

Initially, the cruse team received the on-the job tranng conducted by the Consultant in a one-day cruises from Mwanza. The consultant also orientated himself about capacities and instrumentation of the vessels, sampling equipment and procedures for sampling and facilities for storage of samples. These demonstrations were important background for the further planning and the adjustment of procedures later agreed on. Further the consultant participated in a another sampling cruise from Mwanza to TP18 located in the middle of the lake.

Figure 01: The Joint Cruise team onboard RV TAFIRI II at Port Bell in Uganda - August 2002.

Figure 02: On-board training

The Working Session concept introduced by the Consultant on Integrated Water Quality/Limnology Study brings together the experts on different disciplines of water quality management. The disciplines include eutrophication, water chemistry, water laboratories management, database management, hydrology, meteorology, non-point pollution loading and industrial and municipal effluents. During the working sessions the experts from the three Lake Victoria riparian countries in small groups analyse and evaluate data and information collected and share experiences. The concept has proved to be a powerful force particularly in data quality assessment and bringing the experts from the three countries much closer. It may be argued that working session are costly, but experience shows that the benefits by far out weight costs involved.

Outreach through workshops relevant to water quality management

The communities of the lake basin are an important force in the efforts to rehabilitate the lake. Thus, awareness campaigns to sensitize the public has been an important aspect of the training programme. The sensitization and dissemination of information and research findings have been carried out in form of seminars and workshops, newsletters, bronchures, newspapers, scientific publications, and radio and television programmes. Another avenue for sensitizing the general public has been through invitations of students from the Universities and other higher institutions of learning to undertake their field practical training with the project. Primary and secondary school students have been preparing their project write-ups as a result of interaction with the project.
The project has also provided opportunity for the staff to learn from each other through varied activities such as the joint cruise and study tours.

Efforts aiming to minimize waste production and improve effluents quality and human health, water and sanitation at pilot level have been made. Pilot constructed wetlands to serve as tertiary treatment systems for industrial and municipal effluents, are being studied and feasibility studies, EIA and preliminary designs for a community based simplified sewerage scheme for Igogo ward in Mwanza City have been undertaken. National reviews and Regional harmonization of effluent and receiving water standards are on going, and development of a water quality model as a management tool for Lake Victoria and policies and programs to control non-point source pollution are in progress. Thirty-two (32) shallow wells have been constructed along some shoreline settlements to provide safe and clean water for about 30,000 people

Public education and awareness campaigns, environmental standards, legal policies and some kind of provision of disincentive to pollute are measures put in place to check pollution in the Lake Victoria basin. It is crucial that the quality of effluent discharged, directly or indirectly, into any water body be strictly controlled by regulations, which prescribe a comparatively high standard of purity. In view of the above, a system of issuing discharge permits through the Lake Victoria Basin Water Office has been put in place to keep the levels of pollution under control.

In the efforts to sensitize the communities a number of workshops and seminars were conducted. These include the LVEMP inception workshop of 1997 held in Mwanza to introduce the stakeholders and the general public to the project; the district level sensitization workshops, which covered a wider audience; and the National Scientific Conference of 2001, which provided progress on the implementation of the project.

Furthermore, a stakeholders' workshop on Component vision was held at Mwanza in 2002 followed by a stakeholders' workshop on Integrated Water Quality/Limnology study findings. Also two stakeholders' workshops on Cleaner Production including Managers workshop and the general workshop were held.

Laboratory and field infrastructure
Laboratory Capacities

Following the anticipated increased workload the water quality laboratories were rehabilitated/expanded and equipped and stocked with requisite chemicals and reagents. For instance Musoma Laboratory was upgraded from a container to a separate building(Fig…) likewise Mwanza and Bukoba laboratories were rehabilitated and expanded

The container used to house the laboratory before relocation to the rehabilitated building (on the left)

Figure 03: The Musoma Laboratory

Analyses contributing to the Synthesis Report

Based on the earlier identified water quality issues large number of samples were collected from the monitoring network and analyzed for the following selected parameters:

- Physical: light attenuation, secchi depth, temperature, pH, Conductivity, turbidity, and current speed and direction
- Chemical: Chlorophyll, alkalinity, PO_4, NH_4, NO_2+NO_3, SI, TPN, TPP, TPC, PBSi, DON, DOP, Dissolved reactive silicon, Chlorophyll-a
- Biology: Counts on phytoplankton, zooplankton and benthos with necessary information on sample size.
- Sediments: trap measurements of DW, TPC, TPP, TPN and TBSi with necessary data on exposure time, depth and dimensions of traps.

I. Lake Monitoring

a) Harmonized Water Quality Monitoring Network:
Physical-Chemical, Biological:
Temperature, DO, EC, pH, TN, TPN, DON, NO_2, NO_3, NH_4, TP, TPP, DOP, PO_4, Si, TSS, Phenol Alkalinity, Total Alkalinity, LOI, Chloride, Turbidity, Magnesium, Calcium, Total Hardness, Chlorophyll-a, TBSi, Na^+, K^+.

b) Urban Impact Stations:
Physical-Chemical, Biological:
Temperature, DO, EC, pH, TN, DON, NO_2, NO_3, NH_4, TP, TPP, DOP, PO_4, Si, TSS, Phenol Alkalinity, Total Alkalinity, Chloride, Turbidity, Magnesium, Calcium, Total Hardness, Chlorophyll-a, FC, Na^+, K^+.

II. Industrial and Municipal Effluent Monitoring

a) Industrial Effluents:
Temperature, DO, EC, pH, TN, DON, NO_2, NO_3, NH_4, TP, TPP, DOP, PO_4, Si, TSS, Phenol Alkalinity, Total Alkalinity, LOI, Chloride, Turbidity, Magnesium, Calcium, Total HardnessBOD_5, COD, FC.

b) Municipal Effluents:
Temperature, DO, EC, pH, TN, DON, NO_2, NO_3, NH_4, TP, TPP, DOP, PO_4, Si, TSS, Phenol Alkalinity, Total Alkalinity, Chloride, Turbidity, Magnesium, Calcium, Total Hardness, BOD_5, COD, FC, FS.

c) Urban Runoff:
Temperature, DO, EC, pH, TN, DON, NO_2, NO_3, NH_4, TP, DOP, PO_4, Si, TSS, Phenol Alkalinity, Total Alkalinity, LOI, Chloride, Turbidity, Magnesium, Calcium, Total Hardness, BOD_5, COD, FC, FS.

d) Constructed Wetland:
Temperature, DO, EC, pH, TN, LOI, TPC, BOD_5, COD, DON, NO_2, NO_3, NH_4, TSS, Si, FC, FS, (Hg, Cd, Cr, Pb, Na^+, K^+.) samples sent to Dar es Salaam for analysis.

III. Management of Pollution – Loading

a) Rivers:

Physical-Chemical, Discharges

EC, pH, Temperature, Turbidity, Phenol Alkalinity, Total Alkalinity, Total Hardness, Chloride, Calcium, Magnesium, NO2, NO3, NH4, TP, DOP, PO4, TSS, TN, DON, Si, Na^+, K^+.

b) Atmospheric deposition:

pH, Alkalinity, NO_2, NO_3, NH4, TP, DOP, PO_4, TSS, TN, DON, Si, Hg.

Table 02 summarizes the number of samples (and other managements) collected from the whole monitoring network each year and analyzed. It is there analyses, which have contributed to this report.

Table 02: Samples collected from the monitoring network and analysed during the period 1999-2005

Number of samples (and other measurements) collected from the whole monitoring system each year and analyzed: Tanzania									
Type of Collection	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	
In-lake samples (HMS)			250	482	330	447	179		
Atmospheric deposition		4	26	109	110	152	130		
River sedimentation samples			22	31	53	124	55		
In-lake sedimentation				114	40	100	30		
Zooplankton and phytoplankton			500	964	660	894	358		
River gauging station		60	11	40	672	749	386		
Impact stations (in-lake)	968	1269	1685	1108	183	404	427		
Urban run-off samples	24	221	528	301	94	343	332		
Municipal effluents samples		6	27	33	40	110	56		
Industrial effluents samples		5	207	251	110	206	289		
Artificial Wetlands samples							115		
Rain gauges			137	207	117	77	47		
Shoreline settlements samples	355	668	1273	298	443	231	92		
Total	**1347**	**2233**	**4666**	**3938**	**2852**	**3837**	**2496**		

Field access and deployment

A number of field equipment were installed including automatic water level recorders in Bukoba (1) and Musoma (1); automatic weather stations at Kuruya. Primary school in Mara (1) and onboard RV TAFIRI II (1); rain gauge stations (5). Water quality data logger houses were constructed in Bukoba (1), Mwanza (1) and Musoma (1) but the data loggers were not installed in fear of vandalism experienced during the project period.

A constructed wetland to serve, as a tertiary treatment system for municipal effluent treatment is currently being used for data collection in Mwanza constructed wetland (figure 4).

Figure 04: A constructed Wetland at Butuja in Mwanza City

Research Vessel

The research vessel RV TAFIRI II was made available by the Tanzania Fisheries Research Institute (TAFIRI) after signing a memorandum of understanding with the component on 22 August, 2000.

The research vessel basically designed for trawling task was modified to accommodate the new task of water quality monitoring. It is equipped with a video sounder, VHF radio, hydro graphic winch, a compartment for laboratory work, a deep freezer for storage of samples, kitchen facilities, toilet and bathroom and ten (10) beds. Others are a standby generator, radar, global position receiver, navigation compass, and a life raft.

Transport facilities

To facilitate data collection from the field, both land (cars, and motorcycles) and water transport facilities (fibreglass boats and dinghies powered by outboard engines) were put in place. Other facilities such as mobile cableway system, current meters, global positioning receivers and satellite telephone are in place.

Quality Assurance/Quality Control

Valid data are essential to assess the state of the environment, to track rehabilitation in areas of concern and evaluate progress. The execution of a quality assurance program provides information necessary to assess the validity of the data and to substantiate the conclusions drawn from these data (GLWQB 1989). Thus, the success of the Water Quality Management Component during the period under review entirely depended on the availability of high quality data on the input of nutrients to the lake and concentration in the lake, and other parameters related pollution to the lake and its consequences. This calls for putting in place a Quality Assurance/Quality Control Programme by the three riparian countries implementing the Project. The sampling, field measurements, preservation and analytical methods employed were selected and agreed upon jointly by the three countries so as to facilitate ease of comparison of field and laboratory data. Due to inexperience, the initial data had some problems, but as time went by and the staff got trained in field and laboratory procedures the collected data progressively improved. During the World Bank Mission (2001) it was observed from the fist performance evaluation exercise that data collected was questionable……. This being a new undertaking in the region it should be seen as a common problem in many area of the world attempting to produce good quality data. For example, The Great Lakes Water Quality Board (1989) reports, *"Based on the round robins, in its 1985 and 1987 Reports, the Board described the poor performance of many laboratories. For example, many laboratories that measure the concentration of phosphorus in effluent from municipal sewage treatment plants had difficulty performing the analyses. The Board's most recent (1989) round robin confirms that problems persist for measurement of this relatively straight forward contaminant, and the Board's previous concerns remain valid".* The Regional Interlaboratory Performance Evaluation Report (2005) recorded an excellent to satisfactory performance by the three laboratories of Entebbe, Kisumu and Mwanza.

Monitoring network and databases
Monitoring network:

It was to measure temperatures in different strata, dissolved oxygen, conductivity, pH, factors affecting light penetration such as suspended silt/sediment concentrations, water clarity, and spectral characteristics, biochemical oxygen demand (BOD) levels, levels of heavy metals (mercury, chromium and, lead) pesticide residues, abundance and species. Composition of phytoplankton and zooplankton, phytoplankton, primary production, levels of B-Coli and E-Coli. Analyses of these and other data to establish rates of change in water quality, relate these to the observed status of inputs from the catchment, estimate the effects of poor water quality on the economy of the region, and establish the basis for a practicable pollution control programme.

The program to provide details of limnological changes, model and predict their short and long-term consequences, and provide guidelines for ameliorating potentially disastrous changes. The program to provide quantitative information on nutrient loading and recycling in the lake (particularly the internal loading of sediment phosphorus); sources and mechanics of eutrophication and pollution and their effect on lake productivity (with particular focus on ways to stabilize or reduce eutrophic status); phytoplankton communities and their composition; algal blooms and their dynamics; lake zooplankton, microbes, benthic flora and fanna, lake fly and their roles; primary production including estimation of lake carrying capacity; stratification of the lake and the increasing problem of anoxia; trophic inter-relationships; and lake palaeo-limnology.

The pilot sedimentation study to estimate sedimentation rates at the mouth of Simiyu river. Assess the rate of release of nutrients from sediments, analyse sediment-biota associations, and compare the data soil losses from surrounding areas.

The pilot hydraulic study to measure patterns of water circulation in Mwanza bay to determine the interaction between vertical and horizontal circulation components, improve existing estimates of hydraulic retention periods in the lake, and develop simulation models of the dynamics of nutrients and phytoplankton which will be used to predict the impacts of eutrophication control programmes and pollution intervention strategies.

The Industrial and Municipal Waste Management consists of one core project, namely Management of Industrial and Municipal effluents, two pilot projects on Integrated Tertiary Municipal Effluent Treatment, and Integrated Tertiary Industrial Effluent Treatment, and component for Priority Waste Management Investments. It is to prepare inventories and classifications for all factories and industries in the catchment, assess treatment of effluent before discharge and its dilution and dispersion levels in the receiving water bodies, quantify pollution and nutrient flows from urban runoff, identify and characterize pollution “hot spots” formulate guidelines and effluent discharge standards, establish training arrangements for industrialists and local authorities, launch a public awareness campaign, and initiate pilot treatment projects in the urban centers of Mwanza and Bukoba, and selected industries.

The pilot industrial effluent treatment will create “wetlands” to test tertiary treatment through filtration of industrial waste from various industries in Mwanza City. The pilot municipal effluent treatment to create “wetlands” to test tertiary treatment through filtration of municipal waste in Mwanza City. The programme of Priority Waste Management Investments to construct a community-based simplified sewage scheme in a portion of Mwanza and improve a sludge disposal site in Bukoba municipality.

Management of Pollution Loading to establish a water quality monitoring network throughout the catchment, estimate the effects of changes in land-use planning on pollution loads in the lake, and develop policies and programmes to control non-point source pollution.

Until June 1997 there was no regular water quality-monitoring programme for the Tanzanian portion of the Lake Victoria Basin (Rutagemwa 2000). Thus, this programme is the first comprehensive programme on this part of the lake basin. The design of the monitoring network is based on the objectives and the corresponding answers and information to be generated. It focuses on the media to be sampled including water, sediments and biota, a range of variables (physical, chemical and biological) to be measured as summarized in table 01 and the frequency of sampling, and the hydrological and meteorological parameters. The sampling, field measurements, preservation and laboratory analytical methods employed were jointly selected and agreed upon by the three Lake Victoria riparian countries of Kenya, Uganda and Tanzania. This facilitates ease of comparison of field and laboratory data collected by the three countries.

The in-lake water quality monitoring stations fall into two categories namely the Harmonized Water Quality Monitoring network designed jointly by the Water Quality and Ecosystem Management Components of the three Lake Victoria riparian countries, and the Urban lake (impact) stations located along the three major Tanzanian lake Victoria riparian urban centres of Mwanza, Bukoba and Musoma.

Harmonized Monitoring Network

The study area was divided in two main zones namely the open waters herein referred to as pelagic are (P) and the near shore areas herein referred to as the littoral zone (L). This classification is based on the depths with pelagic area having depths greater than 15 metres and littoral area having depth less then 15 metres. Again based on its large surface area and shallow depth, and the fact that some of the bays are sheltered while others are open, and the variation in climatic conditions between the east and west and the preliminary hydraulic and thermal conditions established by earlier research, the desk design came up with 18 pelagic stations and 11 littoral stations. Each of the stations was located in such a way it fell on a transect joining the Ugandan or Kenyan stations of the harmonized monitoring network. This is meant to examine the temperature profiles along and across the lake at a number of instants in time. This can illustrate for example the variations from north to south and east to west at any one instant.

The naming convention for the stations is as follows:
First letter: Country. T=Tanzania, Second letter: L = Littoral (inshore). P = Pelagic (offshore).
The locations of the stations were chosen so that, as near as possible, they lie on transects along and across the lake.

A data collection system involving the establishment of a lake-wide water quantity and quality-monitoring network and focusing on point and non-point source pollution loadings, eutrophication, hydraulic conditions, and pollution of the lake was put in place. The monitoring network consists of catchment (rivers, municipal and industrial effluents, and atmospheric deposition) and lake-based stations. The in-lake stations comprise of 18 impact stations located along the major urban centres, and 18 pelagic and 11 littoral stations in the southern part of the harmonized network jointly designed by Kenya, Tanzania and Uganda (figure 05).

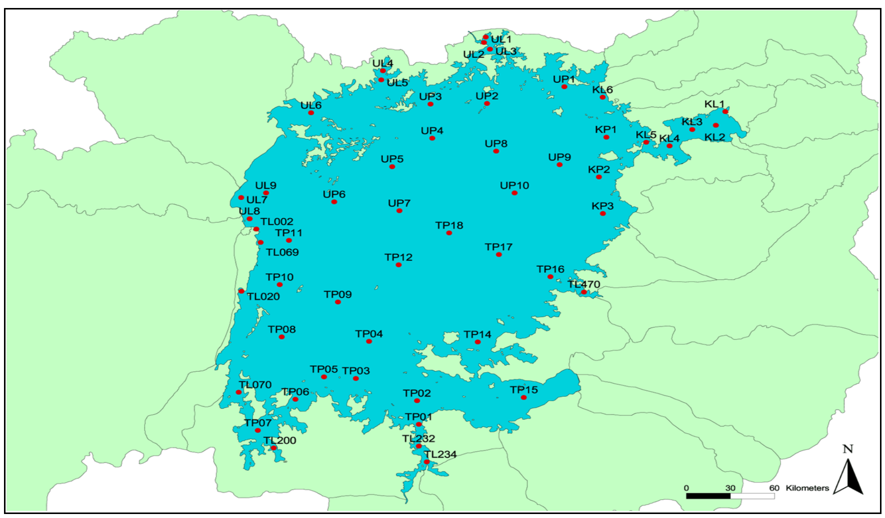

Figure 05: The harmonized in-lake Water Quality Monitoring network established in 2000.

Table 03: In-lake Water Quality Monitoring Network Tanzania

S/No.	Station Number	Global Position		Maximum Depth (in m)
1.	TL-002	31.858217	-1.011017	9.30
2.	TL-020	31.767133	-1.480900	12.50
3.	TL-060	31.883150	-2.110783	7.00
4.	TL-070	31.748517	-2.245183	11.00
5.	TL-200	31.991500	-2.705167	4.00
6.	TL-230	32.868350	-2.590800	9.40
7.	TL-231	32.853467	-2.617783	7.90
8.	TL-232	32.839333	-2.657350	5.00
9.	TL-233	32.868250	-2.711883	4.80
10.	TL-234	32.897483	-2.774050	4.50

11.	TL-470	33.912033	-1.512017	3.50
12.	TP-01	32.849533	-2.490683	17.0
13.	TP-02	32.838390	-2.310217	43.5
14.	TP-03	32.464950	-2.141067	53.0
15.	TP-04	32.546367	-1.860817	60.00
16.	TP-05	32.269967	-2.129033	51.40
17.	TP-06	32.095250	-2.299667	27.00
18.	TP-07	31.866033	-2.534867	11.50
19.	TP-08	32.012017	-1.826717	50.00
20.	TP-09	32.012017	-1.826717	59.00
21.	TP-10	31.999533	-1.430833	42.00
22.	TP-11	32.058717	-1.096050	38.30
23.	TP-12	32.723417	-1.282250	68.10
24.	TP-13	32.209483	-1.865867	70.40
25.	TP-14	32.209483	-1.865867	44.30
26.	TP-15	33.271217	-2.310217	22.40
27.	TP-16	33.653450	-1.371483	48.00
28.	TP-17	33.337833	-1.203083	71.00
29.	TP-18	33.088333	-1.143333	68.50

The catchment stations comprise of fifty-five (55) urban run-off stations, thirty-seven (37) industrial and municipal effluents stations, ten (10) rain-gauge stations (Figure19), eight (8) wet/dry atmospheric deposition stations, ten (10) river gauging stations, two (2) Lake water-level recorders and two (2) automatic weather stations. Other data was collected from the traditional hydrometric, and meteorological stations and the 600-shoreline settlements were used for rapid water quality assessment. A variety of new, high tech equipment was procured to facilitate acquisition of requisite data. The data collected is analyzed and stored in the simple excel based database and later transformed into information packages for stakeholders and decision makers.

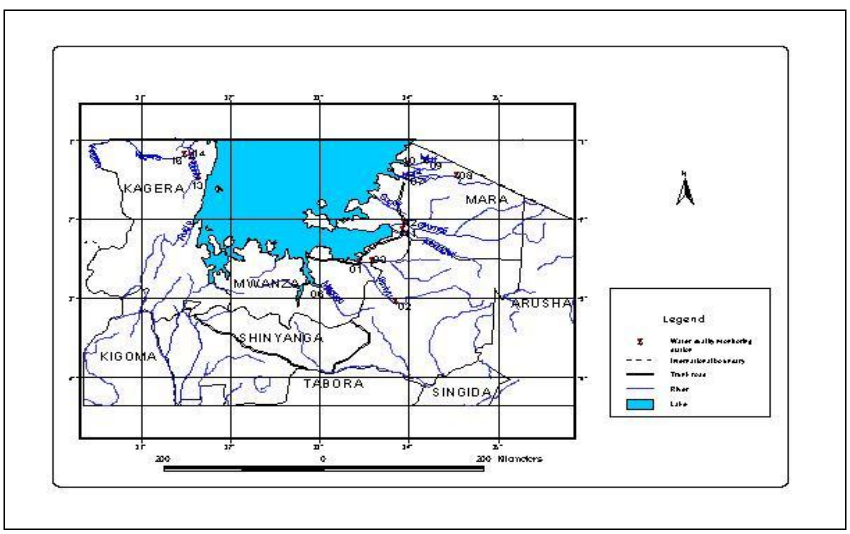

Figure 06: River Water Quality Monitoring Stations in Tanzanian

Urban lake station (impact) monitoring

The in lake impact stations are located along the three urban centres of Mwanza, Bukoba and Musoma with six stations each. (Table. 02, 03, and 04). Selection of the stations was based on influences that caused water quality to vary from place to place and from time to time. Some are located near entrances of streams, effluent outfalls, river mouths.

The selected parameters are: Colour, Turbidity, Alkalinity (Total), and Chloride; Permanganate value, Total Hardness, Calcium, Magnesium, pH, and E. Conductivity; Total dissolved solids, Total phosphorus, Dissolved Reactive phosphorus, Dissolved $O_{2,}$ and Feacal coliform; Total Coliforms, Nitrite $-N_{2,}$ Nitrate $-$ $N_{2,}$ Ammonia $-$ $N_{2,}$ Suspended solids (T.S.S), Silicon (SiO2, DRSi), and Chlorophyll-a.

Table 04: Mwanza Littoral Impact Stations

S/No.	Name of Location	Station Code	Latitude	Longitude
1.	Butuja		S 02º 26.996’	E 032^{0}54.920'
2.	Mahina		S 02º 28.713’	E 032^{0}52.649'
3.	Mirongo river mouth		S 02^{0}30.489’	E 032^{0}53.741'
4.	Capri point		S 02^{0}31.666’	E 032^{0}53.098'
5.	Nyashishi river mouth		S 02^{0}38.926’	E 032^{0}53.436'
6.	Tilapia		S 02^{0}31.966’	E 032^{0}53.739'

Table 05: Bukoba Littoral Impact stations

S/No.	Name of Location	Station Code	Latitude	Longitude
1.	Nyamkazi River mouth	TL 4	31.820	-1.330
2.	Nyamkazi Fishing mouth	TL 6	31.828	-1.333
3.	Kanoni river mouth	TL 9	31.820	-1.340
4.	Bukoba W/S Pump house	TL 10	31.815	-1.346
5.	Kemondo Wharf	TL 18	31.751	-.1478
6.	Kyetema River mouth	TL 16	31.763	-1.460

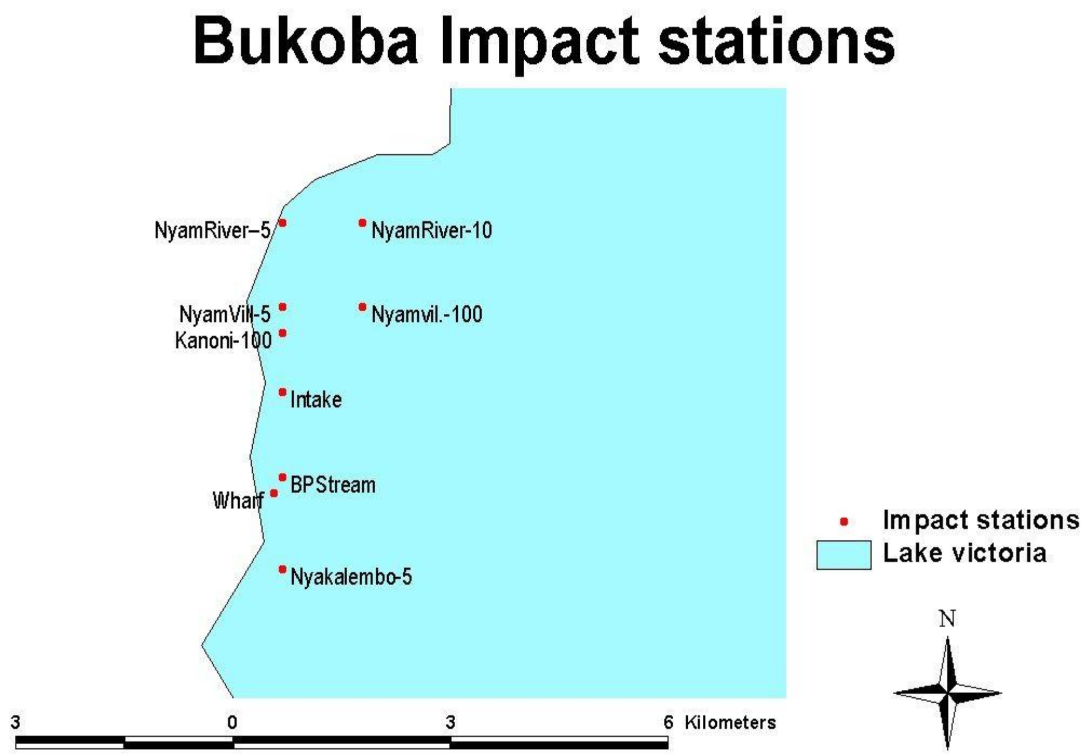

Table 06: Musoma Littoral Impact stations

S/No.	Name of Location	Station Code	Latitude	Longitude
1.	Makoko Point	TL 456	-1.149	33.79
2.	Mwisenge Point	TL 457	-1.49	33.80
3.	Water Pumping Station	TL 458	-1.48	33.81
4.	Mwigobero	TL 462	-1.50	33.82
5.	Machinjioni	TL 467	-1.52	33.84
6.	Mara Mouth	TL 471	-1.52	33.97

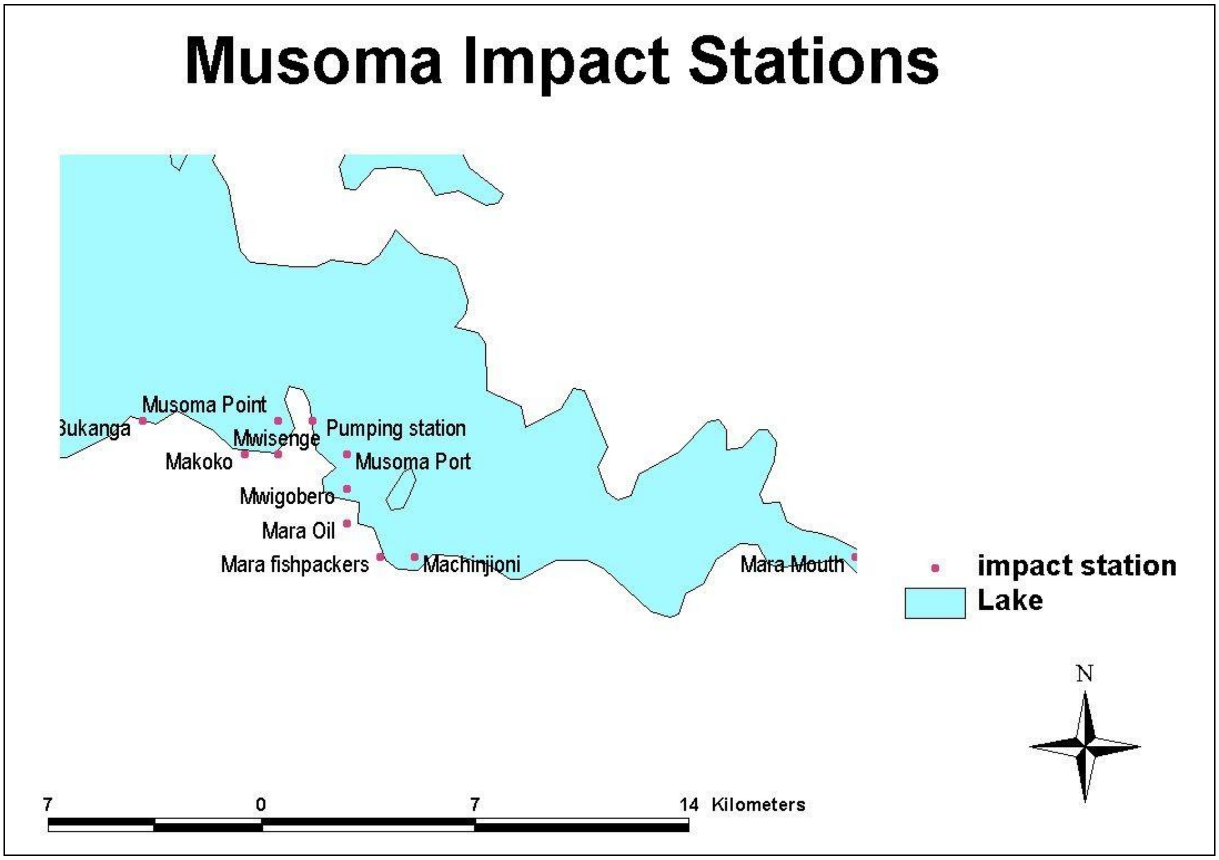

Figure: 08: Musoma Urban Impact Stations

Databases

The Water quality and Ecosystem Component of the LVEMP has conducted extensive field monitoring activities both in the lake and in the catchment. These activities have collected large amounts of data on meteorology, hydrology, pollution loadings from the catchment, industrial and municipal effluents and on water quality and ecosystem in the lake. The data collected are stored in databases as follows:

- **The meteorological and hydrological data** are stored in two databases, the Lake Victoria Basin Database (LVBD) and the Hydata system.

The LVBD consists of the following information:

a) Meteorology (12 stations)
  - Daily maximum temperature, daily minimum temperature, daily lows of sunshine, daily relative humidity and daily rainfall.

b) Stream flow (9 stations) and average daily gauge height (8 stations)

- **Water Quality data**
  During the inception phase of the Integrated Water Quality/Limnology study for Lake Victoria it was agreed that a common and proper water quality database be established for us in the three

Water Quality Component Centres of Mwanza, Kisumu, and Entebbe. It was further agreed that it should be based on standard database software and include GIS facilities in the user interface and for the analysis and presentation of data. A working session for the preparation of the TOR was held in Mwanza in the period 19-23 February 2001, but the Consultant for the task was never contracted.

However, the consultant for the Integrated Water Quality/Limnology study provided on Excel-based Water quality database for storage and presentation of data which is still in use especially for the in-lake data. It is built up with the use of correct relational database principles and allows queries for sorting and selecting data according to a range of user specified criteria. It can produce plots of, e.g. vertical profiles of parameters measured in the lake, and all data measured by instruments onboard survey vessels and the results of all the subsequent laboratory analyses of the water samples. It can also store the results of sediment experiments. The data on water quality and the industrial and municipal discharges collected by field programmes in the catchment can also be stored in the database.

The database has been used very effectively and has proved to be a valuable tool.

Conceptual and Theoretical Models Operationalized

Rainfall – Discharge Models

Rainfall – discharge models are applied to fill gaps in the river discharge measurements. They are also used to estimate the runoff from ungauged catchment

Three different models were considered for use in the river discharges study as follows:

- **Sacramento Model**
  The Sacramental Model is used in the Lake Victoria Decision Support System on which two LVEMP staff had been trained for six (6) months on its use. An attempt to use the model proved futile for the Tanzanian rainfall data was monthly whereas the Sacramento Model requires daily data; It proved difficult and time consuming to reformat the enormous quantities of data for use as input to the model and in general it was not user friendly.

- **NAM Model**
  NAM is an abbreviation of a Danish name, "Nedboer-Afstroemning Model" which means Rainfall – Runoff Model. It is a conceptual model with the following characteristics:

- Lumped (the entire catchment is considered as a single unit with uniform properties.
- The flow of water through the system is conceptualized into a number of reservoirs.
- The parameters partly reflect the physical properties of the catchment.

- **SMAP Model**
  The SMAP model is also a Conceptual Model, but simpler in structure than Sacramento and NAM because it has fewer reservoirs.
  It is best suited to use with monthly rainfall data and was therefore chosen for use on the Tanzanian catchments.

Lake Victoria Decision Support System

The Lake Victoria Decision Support System (LVDSS) Version 2.0 is a comprehensive decision support software for the visualization of spatial and temporal planning of agricultural production, remote sensing of hydrometeorology, simulation of watershed hydrology, regulation of lake level, and operation of the Owen hydroelectric power plant in the Lake Victoria Basin in eastern Africa. This basin includes portions of the nations of Burundi, Kenya, Rwanda, Tanzania, and Uganda. This version of LVDSS includes visualization of five kinds of data (Meteorology, Hydrology, Soils, Land Cover/Terrain, and Population/Political Units) and six application models (Remote Sensing, Hydrologic Simulation, Agricultural Planning, Owen Falls Turbine Allocation, and Lake Management). This manual describes the use of the data visualization modules and the input and output interfaces of the application models.

Lake Victoria is a large and complex system, and it is hard to determine the effective measures for environmental management of the lake basin and to select measures that are in good balance with the (economic) needs of the people, who are living at its shores. In view of this, it is clear that the formulation of common environmental policies is a demanding task models can effectively support the process of optimising and tuning these policies.

However, the use of models for environmental management and decision making is a relatively new science understood by few people. It is, therefore, to be expected that Government staff and staff of many organisations may not have clear expectations regarding the usefulness of modelling. The same applies to the connected collection of data and the related development of insight in the behaviour of aquatic ecosystems. Modelling has its own demands for monitoring, data collection, and knowledge development.
Tanzania National Secretariat in recognition of the need of water quality modelling and the complexity of the exercise did seek collaboration with the University of Dar Es Salaam through Prof. Mwanuzi to give guidance in model application. A number of on-job training has been conducted on model basics including the data requirements and formats. Among the topics covered in the orientation/training were;

- The usefulness and possible uses of the modelling framework for lake basin management and decision making;
- The need to develop monitoring, data collection and research programmes adequate for modelling and which are at the same time cost-effective and sustainable; and
- The need for national and regional tuning of the activities for monitoring, data collection and environmental policy development.

The scientists responsible for modelling now need an in-depth training with the model developer on model usage as a management tool and short course on hydrodynamics, which is the driving force for pollutants movements.

Input data required for the **hydrodynamic model** from Tanzania include:

- Geometry (boundaries of land and islands, inflow locations of rivers, bathymetry); this hah been updated from our cruises depth soundings.
- Meteo forcings (spatial and temporal patterns of wind speed, wind direction, air humidity, air temperature, air pressure, cloudiness, precipitation, evaporation) in the preliminary

model the global winds are applied the actual wind data to be incorporated during the anticipated training with the model developer.

- River inflow (discharge rates, temperature, sediment load) this is available for period 1950 to March 2005.

Input data required for the **water quality model** from Tanzania include:

- Geometry (boundaries of land and islands, inflow locations of rivers, bathymetry); this hah been updated from our cruises depth soundings.
- Meteo forcings (spatial and temporal patterns of wind speed, wind direction, air humidity, air temperature, air pressure, cloudiness, precipitation, evaporation) in the preliminary model the global winds are applied the actual wind data to be incorporated during the anticipated training with the model developer.
- River loads (discharge rates and concentrations of DO, organic matter, nutrients (C/N/P/Si) and suspended sediment; and/or municipal, industrial, and agricultural loads of organic matter and nutrient loads into the rivers) has been established for the entire period up to March 2005.
- Rain loads (precipitation rates; nutrient N/P contents);
- Biological forcing (zooplankton numbers, low priority at this stage) has been established.

When the from other riparian countries of Uganda and Kenya are available the model will be run to simulate the anticipated intervention measure.

CONCLUSION AND RECOMMENDATIONS

The trained laboratory staff, the strengthened laboratories and monitoring network have produced a wealth of data and information thus has formed basis for the report on the current state of the Lake Victoria basin environment. The quality of data and particularly nutrients has improved a great deal. The data generated by studies on constructed wetlands is to be used in sensitising industrialists and municipal councils. The results of the training Cleaner Production indicate that the industries have appreciated the cleaner production options and have already started implementing the today options. The results of the thirty two (32) shallow wells constructed are also very encouraging. According to some of the beneficiaries, there has been remarkable reduction of water borne disease following the commissioning of shallow wells provided by LVEMP through micro project arrangement (Rutagemwa, 2001). Rehabilitation of the Mwanza sewerage system including the oxidation ponds is a big investment the government put in place during the period under review. On completion of the rehabilitation, the by-pass that discharged raw sewage directly to the lake (Figure 5) was closed and the response of the lake is reflected by the drastic fall in faecal coliform count during the year 2004 (Figure 11).

To ensure that the data and information obtained are accurate and reliable for decision making it is recommended that:

- Performance evaluation exercises should be carried out on quarterly basis as part of the regular regional quality assurance and not on an adhoc basis.
- There should be regular meetings of the scientists of the three laboratories to analyze the QC results and design way of improving the performance of the laboratories.
- Laboratories should be equipped with analytical instruments appropriate for detecting levels of concentrations expected in the samples/environment.

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METEOROLOGY/HYDROLOGY

By: R.J. Mngodo, O.I Myanza, and F. Mwanuzi

ABSTRACT

One of the principal objectives of the Water Quality Component is to find the reasons for the changes observed in the lake water quality and ecosystem, and to identify remedial measures. To identify the reasons for the changes requires also a knowledge of the changes in the pollution loadings to the lake, which, in turn, depends on the discharges to the lake from the catchment and the atmosphere and lake outlet to River Nile i.e. hydrology and meteorological characteristics. Using these inputs the water balance of the lake is computed also this allows the calculation of loads of specific water quality variables during the estimation of non-point pollution loadings, atmospheric deposition of nutrients.

The data considered were (1) Rainfall onto, and evaporation from the lake surface (2) Discharges to the lake from all rivers and catchments around the lake and (3) Discharge from the lake into the Victoria Nile. Groundwater discharge to the lake has not been considered since in the past it was not found to be a significant parameter in the water balance. The results of analysis for stable isotopes done using samples from the Tanzania part of the harmonized Lake Victoria monitoring network indicate an insignificant interaction between groundwater and the lake.

The study found that rainfall from the selected three index stations for the long-term period and the period 2001-2004 did not show any significant changes in trend. The LVEMP period, 2001-2004, for two index stations, Mwanza and Musoma, on the eastern side of the lake indicate that there is slight increase in rainfall over the wet season and a decrease in rainfall during dry season. As for the western part of the lake, Bukoba meteorological station showed that there is no change in trend. The new LVEMP period had average rainfall. In general rainfall amount increases from east to west of the lake.

The average total basin inflows from Tanzanian portion shows a declining trend for the period 2001-2004, where flows decreased by 11% and for the long-term period 1950-2004 by 0.8%. On the Tanzanian side of the Lake, it is seen that there is downwards trend in water level, which show that on average water level is decreasing in the lake. In the recent years at Mwanza south station, it has gone down from 1141.24masl in 1998 to 1139.30masl in December 2004; that is 1.94m drop. The decrease may be due to either less inflow into the lake including rainfall falling directly over the lake surface or increased withdrawal of water for consumptive uses within the basin. The lowest level at 1139.30m was recorded in October 2004 and at the end of December 2004 the level increased to 1139.47m

INTRODUCTION

One of the principal objectives of the Water Quality Components is to find the reasons for the changes observed in the lake water quality and ecosystem, and to identify remedial measures. To identify the reasons for the changes requires also knowledge of the changes in the pollution loadings to the lake, which, in turn, depends on the discharges to the lake from the catchment and the atmosphere and outlet to River Nile i.e. hydrology and meteorological characteristics. Provision of this information requires a network of river and lake monitoring stations in order to:

Establish short and long term fluctuations in water quantity in relation to basin characteristics and climate.
Determine the water quality criteria required to optimise and maintain water uses and
Determine seasonal short and long-term trends in water quantity and quality in relation to demographical changes, water use changes and management interventions for the purpose of water quality protection.

Using these inputs an estimate of the total water balance for the lake over the past 50 years was computed in the first phase of LVEMP. The data considered were: rainfall onto, and evaporation from the lake surface, discharges to the lake from all rivers and catchments around the lake and discharge from the lake into the Nile river at Jinja.

A very large amount of historical hydrometeorological data that was initially collected collated, analysed, quality controlled and was used with other similar data from other two countries of whom Tanzania share the lake waters to produce COWI report in 2000 for LVEMP, which acts as a baseline water quality status at the start of the project. In order to document and explain the climatic changes that have taken place over the recent decades, the newly collected data is included in the analysis to give an overview of the present status, particularly the estimation of non-point pollution loadings, atmospheric deposition of nutrients, which leads to the prioritisation and choice of remedial measures.

METHODS

The first part of analysis covers meteorology of the basin on Tanzanian portion followed by the hydrology of the same. Details of the methodology are elaborated in the following sections.

Meteorology

Three national “index” stations Mwanza, Bukoba and Musoma were chosen for period of record including LVEMP period because of the strong climatic gradients across the Tanzanian portion of the Lake Victoria. The mean, maximum and minimum values of three climatic parameters; rainfall, evaporation and temperature are examined and analysed by looking at the following:

- The meteorological trend of the historical data is compared with the three index stations
- Mean data of LVEMP period is compared to the relative long term means (1950-2000)

- Discussion of global and regional climate change

Estimates of rainfall over lake surface and lake evaporation for Tanzanian portion were reviewed with new information on rainfall data.

Discharge data

Concerning the hydrology, catchment rainfall for the Tanzanian portion is estimated for two distinct periods: 1950-2000 and 2000-2004 to check for any inconsistency.

Analysis of river discharge is undertaken by looking at:

- Monthly means from rainfall-discharge modelling for the period 1950-2004, for all catchments
- Discussion of trends over time and representativeness of LVEMP period to longer record
- Decision to use estimates or actual data for loading estimates

It was also intended to look at monthly means from measurement for monitored rivers; the details of monitored rivers are presented in Table 1 below. This was to include a characterisation of land use characteristics. Finally, comparison of measured and estimated mean discharges for major rivers for periods of actual measurement would have been very useful, but unfortunately there was no new discharge data collected on the Tanzanian side. In the absence of new data, discharges for the new LVEMP period were estimated using procedures as described in COWI (2000); i.e. correlation, wet and dry years and rainfall runoff.

Table 1. Tanzania River and Catchment Areas

River Basin	River Basin Area (km^2)	Gauging Station	Catchment area upstream of gauging station (km^2)
Mara	13,393	01.07.07.2 Mara Mine	10,300
Grumeti	13,363	01.10.02.2 Road Bridge (mouth)	11,583
Mbalageti	3,591	01.11.01.2 Road Bridge (mouth)	3,348
Eastern Shore Streams	6,649	02.08.02.2 Mori at Utegi (mouth)	464
		01.09.01.2 Suguti at Suguti (mouth)	1,033
			Subcatchment areas
		Mori River area	2,436
		Mugango area	1,141
		Suguti River area	1,033
		Bunda area	1,455
		Ukerewe Is. Area	584
		Total area	**6,649**
Simyu	11,577	01.12.02.2 Road Bridge (mouth)	10,659
		01.12.01.2 Simiyu at Ndagalu	1,205
		01.12.03.2 Duma at Sayaka	5,320
Magogo-Moame	5,170	01.13.01.2 Road Bridge (Magogo)	1,350
		01.13.02.2 Pambani (Maome)	2,990
			Subcatchment areas
		Magogo River area	1,810
		Moame River area	3,360
		Total area	**5,170**
Nyashishi	1,565	(none)	
Isanga	6,812	(none)	
S. Shore Streams	8,681	(none)	
Biharamulo	1,928	(none)	
Kagera	59,682	01.15.02.2 Kagera at Kyaka Ferry	55,907
		01.15.18.2 Ngono at Kyaka Rd. Br.	2,608
		Area between Kyaka and Lake	1,167
		Total area	**59,682**
W. Shore Streams	733	(none)	

Water level

In addition the historical Lake level records at Mwanza South port station were analysed by looking at the trend over time.

RESULTS

Meteorology

A summary of the three index stations of Mwanza, Bukoba and Musoma is given below in terms of mean, minimum and maximum values. Only rainfall and evaporation are considered in this case due to the fact that longer temperature series could not be obtained to perform this exercise. The trend analysis for these parameters is presented in Figure1a, 1b, 2a, 2b, 3a and 3b below.

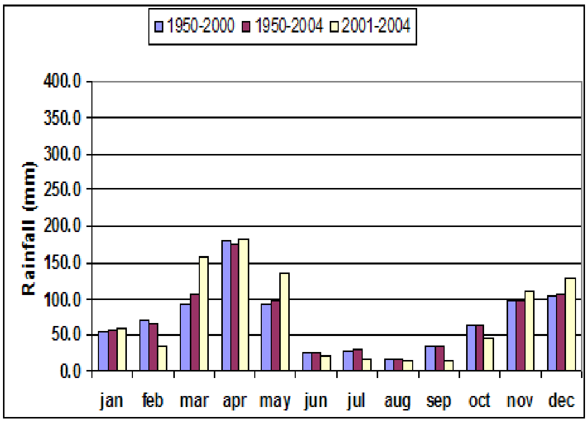

Figure 1a. Average monthly rainfall-Musoma

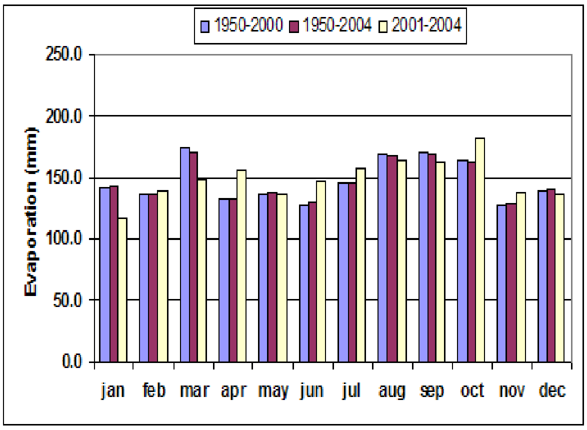

Figure 1b. Average monthly evaporation-Musoma

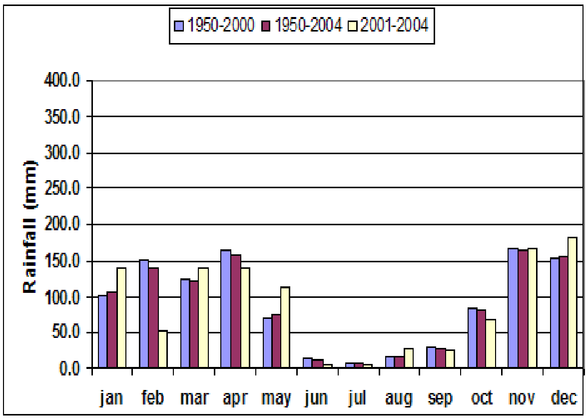

Figure 2a. Average monthly rainfall-Mwanza

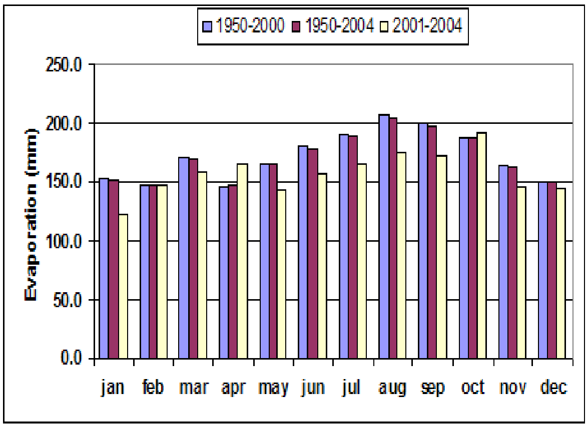

Figure 2b. Average monthly evaporation-Mwanza

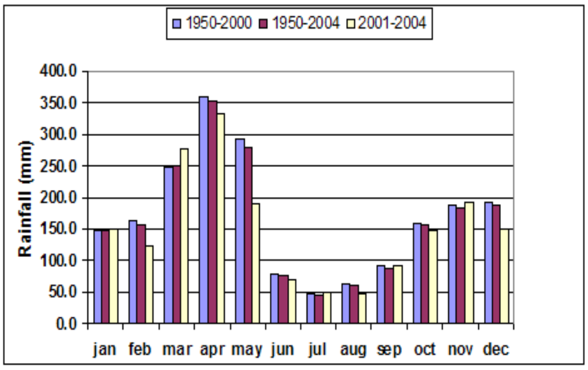

Figure 3a. Average monthly rainfall-Bukoba

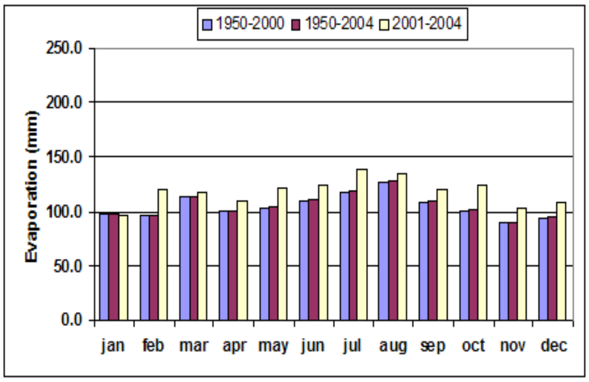

Figure 3b. Average monthly evaporation- Bukoba

Discharge, rainfall runoff and mass balance

In order to obtain mass balance components; the surface inflows, rainfall over lake surface, evaporation and outflow, these parameters were estimated as per procedures outlined in the methodology section. Lake Rainfall and evaporation estimates for national Sector (boxes) of Lake have also been estimated and all results are presented in Table 2.

The results of parameter estimation for mass balance components on Tanzanian portion are listed below in Tables 2-4.

Table 2 Estimated long-term average discharges

Catchment	Discharge (m^3/s) 1950-2000	Discharge (m^3/s) 2001-2004	Discharge (m^3/s) 1950-2004
Mara	38.2	31.9	37.8
Grumeti	11.8	21.1	12.4
Mbalageti	4.3	7.8	4.6
Eastern Shores	18.9	27.0	19.5
Simiyu	39.8	48.5	40.4
Magogo-Moame	8.5	14.4	8.9
Nyashishi	1.7	3.5	1.8
Issanga	31.1	7.5	6.1
Southern Shores	26.1	15.4	16.0
Biharamulo	18.2	22.8	18.5
Western Shores	21.1	16.8	20.8
Kagera	266.0	222.8	262.8
TOTAL	**450.4**	**439.4**	**449.6**

The average total basin inflows from Tanzanian portion for the period 1950-2004 is **449.6 m^3/s**, this shows 11% decrease in inflows for the LVEMP period 2001-2004 and overall decrease in long term period 1950-2004 by 0.8% when compared to the previous period of 1950-2000. There has been a decrease in flows in almost all the rivers flowing from the east and south of the lake. Flows from western side of the Lake are slightly above average.

Rainfall over the lake

In the estimation of rainfall over the lake, the lake area was divided into polygons (boxes), which are shown in Figure 4, representing rainfall influences from the stations selected. In this method, each rain polygon (box) had a reference rainfall station.

Table 3 shows the rainfall boxes for the Tanzanian portion of the Lake Victoria. The mean annual rainfall in each box was computed using the rainfall isohyetal curves derived by drawing curves that link stations with similar average rainfall totals. Then the daily rainfall in each box was calculated from equation 1:

$$R_{box} = R_{ref} \times MAR_{box} / MAR_{ref} \quad \textbf{(1)}$$

Where R_{box} = Daily rainfall over the box

R_{ref} = Daily rainfall at reference station

MAR_{box} = Mean annual rainfall in the box

MAR_{ref} = Mean annual rainfall at reference station

Finally the average daily rainfall for the lake was calculated as the sum of the areal weighted means of the daily box rainfall (Equation 2).

$$Lake \quad Rain = \sum_i (R_{box} \times Weight) \quad \textbf{(2)}$$

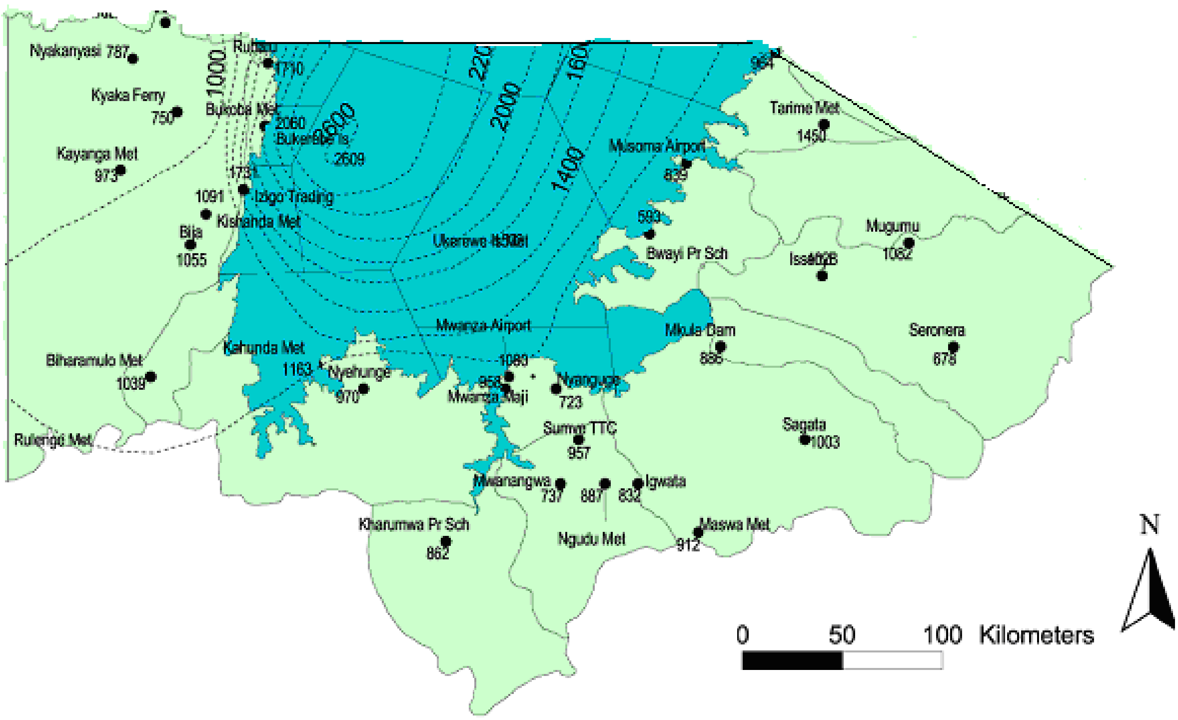

Figure 4. Mean Annual Rainfall over Lake Victoria with rainfall boxes

Table 3. Mean Annual Rainfall for Box

Box No.	Name	Weight	Mean Ann. Rainfall for Box (mm)	Mean Ann. Rainfall for station (mm)	Mean Ann. Rainfall (1950-2004) (mm)
1	Musoma	0.135	1300	839	901
2	Ukerewe	0.258	1600	1502	1515
3	Mkula	0.040	886	886	886
4	Mwanza	0.094	1000	958	966
5	Bukerebe	0.190	2400	2609	2609
6	Kahunda	0.173	1450	1163	1165
7	Izigo	0.048	1950	1731	1731
8	Bukoba	0.017	2400	2060	2020
9	Rubafu	0.046	2300	1710	1710

Lake evaporation

A similar approach as that used for estimating lake rainfall was applied in the estimation of the lake evaporation only that five evaporation boxes were identified. Table 4 shows mean annual evaporation boxes for Tanzanian portion of the lake. Pan Evaporation data was used for the entire period. Figure 5 shows the lake evaporation boxes used to compute the average rainfall for the entire lake surface as well as mean annual evaporation at each station.

Evaporation data is available from the HYDROMET Project period onwards, i.e. from 1970. However there are many with data in the period 1975-2004. The monthly average evaporation was used to fill the gaps in the record. Mwanza was found to have annual evaporation maximum evaporation in the Lake Victoria catchment while Bukoba has the minimum evaporation.

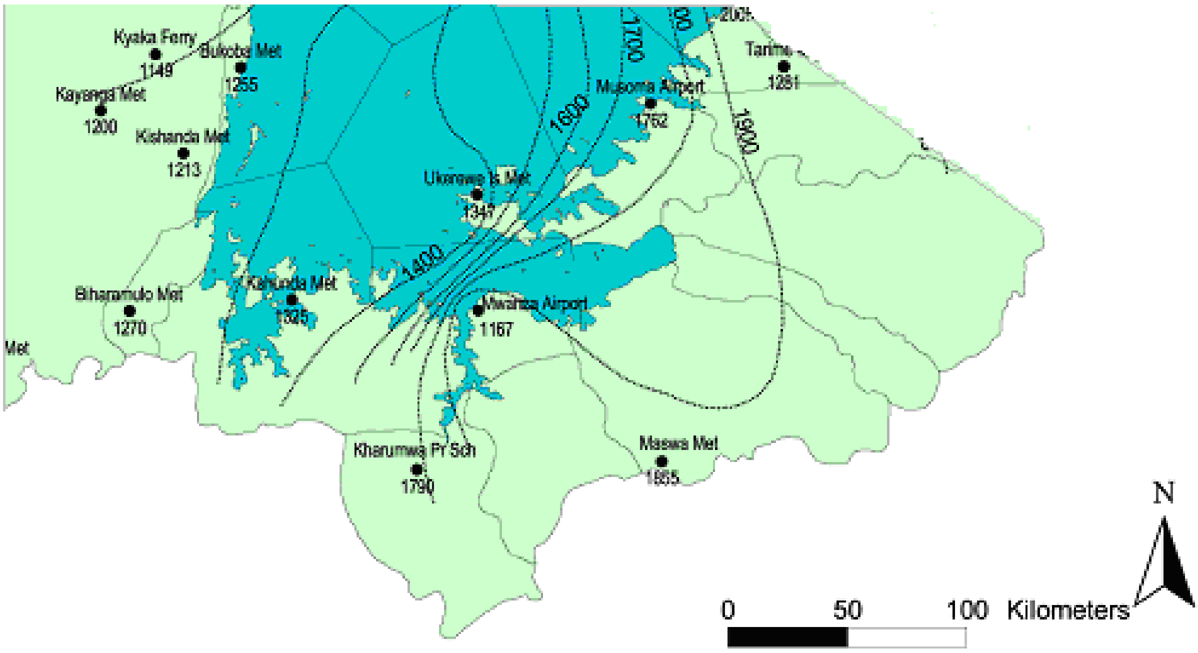

Figure 5. Mean Annual Rainfall over Lake Victoria with rainfall boxes

Table 4. Mean Annual Evaporation for Box

Box No.	Name	Weight	Mean Ann. Evaporation for Box (mm)	Mean Ann. Evaporation for station (mm)	Mean Ann. Evaporation (1950-2004)(mm)
1	Musoma	0.184	1763	1766	1766
2	Ukerewe	0.256	1347	1347	1347
3	Mwanza	0.163	2026	2033	2033
4	Kahunda	0.168	1326	1328	1328
5	Bukoba	0.229	1255	1267	1267

Water level Trend

Mwanza south water level records are available from 1965-2004 although the earlier records have big gaps from 1965-1971. Jinja station, at the outlet of the Lake, has longer water level records. The datum for Mwanza south station is 1131.50masl while that of Jinja is 1122.887masl. Water level records for Mwanza south station shown in Figure 6 while those of Jinja station are shown in Figure 7.

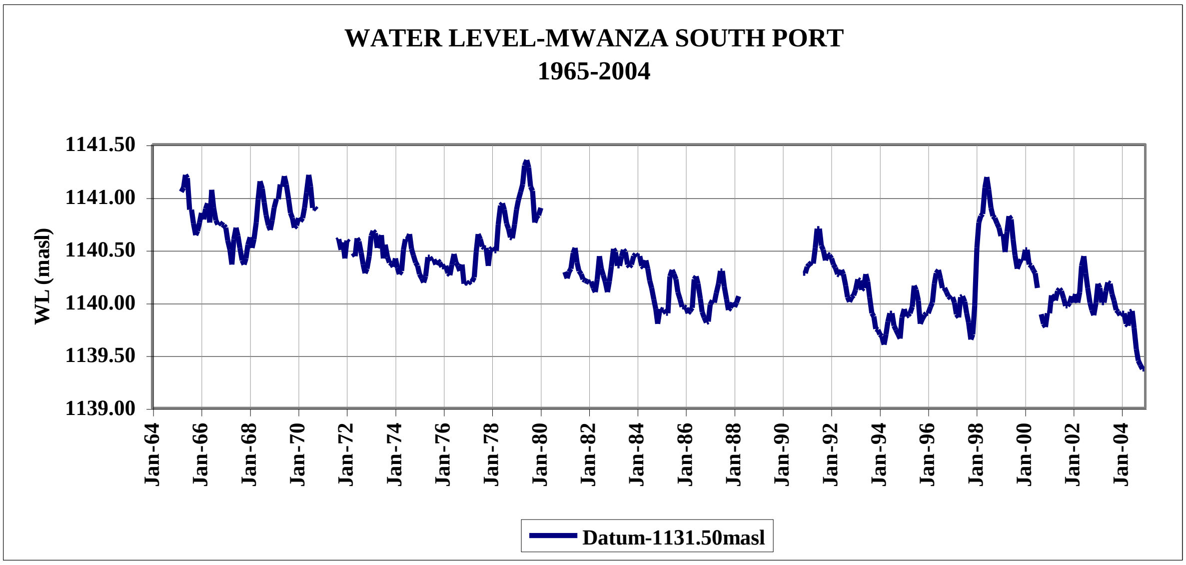

Figure 6. Water level records for Mwanza station

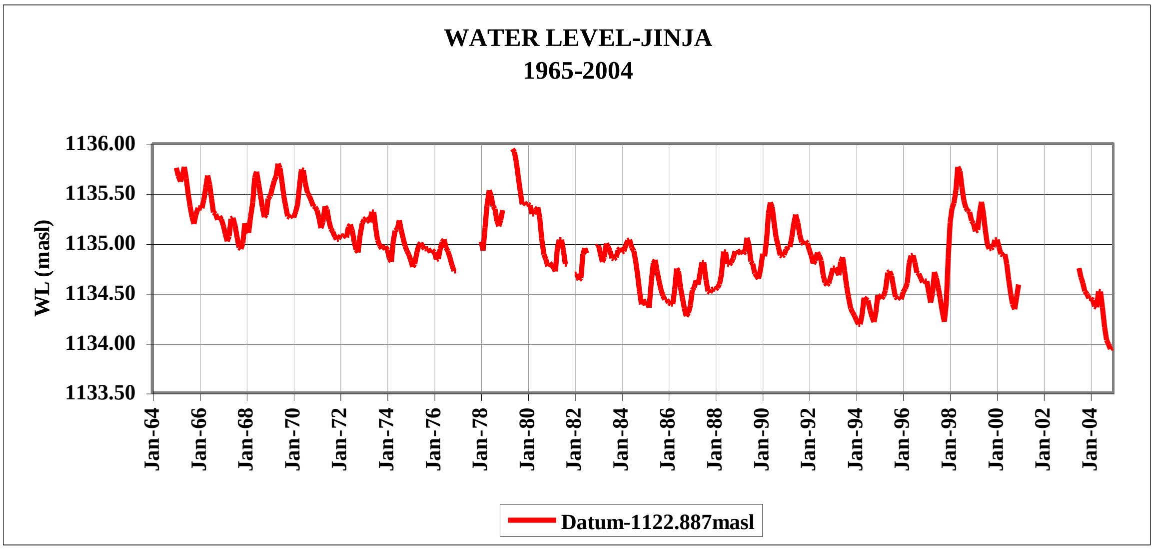

Figure 7. Water level records for Jinja station

DISCUSSION

Rainfall and evaporation

The trend exhibited by the three index stations does give a general picture on the rainfall conditions of the Lake basin over the past 4 years, however it must be noted that this period of 4 years is too short to have any statistical significance.

Rainfall for the previous long-term period 1950-2000 and the period that includes additional data, 1950-2004, for the three index stations did not show any significant changes in trend. The LVEMP period, 2001-2004, for two index stations, Mwanza and Musoma, on the eastern side of the lake indicate that there is increase in rainfall over the wet season and a decrease in rainfall during dry season; this also could be attributed by short length of the LVEMP period where data are not smoothened. The long-term period data is smoothened well enough. As for Bukoba, the trend for the new period is more or less the same as for the long-term period. The new LVEMP period had average rainfall. In general rainfall amount increases from east to west of the lake.

During the LVEMP period of 2001-2004, the average annual evaporation for Musoma Met station increase slightly by 1% and this value was further smoothened in the combine long-term period of 1950-2004 to a mere 0.1%. As for Mwanza Airport evaporation decreased by 8.3% for the LVEMP period but overall the increment was reduced to 0.6% for the period 1950-2004. Although there was an increase of 13.3% in evaporation for Bukoba Airport, the long-term period of 1950-2004 show a decrease in evaporation by only 1% due to smoothening effect. Lehman (1998) concluded that climatic changes appear to be part of a global change in climate conditions of the high elevation tropics.

Catchment flows
There has been a decrease in flows in almost all the rivers flowing from the east and south of the lake. Flows from western side of the Lake are slightly above average. The average total basin inflows from Tanzanian portion shows a declining trend for the period 2001-2004, where flows decreased by 11% and for the long-term period 1950-2004 by 0/8%.

Water level
The water level record of Lake Victoria over decades, centuries and millennia indicates that it responds sensitively to changes in rainfall and evaporation. Even in its modern condition, Lake Victoria is barely an open lake with flushing time of over 100 years (Hecky *et.al.*, 2004). On the Tanzanian side of the Lake, there is downwards trend in water level, which show that on average water level is decreasing in the lake. This downward trend was also reported by Rutagemwa *et.al.*, (2004) when an assessment on the state of Lake Victoria was done on Tanzanian portion. In the recent years at Mwanza south station, it has gone down from 1141.24masl in 1998 to 1139.30masl in December 2004; that is 1.94m drop. The decrease may be due to either less inflow into the lake including rainfall falling directly over the lake surface or increased withdrawal of water for consumptive uses within the basin. The lowest level at 1139.30m was recorded in October 2004 and at the end of December 2004 the level increased to 1139.47m. This drop in water level is very evident that it can also be traced on objects that in the lake such as the famous Bismark rocks in Mwanza (Picture 1.) as shown below.

Picture 1. Bismark rocks near Mwanza showing the drop in water level

Mass balance components

Inflow due to surface water discharge from Tanzanian portion for the period between 2001 and 2004 have increased by 11% from the period 1950-2000. This result is based on simulated data, as there is almost no readily available observed data. Water level records show that the lake has a downward trend. Other mass balance components; rainfall and evaporation do not show any significant change although the southern part of the lake received on average slightly less rainfall.

The mass balance does not include groundwater discharge to the lake because up to now it has not been found to be a significant parameter in the water balance (McCann 1972). Also preliminary results (Figure 8) of analysis of samples from the Tanzania part of the harmonized Lake Victoria monitoring network and analysed for stable isotopes indicate an insignificant interaction between groundwater and the lake (Rwegoshora *et al*, 2004).

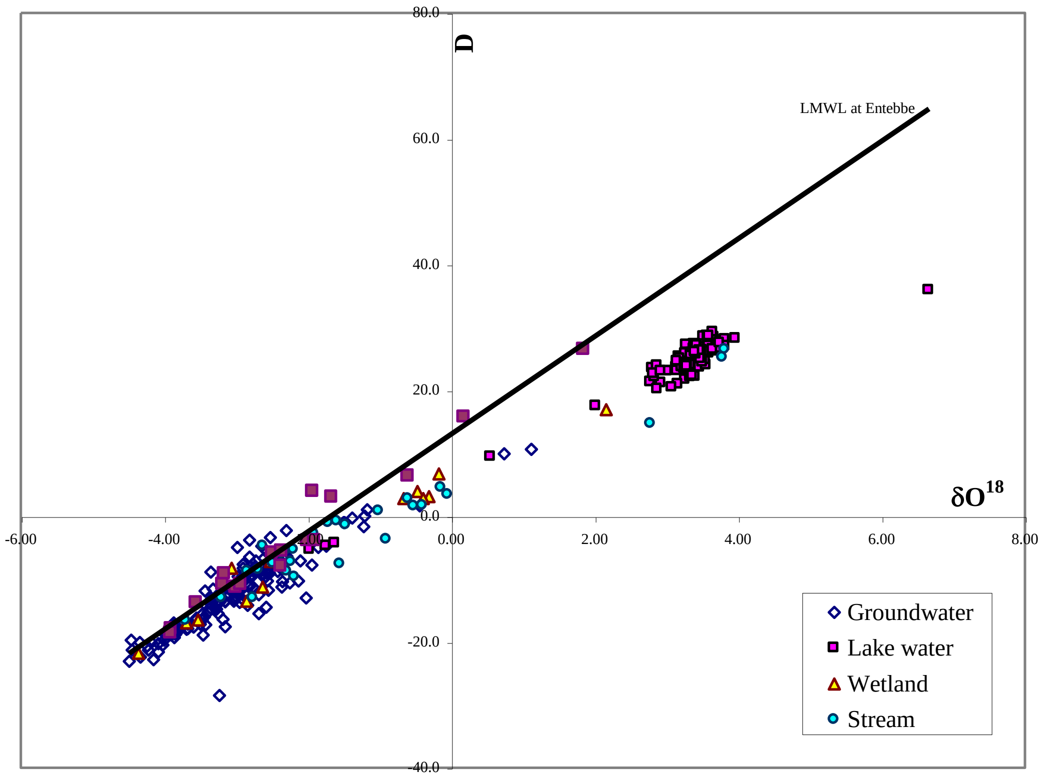

Figure 8. Deuterium-Oxygen-18 relationship in the Lake Victoria watershed (Tanzania part)

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

This study examined the trend of meteorological parameters and well as hydrological parameters. Rainfall from the three index stations for the long-term period and the period 2001-2004 did not show any significant changes in trend. The LVEMP period, 2001-2004, for two index stations, Mwanza and Musoma, on the eastern side of the lake indicate that there is slight increase in rainfall over the wet season and a decrease in rainfall during dry season. As for the western part of the lake, Bukoba meteorological station showed that there is no change in trend. The new LVEMP period had average rainfall. In general rainfall amount increases from east to west of the lake.

The variation in water levels of Lake Victoria is determined by interplay between hydrologic processes that bring water into and take water away from the lake. The current declining levels of Lake Victoria are raising environmental concern to all level of people. Observation of records has revealed that since massive storage of 1961-1964 the lake level has been falling to return to the pre 1960 levels, which are considered as the natural lake levels. The limited rains on the lake in recent years resulted in falling of lake levels, however, increased outflows at the Owen Falls dam for power generation may have triggered accelerated fall in lake levels starting from 2001. Towards the end of 2004 lake elevation is about the pre-1960 average. Consultation with other riparian countries may verify the level of abstractions that are affecting the levels.

The techniques that were developed in the first report (COWI, 2000) and used for rainfall runoff modeling are quite useful. The various data filling methods also proved to be very practical.

The outcome of mass balance provides a basis for water quality studies especially in assessment of pollution loads. A clear picture of the total mass balance will be obtained when the three portions of Kenya, Uganda and Tanzania will be considered as one unit.

Recommendations

- Data collection of relevant parameters should be an ongoing exercise and thus should be given due consideration by the MAJI office and the project.
- Equipment and instruments in all monitoring stations should be in good working order to enable smooth data collection.
- River gauging stations for the ungauged catchments that were recommended in the first phase of LVEMP should be established as soon as possible.
- There should be consultations with other riparian countries to verify on the level of water abstraction for various uses.
- Mass balance of Lake Victoria should be constantly updated using national and regional data from the riparian countries.

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NON POINT POLLUTION LOADING IN TANZANIA CHAPTER

By: O.I. Myanza, D.K., Rutagemwa, and F. Mwanuzi

ABSTRACT

Well-documented changes have occurred to the water quality in Lake Victoria and its ecosystem. Among them, eutrophication has been observed frequently over the past two decades and is caused by numerous factors. One of the principal objectives of the WQ Components is to find the reasons for the changes observed in the lake water quality and ecosystem, and identify remedial measures. The water quality of Lake Victoria is the sum of all the inputs and outputs to and from the lake, together with the reaction of the ecosystem to these inputs and outputs. One of the sources or input to the lake is the non point sources, which have been identified to be through rivers and that which falls on the lake directly. The determination of pollution loads from the non-point sources has been limited to nitrogen, phosphorus and suspended sediment loads. To be able to quantify these loads the study aimed at estimating all non-point pollution loadings to Lake Victoria from all major rivers and the atmosphere and also to identify source distribution in relation to land-use in the catchment.

The atmospheric deposition was divided into wet deposition, washed down by the rain, and dry deposition which is the amount of nutrients deposited onto the water surface from the air during dry weather periods. For wet deposition, rainwater has been sampled and analyzed for various parameters including total-nitrogen, and total phosphorus. Due to lack of special sampling equipment for dry deposition, a simple method has been applied implying analysing the increase of nutrients in distilled water exposed in a bucket for a certain time. The total atmospheric deposition load was then calculated by summing up the wet and dry season loads. The effects of sources such as nitrogen fixation by blue-green algae on the lake and detailed assessments of the effect of landuse changes (population pressure, deforestation etc.) are not considered.

This study confirms earlier findings that the predominant source of nutrient loading to Lake Victoria is atmospheric deposition which contributes to 84 and 75% of N and P respectively, followed by catchment loads contributing about 15 and 23% of N and P of the total loads respectively. These two sources when combined indicate that non point loads accounts for 99% of N and 98%P loads to the lake. The suspended sediment load to the lake is estimated at 4,905.2ktons/year, with Simiyu River carrying the largest suspended sediment load estimated at about 42.3% of the total load to the Lake.

It was observed that there is a tremendous variation in the nutrient loads and sediments of the rivers, both through space and time. For example, nitrogen and phosphorus both accumulate down a watershed as successively larger drainage areas are integrated. These two nutrients also vary significantly with the seasons. Nitrogen and phosphorus concentrations are highest in the early rainfall. This is due to factors associated with early runoffs, such as the release of nutrients stored in the soil Simiyu and Kagera Rivers. These seasonal peaks are most pronounced in the headwaters of the watershed.

INTRODUCTION

In practical terms, non-point sources pollution does not result from a discharge at specific single location but generally results from land run-off, precipitation, atmospheric deposition or percolation, which pickup pollutants and deposit them into water bodies such as river and lake Figure 1 shows river water just after a rainy day and sample was taken. This implies that human activities are responsible for the much of the positive feedback which creates environmental changes if thresholds are transgressed. Generally, pollution from non point sources occurs when the rate at which pollutant materials entering water bodies exceeds natural levels.

Lake Victoria receives constant nutrient additions from atmosphere, tributary rivers (Figure 2), municipalities and industries, in which the greater inputs of N and P are by atmospheric deposition (LVEMP, 2002, Tamatamah, 2001, Tamatamah, 2005).

Figure 1:.River water after a rany day and sampling fo quality analysis.

Although, it is likely that the lake has always experienced increased productivity since 1900 (Lipiatou et al, 1996), the present large additions of nutrients must contribute substantially to the degeneration of both lake water quality and its fishery (Rutagemwa, 2004). The extreme dominance blue green algae (Hecky, 1993 LVEMP, 2002) and large bloom of scum forming algae now typifying the lake are symptomatic of eutrophication caused by excessive nutrients from the catchments (Scheren et al, 2000, Hecky, 1993) In Lake Victoria, although the causes of eutrophication are well known, the rate of enrichment its source and its numerous effects in the Lake Victoria have only been quantified in a preliminary very way (LVEMP 2002, Tamatamah, 2005).

The objective of this study is to produce the present estimate of all non-point pollution loadings to Lake Victoria from all major rivers and the atmospheric deposition to identify source distribution in relation to land-use in the catchment for management purposes.

For the Tanzanian catchments, measurements have been made during the whole study period on Kagera River system, Simiyu, Magogo-Moame, Mbalageti, Duma, Grumeti, Mara, and Mori. Consequently data records from the catchment river stations, sampled from 1998 to year 2004 are available to the study.

Study Area:
Lake Victoria terrestrial catchment covers about 197,500 km2 (LVEMP, 2002). The lake is located at an elevation of about 1134m asl (Akiyama, 1977, Bronkonsult, 1978), with the surrounding hills rising to about 1400m asl (Bronkonsult, AB, 1978). Part of the catchment lying in Tanzania has a total area of 115,000km2 (LVBWO, 2002), with Precambrian granites and gneisses being the oldest rocks outcropping in the lake region (Bronkonsult AB, 1978), while the youngest rocks in the basin varies from Palaeozoic to Kainozoic (recent). Major rivers flowing into the lake (figure 2), include Kagera, in the west, Magogo-Moame, Mbalageti, Grumeti, Mori and Mara in the East. Kagera and Mara are trans-boundary rivers, Kagera River, drains the mountains of Rwanda and Burundi and Mara enters the country from Kenya.
Generally, July is the coolest month and the warmest months is variable and fluctuates in the period between October and February. Rainfall varies considerably per season with maxima in March through May and November through December. The human population in the lake basin is about 30million and is increasing at a rate among the highest in the world (World Bank, 1996).

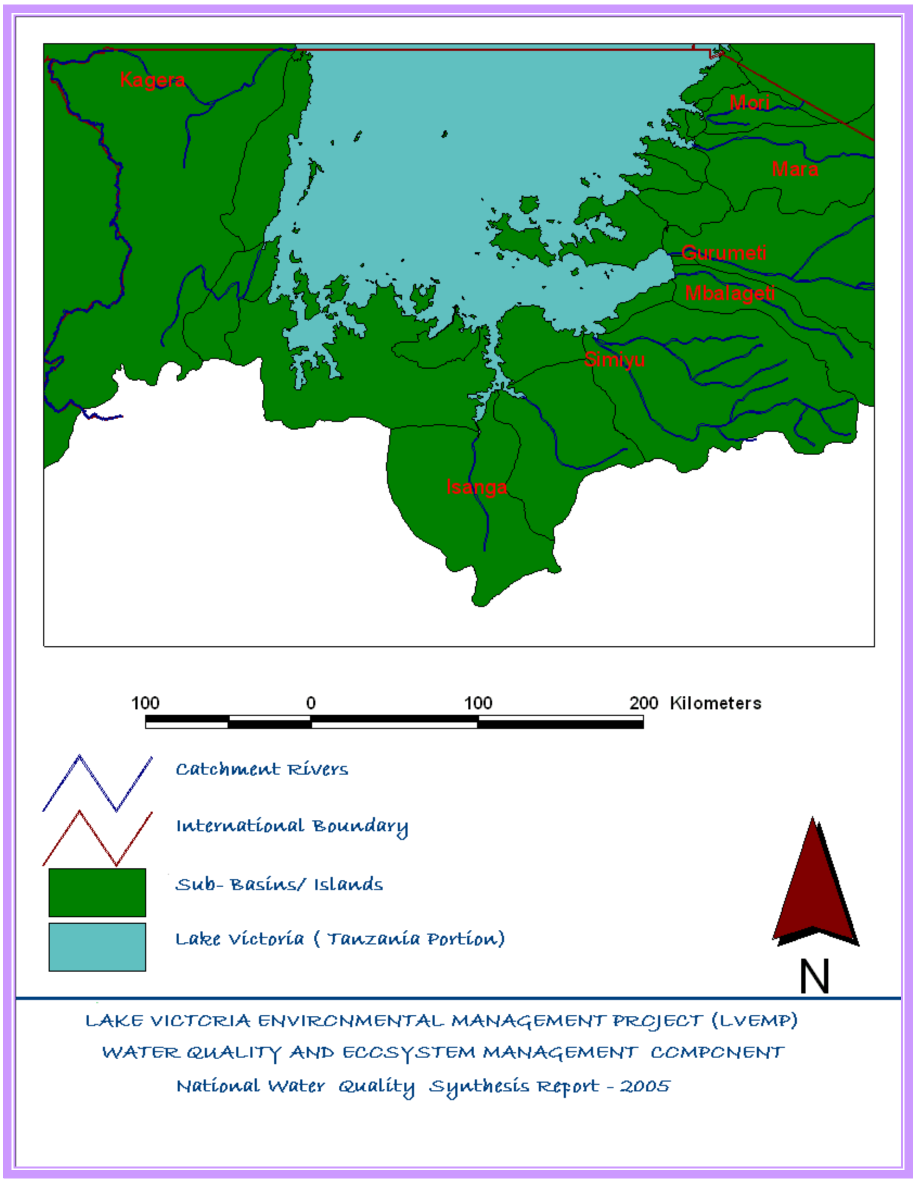


Figure 2: Map Showing River Systems in the Tanzania part of Lake Victoria basin.

METHODOLOGY

The determination of pollution loads from the non-point sources has been limited to nitrogen, phosphorus and suspended sediment. The overall approach was to determine total nutrient loads of critical nutrients (nitrogen and phosphorus) as suggested by Bootsma et al (1999), and suspended sediment load originating from all non point sources for specified catchments and determination of contribution of atmospheric deposition.

The total nutrients (in terms of N and P) and sediment loads from the catchments was estimated using river nutrient concentration data collected at water quality sampling stations. The sampling stations fixed in rivers, were generally sampled for both water quality taken simultaneously with discharge measurement. Sample for laboratory analysis were collected from surface, while electrical conductivity, pH and temperature are measured insitu using field meters on unfiltered sample. In the laboratory TSS was measured from 500mls sub-sample that was filtered from pre weighed GF/C and dried at 105ºC for 2hrs and weighed again, the difference being the weight of the sediment in the sample. The resulting filtrate was stored at 4ºC throughout the completion of the analysis. The nutrients (N and P) were analysed using standard methods for water and wastewater analysis (AWWA, APHA, WEF 1998), using Hitachi Spectrophotometer Model U-2001. To ensure that data obtained are accurate, reliable and adequate for intended use, internal quality control (intra laboratory) samples of known concentrations were prepared and subjected to the same measurements procedures as that used for water samples. The resulting data were grouped by site and seasons and analysis conducted between each site within each season to allow for the calculation of annual loads for each sampling station/catchment. For the purpose of this study, data collected for the last seven years (1999 –2005) have been used. Data collected by Tamatamah (2000) have been used to fill in existing data gaps in order to compute annual "exported" loads for phosphorus and suspended sediment, while that collected by Chadha (1972),has been used to predict the suspended sediment loads trends in Kagera River.

Samples for dry and wet atmospheric deposition have been collected from four (4) land based stations and two islands near the towns of Mwanza and Bukoba (figure 3 below). The atmospheric deposition has been divided into wet deposition i.e. the deposition of nutrients washed out by the rain from the atmosphere, and dry deposition which is the amount of nutrients deposited onto the water surface from the air during dry weather periods. For wet deposition rainwater has been sampled and analysed nitrates and phosphates using the same methods as described above. Due to lack of special sampling equipment for dry deposition, a simple method has been applied implying analysing the increase of nutrients in distilled water exposed in a plastic bucket with surface area of $0.07m^2$ for a certain period of time normally 24hrs. After retrieval, the samples are transported to the laboratory immediately, where the portion is filtered for dissolved nutrients while the other portion is preserved for determination of other forms of nutrients.

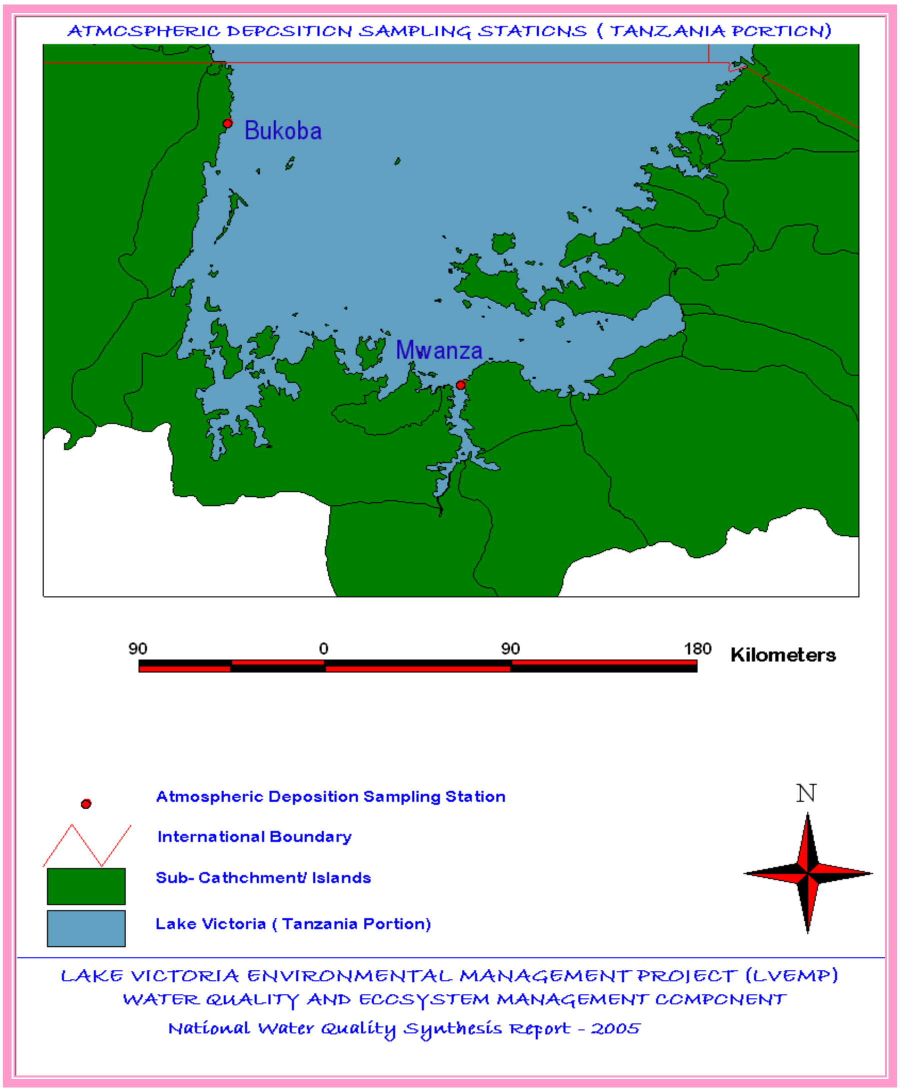


Figure 3: Sampling stations for atmospheric deposition

For the purpose of expressing phosphorus loading to the lake, the sum of soluble reactive (SRP), soluble unreactive (DOP), and potentially desorbable from particulate matter is substituted for total phosphorus. To normalize the concentrations of nutrients for each catchment river and wet atmospheric deposition for each point (Tamatamah, 2002), flow and volume weighted has been calculated. The resulting volume weighted mean concentrations were then used to estimate the exported mass of nutrients (P and N) and suspended sediment load.

For dry atmospheric deposition, the daily deposition was calculated using the relationship below.

$$\text{Deprate. } (\mu g/m2/d) = (C_2 x V_2 - C_1 x V_1) / (A x t) \qquad 1$$

Where:-

C_1 and C_2 are initial and final concentrations respectively

V_1 and V_2 are volumes (litres) before and after deployment respectively

t is the deployment time in days

A is the area of bucket

For the whole lake, the deposition rate was calculated as follows:-

Deprate ((mg/d) = DepratexDdxA, where Dd= number of dry days and A is the Rain Box Area

For wet atmospheric deposition samples, volume weighted mean concentration have been calculated to normalize the concentrations between light rains which have relatively high concentrations and heavy rains in which the samples may be more dilute (Tamatamah,2005). The relationship below has been used.

$$VMC(\mu g/L)=(C_1V_1+C_2V_2+\ldots\ldots+CnVn)/(V_1+V_2+\ldots\ldots\ldots+V_n) \quad 2$$

Where:-

WMC= Weighted Mean concentration,

C_1, C_2 to C_n are Concentrations

$V_1$and V_2 and Vn are volume of samples collected.

Drate (mg/d) = WMCxAxRainfallxdw, where A is the area of rain box and dw is number of wet days

RESULTS AND DISCUSSIONS

Catchment Loads

To identify the long-term impact of land use on non point sources pollution the flow weighted mean concentrations for each of the rivers in the basin has been calculated. The weighted mean concentrations of phosphorus (TPP, TP, DOP and SRP), nitrogen and suspended sediment from different rivers in catchment are given in table 1 below. Two river catchments have been used as index for detailed analysis; these are Kagera and Simiyu in the Western and Eastern shore of the lake. Kagera and Simiyu rivers are two rivers in the basin which possesses two different characteristics depending on seasons. Generally, Kagera River in the western part flows throughout the year (perennial), while those in the eastern are seasonal (ephemeral), and typical dries up completely between July to October.

Table: 1: Weighted mean concentrations of sediments and nutrients for Kagera River

Date	EC µS/cm	pH units	NO_3-N (mg/L)	TP (mg/L)	TDP (mg/L)	TPP (mg/L)	DOP (mg/L)	PO_4 (mg/L)	TSS (mg/L)	Index Station mean Rainfal (mm)
JAN	120	7.51	0.002	0.393	0.345	0.048	0.231	0.114	-	151.3
FEB	111	7.30	0.307	0.205	0.085	0.120	0.031	0.054	66.0	124.0
MAR	89	7.12	-	0.300	0.144	0.156	0.083	0.061	56.2	277.5
APR	97	7.10	-	0.227	0.119	0.108	0.022	0.097	75.7	333.0
MAY	106	7.22	-	0.151	0.079	0.072	0.015	0.065	77.5	191.3
JUN	107	7.44	0.070	0.113	0.063	0.050	0.033	0.030	167.7	70.1
JUL	100	7.53	-	0.056	0.043	0.013	0.018	0.025	312.8	50.0
AUG	98	7.08	0.012	0.132	0.054	0.078	0.028	0.026	194.3	48.7
SEP	110	7.10	-	0.251	0.097	0.154	0.031	0.066	234.5	92.7
OCT	127	7.45	-	0.274	0.151	0.122	0.129	0.022	188.3	149.6
NOV	163	7.09	-	0.350	0.217	0.133	0.151	0.066	179.5	193.1
DEC	113.9	7.61	-	0.599	0.456	0.143	0.231	0.225	-	151.1
Mean	111.8	7.29	0.10	0.25	0.15	0.10	0.08	0.07	155.2	152.7

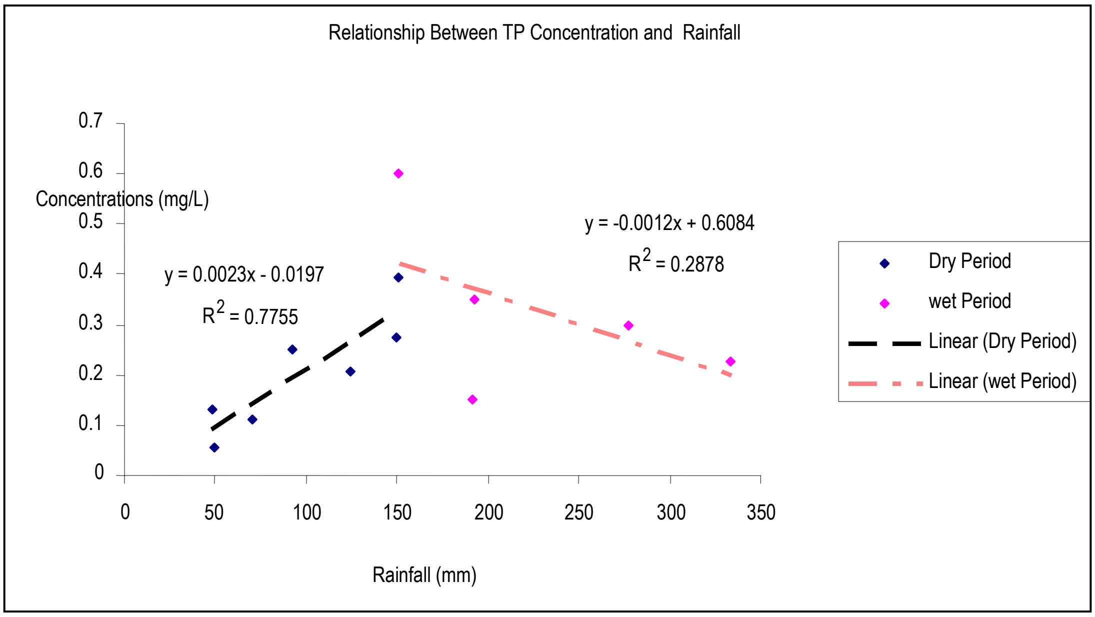


Fig 4: .Relationship Between TP and Rainfall in Kagera River in Wet and Dry periods

Kagera Catchment

The concentrations of all forms of phosphorus vary strongly with seasons. During the dry period there is an increased trend in concentrations of both dissolved and particulate phosphorus, with dominance of the particulate form (59%). With continued rainfall, the concentration of particulate form of P decreases while that of dissolved form increases. Generally, the concentration of particulate form of P has been found to be high during the early storm runoff and decrease with continued rain. Significant relationship exists between rainfall in the catchment and total, dissolved and particulate form of phosphorus during dry season, the strongest (R^2=0.77) being between TP and rainfall. Poor relationship (R^2=0.29) exists between phosphorus and rainfall in wet season; however a general trend indicates the decrease in concentration with increased rainfall indicating dilution. The same relationship exists with the dissolved form of phosphorus, however with small R^2 (0.58). No significant relationship have been observed for particulate form of phosphorus both in dry and wet season, although the trend of increasing concentration with rainfall in the catchment is evident (R^2=0.16).

The results indicate that, while rainfall and consequently river discharge is the main factor controlling concentration of total and dissolved form of phosphorus during dry season in Kagera River, factors other than discharge, which are possibly related to rainfall exert significant control during wet season. The TP attains its minimum value in July during the dry period. The concentration of phosphorus simply increases as water flow decreases from August to reach seasonal maximum value during the months of December at about 0.599mg/L. This is the climax of short rains following the dry period and is dominated by dissolved form of phosphorus).

Generally, the dominance of the phosphorus species in the river is cyclic, depending on rainfall. The overall concentration of TP varied with the lowest values coinciding with dry period in July.

The possible explanation for this variation is that, phosphorus is mineralised and accumulates in soils during the dry period. With the onset of rainfall, water begins to flow through the upper soil horizons, mobilizing the accumulated minerals including phosphorus. Each storm progressively flushes this phosphorus so that by July there is little phosphorus found in soil.

For the TSS, the general trend is that the concentrations are low during rainy season (Table 1) implying that dilution of the sediments takes place during wet season, while they are high during dry season.

Therefore it can be concluded that rainfall and consequently river discharges are the major controlling factor of nutrients and sediment transport in Kagera River and that the dissolved form of phosphorus dominates (60%) in the form of phosphorus carried down by Kagera River and therefore available immediately for biomass production as soon as it reaches the lake.

On average, the suspended sediment concentration in Kagera River is currently estimated at 145.4mg/L, and is rated second to Simiyu River.

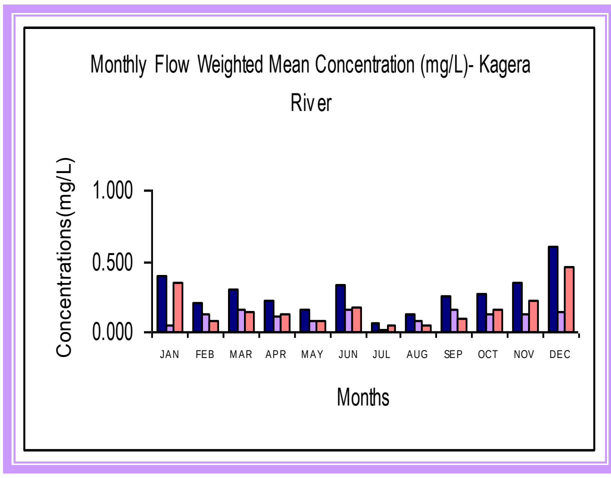


Figure 5: Estimates of Concentrations (Kagera)

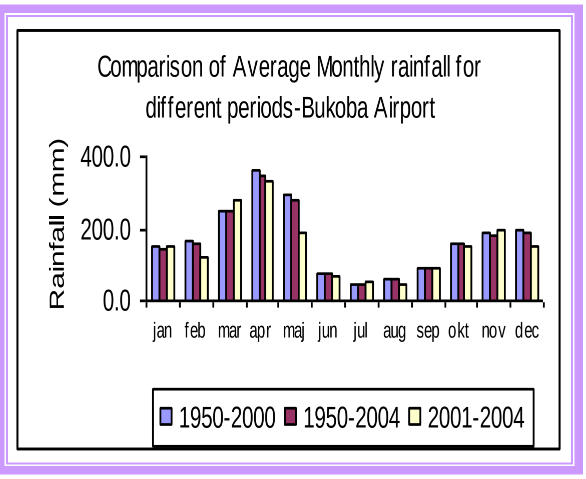


Figure 6: Average Rainfall –Bukoba Airport

Simiyu River Catchment

The headwaters of the Simiyu River are located within the Serengeti National Park and adjacent to Maswa Game Reserve. The slope of this river is 0.5mkm-1 and ephemeral. In a normal year they remain dry in the months of August, September and October (Tamatamah, 2002). The discharge patterns in Simiyu River have strong seasonal dynamics with short rainfall mainly in November to mid January and long rain in March to May (Tamatamah 2002, Rwetabula et.al 2005). According to Tamatamah (2002), the Simiyu basin has a quick hydrographic response to rainfall, with approximately 50% of the annual flow into Lake Victoria observed during a short period of heavy rains between March and May.

Nutrient concentrations

The summary of flow weighted mean concentrations for phosphorus and nitrate are given in table 22 below and represented in fig.22 indicating strong seasonal variations. No data for the month of February have been obtained. High concentrations of phosphorus are associated with flow patterns and higher concentrations found in April, November and December which are the rainfall seasons in the catchment, indicating that gross amount of nutrients/contaminants are collected by runoff from agricultural fields (Rwetabula et al, 2005), with dominance of particulate form of phosphorus, resulting into low TP: TPP ratio varying between 1 to 2.

Table 2: Summary of Concentrations (VWM) for Simiyu River

Date	NO3 (mg/L)	TP(mg/L)	TPP(mg/L)	DOP(mg/L)	PO4(mg/L)	TSS(mg/L)
JAN	0.203	1.645	1.355	0.111	0.18	723.5
MAR	-	0.522	0.256	0.177	0.089	103.9
APRIL	0.43	4.027	3.307	0.14	0.579	1799.0
MAY	0.032	0.866	0.229	0.174	0.463	192.2
JUN	0.864	0.48	0.245	0.178	0.057	70.0
SEPT	0.197	0.417	0.099	0.064	0.253	75.5
NOV	0.069	3.207	3.085	0.025	0.096	1675.4
DEC	0.135	2.403	2.088	0.014	0.301	1121.6

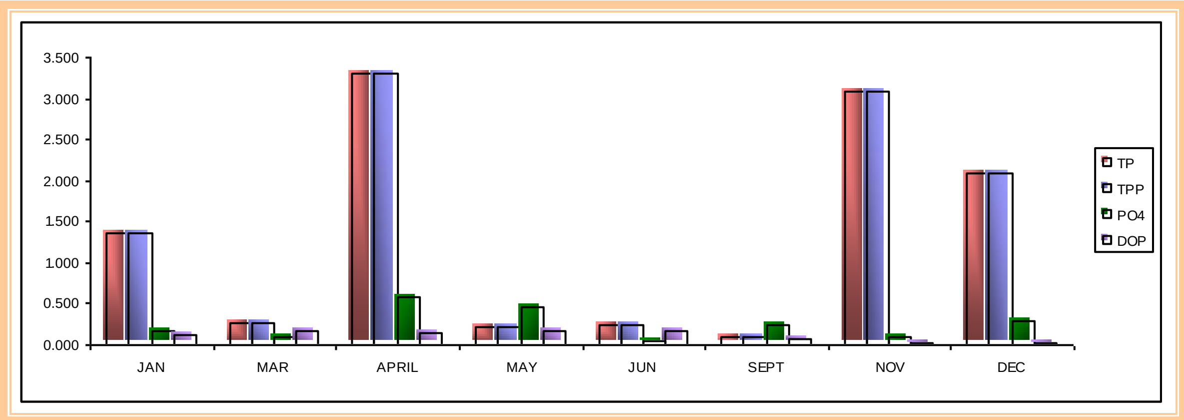
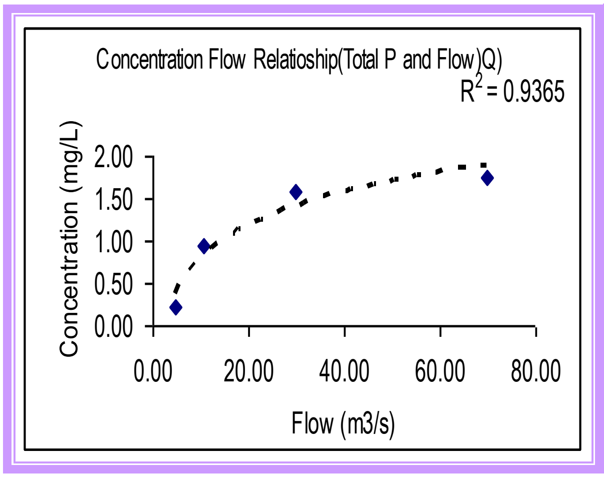


Fig 7: Temporal variation of P species- Simiyu Catchment

Concentrations flow relationships for phosphorus indicates that statistically significant relationship exist between flow and TP and TPP (figure), the relationship being logarithmic, while no statistically significant relationship between flow and dissolved form of phosphorus. Significant linear relationships have also been observed between TP and TSS, and TP and TPP both with coefficient of variation (R2) of 0.98. This violates the principles of dilution. The higher the flow the less is the concentration. We are not so sure for this let us remove remove these figures(flow vs conce.)



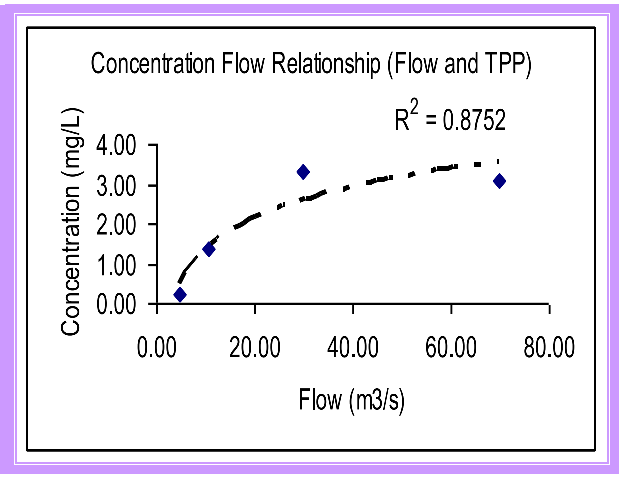
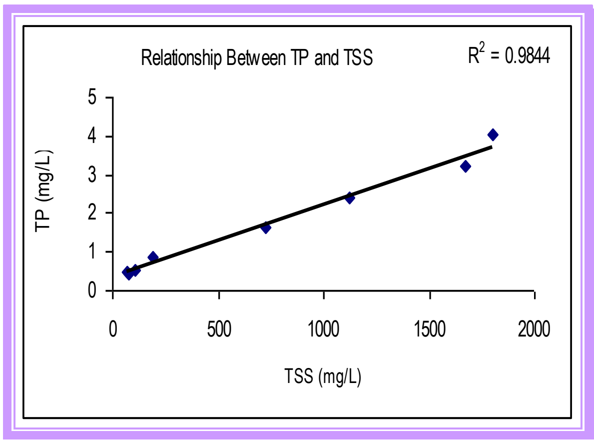


Figure 8: Flow TP Concentrations Relationship

Figure 9: Flow TPP Concentration Relationship



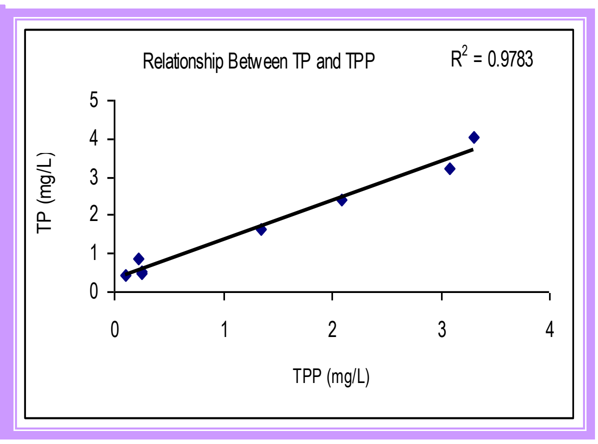


Figure 10: TP and TSS Concentrations Relationship

Figure 11: TP and TPP Concentration Relationship

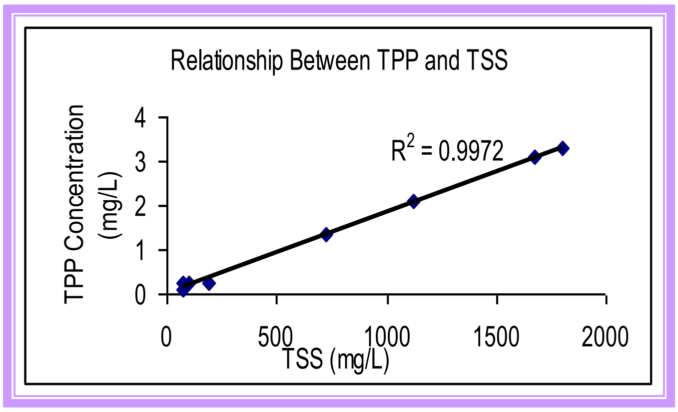


Figure 12: Relationship between TPP and TSS

The highest concentration of suspended sediment at Simiyu River has been recorded in April, which is normally the heavy rain period in the catchment. The concentrations are also high in the months of November and December which are normally the short rainfall periods. Generally, the concentrations are high during rainy seasons. The highest value recorded is estimated at 1,799mg/L. The average concentration is estimated at 0.720mg/L

Atmospheric Deposition

Data on the deposition of nutrients from the atmosphere as dry or wet deposition has been collected from analysed for dissolved nutrients. Samples for dry atmospheric deposition have been collected from Musira and Gabalema Island in Mwanza. The wet deposition data are available from Bukoba and Mwanza.

Samples for wet deposition has been collected from land-based stations and represent as such the deposition as it would appear in the whole lake. Some researcher on atmospheric deposition has registered their reservations on how well atmospheric deposition measurements at single site represent deposition over the entire lake (Scheren et al, 2000, Bootsma et al, 1999). Lake Victoria with area of 68,800 km^2 the atmospheric deposition would be expected to decrease with the distance to land. However, with intensive burning of grasses in the islands for the purpose of drying fish, significant contribution is also expected from the islands.

Wet atmospheric Deposition

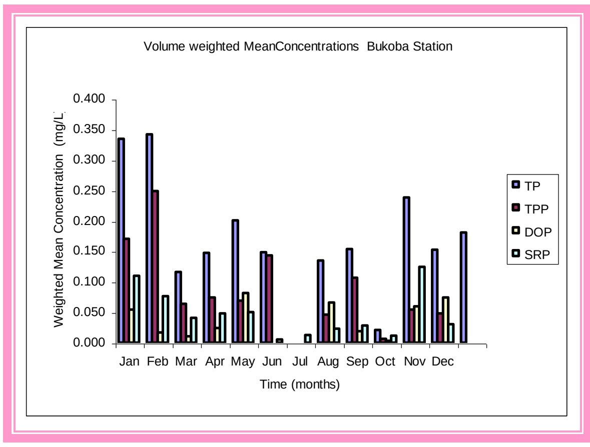
Volume weighted mean concentration for Bukoba station are given in table 3. Seasonal variations of both TP and TN for the two stations are evident (Fig 13 and 14). In Bukoba, the highest concentrations of TP recorded in the months of Jan, Feb and Nov, which is normally the beginning of rain season (heavy rain and short rain), while that of TN has been recorded in June and July, the beginning of dry period. The particulate form of P is high in the wet atmospheric deposition at the start on rain season, indicating that high TP concentrations are characteristics of the first rains after prolonged dry periods. The concentration decreases as the rain continues.

Significant positive relationship has been observed between both particulate and dissolved form of phosphorus with coefficient of variation (R^2) between 0.73 to 0.86 for SRP, TDP and TPP (Figure 15-17).

No significant relationship has been observed between the different forms of nitrogen ((R^2 about 0.24).

Table 3: Weighted Mean Concentration from atmospheric Deposition- Bukoba station

	Si (mg/L)	PbSi (mg/L)	TP (mg/L)	TPP (mg/L)	TDP (mg/L)	DOP (mg/L)	SRP (mg/L)	TN (mg/L)	NO3 (mg/L)	NO2 (mg/L)
Jan	-	-	0.334	0.17	0.164	0.054	0.11	-	0.114	0.004
Feb	0.002	0.007	0.342	0.249	0.093	0.017	0.076	0.137	0.039	0.003
Mar	0.055	0.124	0.116	0.064	0.052	0.011	0.041	0.017	0.041	0.005
Apr	0.519	0.732	0.147	0.074	0.073	0.024	0.049	0.052	0.065	0.014
May	0.032	0.171	0.201	0.069	0.131	0.081	0.05	0.151	0.103	0.033
Jun	-	-	-	0.143		-	0.005	0.619	-	0.002
Jul	-	-	-	-		-	0.012	0.718	-	0.004
Aug	0.023	0.011	0.147	0.046	0.089	0.066	0.023	-	0.073	0.002
Sep	0.985	0.036	0.154	0.106	0.047	0.019	0.028	-	0.057	0.004
Oct	0.023	0.013	0.021	0.006	0.015	0.003	0.012	-	0.005	0.002
Nov	1.64	0.089	0.238	0.054	0.184	0.06	0.124	-	0.058	0.003
Dec	0.165	0.081	0.153	0.048	0.104	0.074	0.03	-	0.054	0.002



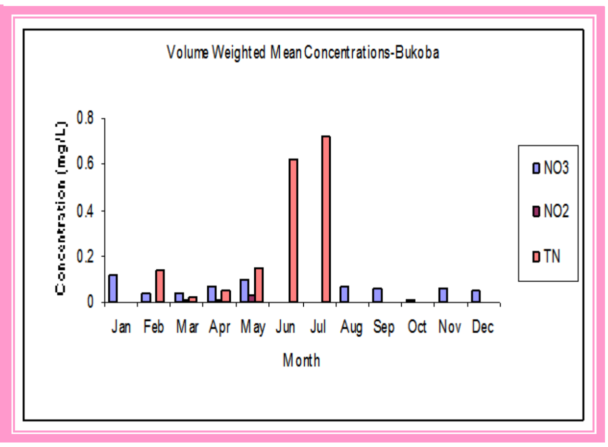


Figure 13: Temporal Variations Weighted Means Concentration of phosphorus

Figure 14 : Temporal variations Mean Concentrations of Nitrates

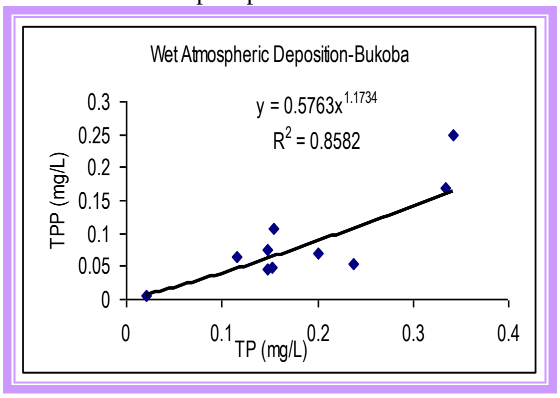


Figure 15: TP and TPP Relationship -Bukoba

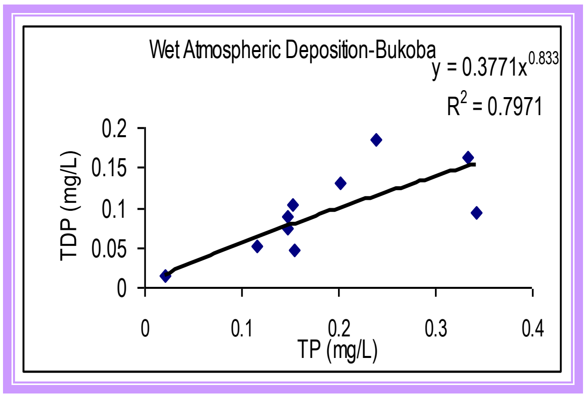


Figure 16: TP and TDP Relationship- Bukoba

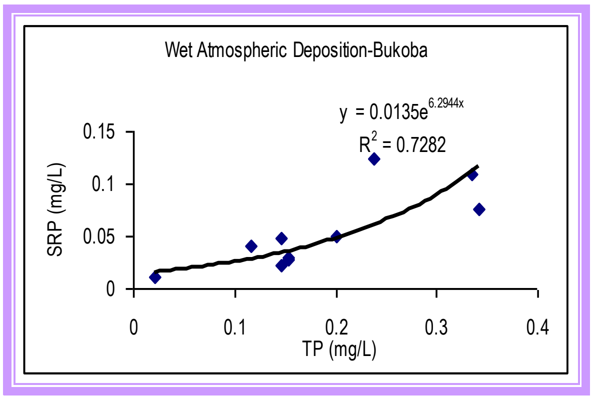


Figure17: Relationship between TP and SRP

Volume weighted mean concentration for Mwanza station are given in table 4 below. The highest concentrations of TP are observed in the months of August and October. Slightly higher concentrations have been observed in March, April and May, which are normally rain periods. No sufficient data for TN to make trend analysis are available for this station. High concentrations of TP have been observed during the months of August and October. Generally, the particulate form of phosphorus (TPP) dominates during the long rain (wet) period, while the dissolved form of phosphorus (TDP) is high during dry period. Unlike Bukoba, no significant relationship have been observed between TPP and TP (R2= 0.2027). Fairly significant relationship have been observed between TP and TDP (R2=0.54).

Table 4: Volume Weighted Mean Concentration - Mwanza Station

Month	TP mg/L	TDP mg/L	TPP	TN mg/L	NO3 mg/L
JAN	0.03	0.016	0.014	0.526	0.2
FEB	0.05	0.025	0.025	-	0.2
MAR	0.074	0.05	0.024	-	0.197
APR	0.054	0.021	0.033	-	0.104
MAY	0.061	0.054	0.007	-	0.27
JUNE	-	-		-	-
JULY	0.059	0.035	0.024	-	0.24
AUG	0.09	0.07	0.02	-	0.42
SEP	-	-		-	-
OCT	0.082	0.035	0.047	-	0.27
NOV	0.06	0.047	0.013	-	0.264
DEC	0.045	0.04	0.005	1.23	0.314

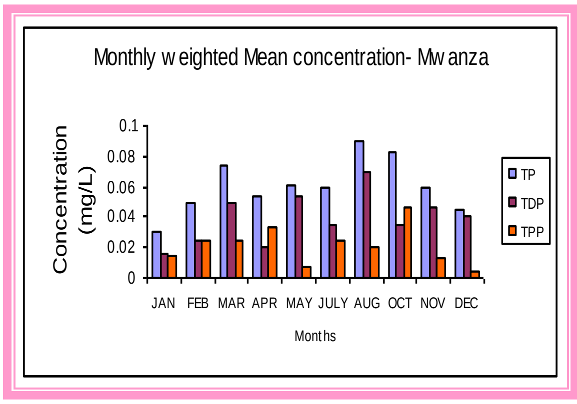


Fig 18: Seasonal Variations in phosphorus-Mwanza

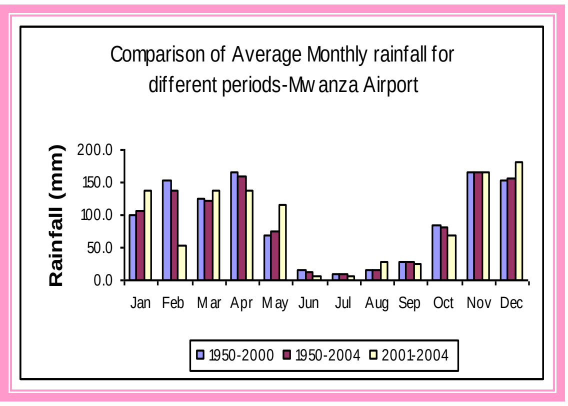


Figure 19 Average Monthly Rainfall – Mwanza

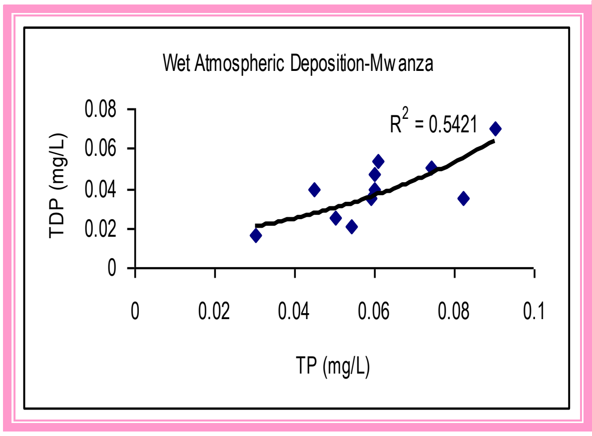


Figure20: Relationship between TP and TDP –Mwanza

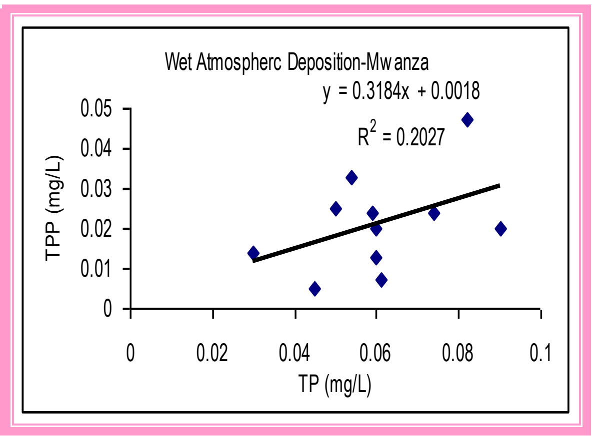


Figure 21: Relationship between TP and TPP

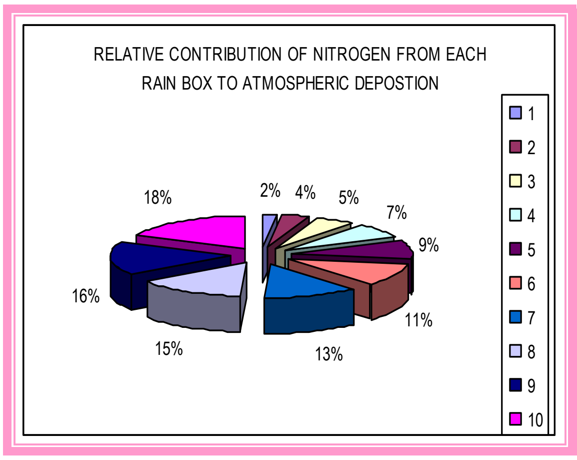
SUMMARY OF NON POINT LOAD

The estimates of total loads of nitrogen and phosphorus from atmospheric deposition are given in table 5 below while that from the catchment is summarized in table 6.

Table 5: Typical Concentrations and Atmospheric Deposition Loads to Lake Victoria

STATION		Area of Box	Average Rain	Conc. Rain		Wet Deposition		Dry Deposition		Dry Deposition		Total Deposition	
Box No.	ST-NAME	(km2)	(mm)	N-mg/l	P-mg/l	kgN/d	kgP/d	mgN/m2/d	mgP/m2/d	kgN/d	kgP/d	kgN/d	kgP/d
1	Muhuru	5247.3	1250	1.65	0.06	29,650.65	1,078.21	3.21	1.38	15,159.4	6,536.0	44,810.1	7,614.2
2	Musoma	4490.7	1300	1.65	0.06	26,390.61	959.66	3.21	1.38	12,973.6	5,593.6	39,364.2	6,553.3
3	Ukerewe	9300.4	1600	1.65	0.06	67,268.92	2,446.14	3.21	1.38	26,868.9	11,584.6	94,137.8	14,030.7
4	Mkula	1286.7	886	1.65	0.06	5,153.48	187.40	3.21	1.38	3,717.3	1,602.7	8,870.8	1,790.1
5	Mwanza	2706.4	1000	1.65	0.06	12,234.62	444.90	3.21	1.38	7,818.8	3,371.1	20,053.4	3,816.0
6	Bukerebe	7028	2400	1.65	0.06	76,249.30	2,772.70	3.21	1.38	20,303.9	8,754.1	96,553.2	11,526.8
7	Kahunda	5009.1	1450	1.65	0.06	32,833.61	1,193.95	3.21	1.38	14,471.3	6,239.3	47,304.9	7,433.3
8	Izigo	1553.4	1450	1.65	0.06	10,182.48	370.27	3.21	1.38	4,487.8	1,934.9	14,670.3	2,305.2
9	Bukoba	635.1	2400	0.28	0.18	1,169.28	751.68	3.21	1.18	1,834.8	674.5	3,004.1	1,426.2
10	Rubafu	1413	2300	0.28	0.18	2,493.08	1,602.69	3.21	1.18	4,082.2	1,500.6	6,575.2	3,103.3
TOTAL ATMOSPHERIC DEPOSTION (kg/d):												375,344	59,599
TOTAL ATMOSPHERIC DEPOSITION (tons/y)												137,001	21,754

Table 5 above indicates that about 21,754 tons of phosphorus and 137,001 tons of nitrogen are deposited annually into Lake Victoria (Tanzanian part), with the highest contribution (70%) of nitrogen deposited from wet atmospheric deposition and that of phosphorus (80%) coming from dry falls.



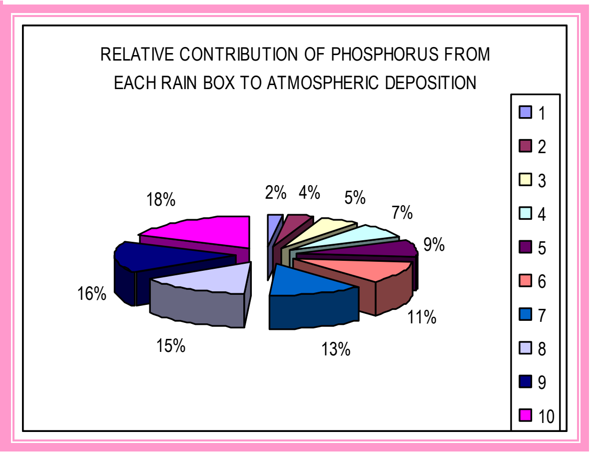


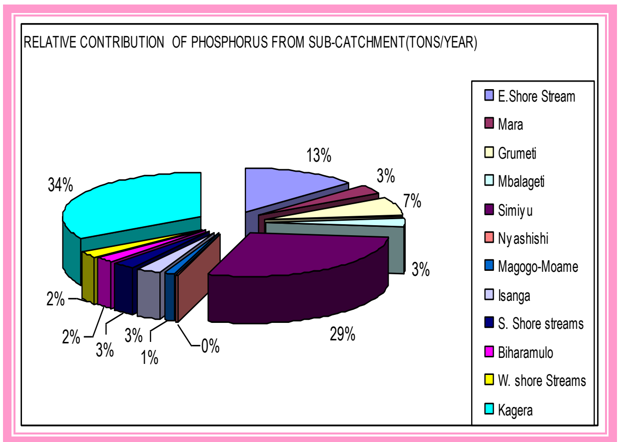
Figure 22: relative contribution of Nitrogen to Lake Victoria

Figure 23: Relative contribution of Phosphorus to Lake Victoria

CATCHMENT LOADS

Table 6: Catchment Loads

No.	Sub-Catchment	Area (km^2)	Discharge (m^3/s)	Nutrients/Sediment Loading (t/y)			Nutrient and Sediment Yield ($kg/km^2/y$)		
				N	P	TSS	N	P	TSS
1	E.Shore Stream	6644	20.2	796.9	895	278,891	120	135	41976
2	Mara	13393	41.72	1645.9	228.9	294,186	123	17	21966
3	Grumeti	13363	12.97	511.7	464.6	179,056	38	35	13399
4	Mbalageti	3591	5.29	208.7	189.5	73,031	58	53	20337
5	Simiyu	11577	42.98	1695.6	1904.4	2,075,144	146	164	179247
6	Nyashishi	1565	1.66	30.8	25.8	12,383	20	16	7912
7	Magogo-Moame	5207	8.94	166.1	62.6	66,688	32	12	12807
8	Isanga	6812	29.79	553.3	208.6	222,219	81	31	32622
9	S. Shore streams	8681	24.62	457.3	172.4	183,654	53	20	21156
10	Biharamulo	1928	18.36	708.1	140.1	110,560	367	73	57345
11	W. shore Streams	733	21.31	821.9	162.6	128,325	1121	222	175068
12	Kagera	59682	279.46	16357	2238.5	1,281,065	274	38	21465
TOTAL LOADS FROM THE SUB CATCHMENTS				**23,953**	**6,693**	**4,905,201**			
AVERAGE LOADS FROM THE SUBCATCHMENT							**202.8**	**67.91**	**50,442**



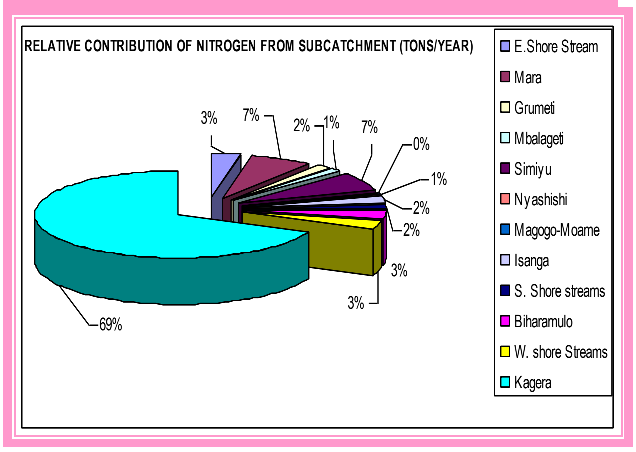


Figure 24: Relative Contribution of Phosphorus from Sub-Catchments

Figure 25: Relative Contribution of Nitrogen from Sub-Catchments

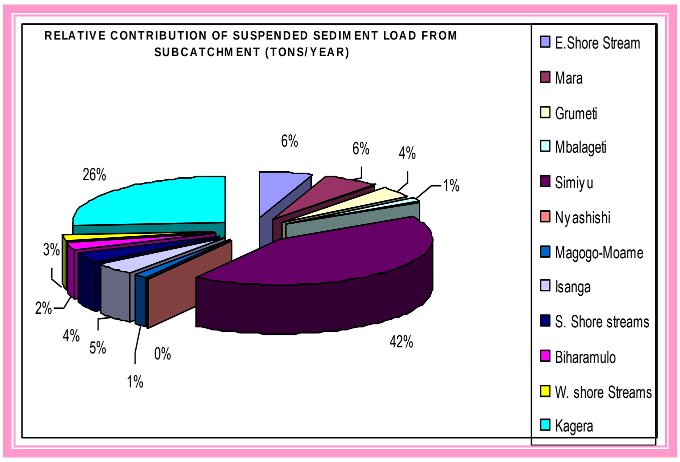
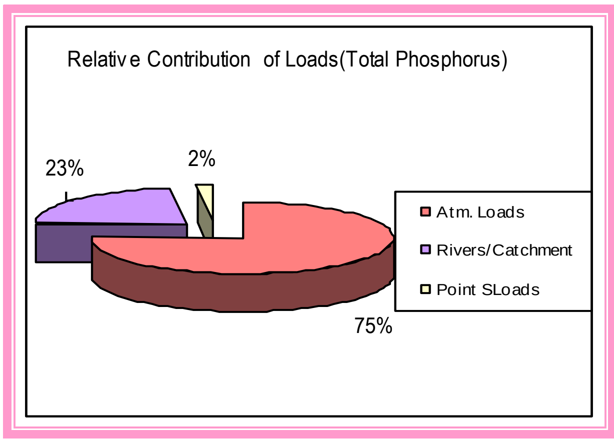


Figure 26: Relative Contribution of Sediment Loads from Sub-Catchments

Table Nutrients Ratios

No.	Sub-Catchment Name	Area km2	Mean Discharge (m3/s)	Volume Weighted Mean (VWM) Concentrations			Concentration Ratio of Parameters		
				N	P	TSS	N:P	TP:TSS	TN:TSS
1	E.Shore Stream	6644	20.2	1.25	1.4	437.8	0.8904	0.0032	0.0029
2	Mara	13393	41.72	1.25	0.17	223.6	7.1905	0.0008	0.0056
3	Grumeti	13363	12.97	1.25	1.14	437.8	1.1014	0.0026	0.0029
4	Mbalageti	3591	5.29	1.25	1.14	437.8	1.1013	0.0026	0.0029
5	Simiyu	11577	42.98	1.25	1.41	1531	0.8904	0.0009	0.0008
6	Nyashishi	1565	1.66	0.59	0.49	236.5	1.1938	0.0021	0.0025
7	Magogo-Moame	5207	8.94	0.59	0.22	236.5	2.6534	0.0009	0.0025
8	Isanga	6812	29.79	0.59	0.22	236.5	2.6524	0.0009	0.0025
9	S. Shore streams	8681	24.62	0.59	0.22	236.5	2.6526	0.0009	0.0025
10	Biharamulo	1928	18.36	1.22	0.24	190.9	5.0542	0.0013	0.0064
11	W. shore Streams	733	21.31	1.22	0.24	191	5.0547	0.0013	0.0064
12	Kagera	59682	279.46	1.86	0.25	145.4	7.3071	0.0017	0.0128

The E, shores streams, Grumeti, and Mbalageti are very rich in P:TSS (about 0.002-0.003), while others are around 0.001. also these have low N:P , but all streams relative to Kenya streams have low N:P



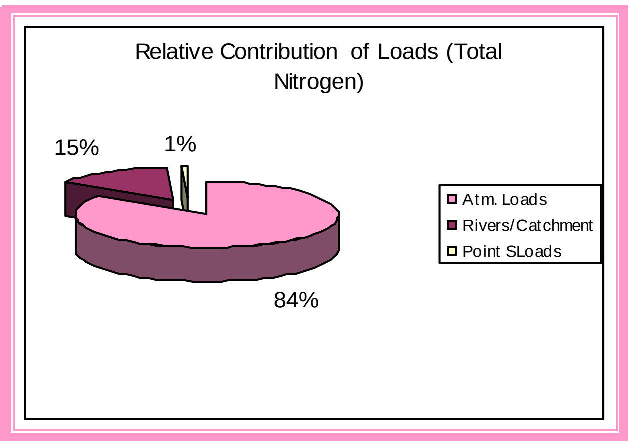


Figure 27: Relative Contributions of Phosphorus loads to the lake.   Figure 28: Relative Contribution of Nitrogen Load to the Lake

Table.7: Estimated annual atmospheric deposition of N and P to the lake

STATION		Area of Box	Average Rain	Conc. Rain		Wet Deposition		Dry Deposition		Dry Deposition		Total Deposition	
Box No.	NAME	(km2)	(mm)	N-mg/l	P-mg/l	kgN/d	kgP/d	$mgN/m^2/d$	$mgP/m^2/d$	kgN/d	kgP/d	kgN/d	kgP/d
1	Muhuru	5247.3	1250	1.65	0.06	29,650.65	1078.2	3.21	1.38	15159.4	6536.0	44810.1	7614.2
2	Musoma	4490.7	1300	1.65	0.06	26,390.61	959.7	3.21	1.38	12973.6	5593.6	39364.2	6553.3
3	Ukerewe	9300.4	1600	1.65	0.06	67,268.92	2446.1	3.21	1.38	26868.9	11584.6	94137.8	14030.7
4	Mkula	1286.7	886	1.65	0.06	5,153.48	187.4	3.21	1.38	3717.3	1602.7	8870.8	1790.1
5	Mwanza	2706.4	1000	1.65	0.06	12,234.62	444.9	3.21	1.38	7818.8	3371.1	20053.4	3816.0
6	Bukerebe	7028	2400	1.65	0.06	76,249.30	2772.7	3.21	1.38	20303.9	8754.1	96553.2	11526.8
7	Kahunda	5009.1	1450	1.65	0.06	32,833.61	1194.0	3.21	1.38	14471.3	6239.3	47304.9	7433.3
8	Izigo	1553.4	1450	1.65	0.06	10,182.48	370.3	3.21	1.38	4487.8	1934.9	14670.3	2305.2
9	Bukoba	635.1	2400	0.28	0.18	1,169.28	751.7	3.21	1.18	1834.8	674.5	3004.1	1426.2
10	Rubafu	1413	2300	0.28	0.18	2,493.08	1602.7	3.21	1.18	4082.2	1500.6	6575.2	3103.3
TOTAL ATMOSPHERIC DEPOSTION (kg/d):												375,344	59,599
TOTAL ATMOSPHERIC DEPOSITION (tons/y)												137,001	21,754

CONCLUSIONS

It is undisputedly that atmospheric deposition is the predominant source of nutrient loading to Lake Victoria confirming earlier observations by LVEMP (2002) and Tamatamah (2001). Other significant sources are river loads possibly due to agricultural activities in the catchment. These two sources when combined account for 99 and 98% of the total N and P inputs to Lake Victoria. The catchment loads contributes to about 15 and 23% of N and P of the total loads respectively. Total inputs to the lake including Industrial and municipal sources are currently estimated at 162,224 and 28,949 tonnes /year of N and P respectively.

The current atmospheric deposition loads is higher than that estimated by Tamatamah (2002) and LVEMP (2002), this is possibly due to the fact that more data covering different seasons has been collected compared to previous data. Tamatamah, (2002), collected data in Bukoba between June and December, missing the period between January and May, which are the rain period in the region, and according to the present studies, the areas in the western part of the lake Kagera inclusive, contributes to the highest phosphorus deposition compared to dry falls. For LVEMP (2002) studies, the major limitation was the small sample size of rain data used e.g. for Bukoba, only 5 data were used giving an average value of 0.03 compared to the current 0.18mg/L

Phosphorus load to the lake by dry and wet falls has been found to have a very strong spatial and temporal variability. In the western part of the lake, higher contribution of phosphorus is by wetfalls while in the eastern part, the dryfall contribute to the largest amount of phosphorus load. However, the comparison of the overall deposition of phosphorus to the lake indicates that the dry falls is higher than the wet falls confirming earlier findings by Tamatamah (2005), although at a much higher percentage of 85 compared to 75%.

The suspended sediment load from the catchments to the lake is currently estimated at 4,905.2ktons/year, with Simiyu River carrying the largest suspended sediment load estimated at about 42.3% of the total load to the Lake, which is in the same order of magnitude with those suggested by Machiwa (2001). Kagera River is rated the second contributing to about 26.1%. Simiyu catchment is therefore generating high yields of sediments (179.2ktons/km2/y) confirming earlier observation by Machiwa, (2002), possibly due to its relatively large size and many agricultural activities (Rwetabula, 2005).

There is tremendous variation in the nutrient loads and sediments of the rivers, both through space and time. For example, nitrogen and phosphorus both accumulate down a watershed as successively larger drainage areas are integrated. These two nutrients also vary significantly with the seasons. Nitrogen and phosphorus concentrations are highest in the early rainfall. This is due to factors associated with early runoffs, such as the release of nutrients stored in the soil Simiyu and Kagera Rivers. These seasonal peaks are most pronounced in the headwaters of the watershed.

Two potentially important sources of nutrients that remain to be considered are recycling within the lake and subsurface inflow of groundwater. Up to now, it has been found that groundwater is not significant parameter in water balance (MacCann, 1972). Also preliminary results of samples from Tanzania analysed for stable isotopes indicate insignificant interaction between groundwater and the lake (Rwegoshora et al.)

River flow early in the rainy season are carried much higher conc of both sediments and nutrients than similar flow late in the the rainy season. This is likely due to the flushing out of debris from the prolonged dry season and soil losses from the cultivated planted fields prepared for the beginning of the rains.

RECOMMENDATIONS

It must be said that the estimation of non-point pollution sources is at an initial stage and consequently it is strongly recommended to continue the work and improve the load estimates both from land and from the atmosphere. Various data gaps have been identified and therefore a great need to fill in the existing data gaps. The following particular recommendations and outstanding issues are given:

River water quality

Time series are needed. The capacity for field work is a constraint there should be emphasis on down stream stations. The Kagera and Simiyu rivers together account for more than half of the land based nutrient and suspended sediment loads and should be given overall priority

Atmospheric deposition

In addition to the stations located on land, emphasis should be laid on collection of offshore samples, on islands and onboard the ships when sampling for the Lake Water Quality programme.

Landuse information

In Tanzania practises of application of agrochemicals on different crops should be identified.
Major issue has been omitted from the assessment work, namely the quantification of nutrient runoff due to deforestation and alteration of soils caused by agriculture. A way of estimating such effects in the future would be to use an integrated river basin model with water quality module. When reliable time series of water quality measurements are available, as well as distribution of agrochemical inputs, the nutrient balance of such a model would indicate where major runoff of nutrients takes place from sources other than agrochemical runoff.

Finally, the study has not included an assessment of the importance of nitrogen fixing blue-green algae which may contribute significantly to the nitrogen budget.

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INDUSTRIAL AND MUNICIPAL LOADING – POINT SOURCES

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ABSTRACT

Industries and urban centres (towns) represent point sources of pollution. This pollution if not well managed they can end up into the lake and pollute it especially the near shore waters. This study is aimed at identifying and quantifying municipal and industrial wastewater pollution from the urban centers and industries respectively. The magnitudes of this pollution was measured, but where reliable measurements of representative flows and concentrations were difficult to establish, professional estimates from production figures, economic turn-over, water and energy consumption by industries, and population numbers, have been used.

From 2000-2005 samples from 19 large urban centres and 31 Industries were collected and analyzed for selected water quality variables namely BOD_5, TP, TN, TSS and FC according to standard methods. From the study it is seen that the main point sources are concentrated in Mwanza City, and Musoma and Bukoba Municipalities. The total resulting municipal pollution load (Kg/day) from the urban centres of 996,108 inhabitants into Lake Victoria was found to be: BOD_5 9,998; TN 1,778; 711, TSS 6,664, and FC 6.3 x 10^{14} No./day while the resulting industrial load was found to be: BOD_5 5,201; TN 653; TP 185; TSS 4,934 and FC 1.1 x 10^{14} No./day. Urban centers contribute more pollution loading to the Lake compared to industries. They contribute 66% BOD_5; 73% TN; 79% TP; 57% TSS and 85% FC. This shows how urban growth is a threat to the Lake pollution since the urban pollution in the 1950^s were quite low as compared to the current period.

This situation calls for immediate mitigation measures that include: public awareness, developing a culture of industrial and municipal environmental compliance, construction and use of proper sanitary facilities, efficient wastewater treatment facilities, cleaner production technology and enforcement of compliance to effluent standards

This study is highly valuable as it provides pollution inventories, which can accelerate environmental compliance, by providing the information base to understand Pollution problems; identify priority options; make informed decisions; and identify opportunities for waste minimization and Cleaner Production. A database has been prepared and documented and can be used for management purposes.

Key Words: Pollution loads, Point sources, Lake Victoria, Water quality, Mitigation Measures.

INTRODUCTION

Industrial and municipal effluents are primary contributors to point source discharges into Lake Victoria. These are loads entering the environment at a single, readily identified entry point, not caused by diffuse sources as the non-point pollution. Point sources are specific discharges from municipalities or industrial complexes; e.g. organics or metals entering surface water due to wastewater discharge from manufacturing plant (Liu and Liptak 1997). Point sources are relatively easy to regulate. Point sources waste discharges in the Lake Victoria basin are controlled by the Lake Victoria Basin Water Office through the legal framework for the water resources management which is provided by the Water Utilization (Control and Regulation) act No 42 of 1974, and its amendments No 10 of 1981 and No. 8 of 1997 and the discharge permit system. The permits for each input specifies the duration, quality, quantity and other conditions of the waste permitted to be discharged to a river or lake at a particular location (LVBWO 2005). Application forms to be filled before a request for a discharge permit is considered are appended to this paper (APPENDIX II & III). The National Water Policy requires these permits be drawn up in such a way that water quality objectives for the receiving waters are met (MoWLD 2002). This often requires industries and urban centres to treat their waste to remove pollutants before discharging to the environment. Waste discharge permits are legal documents. If the levels of pollutants in the waste or the quantity of waste discharged exceed the limit set down in the permit, the person or company responsible for that discharge can be prosecuted by law. The basin water staff has an obligation of inspecting waste discharges from time to time and takes samples of effluent, which can be analyzed to determine whether the permit is being met. The issuing and enforcement of permits for industrial and urban centres' waste discharges if implemented efficiently they can improve the quality of receiving water bodies. However, the Lake Victoria Basin Water Office is still an infant (three years old) and with inadequate capacities in terms of human resources, funds and facilities.

During the last few years, industries in the Lake Victoria Basin have suffered from considerable structural and economical problems, and many public enterprises are now being privatized. However, because of the EAC economic common market, existing airports, good arterial roads and an attractive living environment, the area may become an important industrial location in near future. Industrial activities so far includes fish processing, coffee processing, cane sugar manufacturing, Textile Mills, abattoirs, Gold mines, soft drinks industries, breweries, vegetable oil industries etc. One tannery, three dairies, six vegetable oil industries, one soap industry and two fish processing industries closed down due to various reasons. Almost all industries are concentrated in the three major urban centers of Mwanza City, and Musoma and Bukoba Municipalities, which have better infrastructure and much needed services e.g. roads, power, water supply etc. (LVEMP 2005).

In Tanzania and other countries within the sub-region, waste stabilization pond systems are the technology of choice for wastewater treatment. The principle reason is the low investment and operation costs as compared to the conventional treatment systems (Okurut 2000). Effluent treatment facilities in Lake Victoria basin industries range from Waste stabilization Ponds (WSPs) to no treatment at all. It cannot be denied that most industries in the Lake Victoria basin have been established without serious prior environmental consideration. Local industrial managements and town planners lacked awareness as well as expertise on the environmental impacts arising from the industrial processes. The siting, choice of technology and the actual operation of these industries were implemented without considering the environmental implications. Most industries were commissioned without pre-treatment facilities for unwanted wastes and indeed, nobody bothered as to how and in what form industrial wastes would be disposed off. The few industries, which had treatment facilities, had them poorly maintained and most are not complying with the set effluent standards. Designs of most facilities were generally poor and the execution worse. Land availability has always been a constraint to the application of WSPs technology. Environmental education and awareness of the majority of the stakeholders in the catchment area is still very low. Not until 2005 when Environmental law was enacted, Environmental Impact Assessment (EIA) was optional and as a result, few, if any EIAs, were conducted before commissioning of the industries. Some of the industries were not purpose designed including cotton godowns turned into fish processing industries during the "fish boom" (Mnyanga, 2005). Problems associated with the poor designs and configurations of the facilities include overloading, short detention time, short-circuiting, poor inlet and outlet arrangements, sludge removal and re-suspension etc. As a result of the above, they discharge raw or partial treated effluents into the environment. The discharge of untreated or partially treated wastewater is suspected to have led to heavy pollution of the aquatic environment in and around the lake.

Urban centers in the Lake Victoria basin with the exception of Mwanza City are all not sewered. The urban population use onsite sanitation including pit latrines, septic tanks coupled with soak-way pits, VIPs and open defecation. Mwanza, the only city in the basin is 3% sewered (only the central part) serving 7% of its population. The collected sewage is treated through a ten Waste Stabilization Ponds System (one anaerobic, one facultative and eight maturation all in series) at Butuja and disposed into the Iloganzala Stream before entering Lake Victoria about 200m away through an encroached natural wetland. However, some areas of the city being hilly and rocky part of its squatter population is forced to construct shallow pit latrines with spillways, which are opened during rainy season and take advantage of surface run-off to flush the contents to the Lake.

The effects of pollution from point sources in receiving water quality are manifold and depend on the type and concentration of pollutants (Nemerous and Dasgupta, 1991). Soluble organics, as represented by high BOD waste, deplete oxygen in surface water. This can result in fish kills, the growth of undesirable aquatic life, and undesirable odours. Trace quantities of certain organics cause undesirable tastes and odours, and certain organics can be biomagnified in the aquatic food chain. Suspended solids decrease water clarity and hinder photosynthetic processes, if solids settle from sludge deposits, changes in benthic ecosystem results. Colour, turbidity, oils, and floating materials influence water clarity and photosynthetic processes and are aesthetically undesirable. Excessive nitrogen and phosphorus lead to algal overgrowth with contaminant water processes. Chlorides cause a salty taste in water; and in sufficient concentration, water usage must be limited. Acids, alkaline, and toxic substances can cause fish kills and create imbalances in stream ecosystems. Thermal discharges can also cause imbalances and reduce the stream water assimilative capacity stratified flows from thermal discharges minimize normal mixing patterns in receiving streams and reservoirs (Liu and Lipták, 1997). Poor sanitary conditions and polluted water are associated with the Water borne and other water related diseases. The diseases common in the Lake Victoria basin include malaria, cholera, typhoid, dysentery, diarrhoea, intestinal worms, amoebiasis, and Bilharzias (Mnyanga 2002b).

This chapter focuses on the contribution of Point Sources to Lake Victoria pollution. It reveals results of the study conducted between 2000-2005 aimed at identifying and quantifying municipal and industrial wastewater pollution from the urban centers and industries respectively.

METHODOLOGY:

The determination of pollution loads from the point sources has been limited to the following parameters: Biochemical Oxygen Demand (BOD_5), Total-Nitrogen (TN), Total-Phosphorus (TP), Total Suspended Solids (TSS), and Faecal Coliforms (FC) because of their relevance as health indicators and their contribution to eutrophication of the Lake.

Two criteria have been used for selection of point sources for the assessment. Thus, only towns with more 10,000 inhabitants have been included, defining smaller town as rural settlements. For the selection of industries, only those which could be called "wet" industries (using water in the production) have been considered.

For each of the point sources the following information has been identified and assessed:

- Name of sub-catchment area for location of point source
- Town and/or province area for location of point source
- Co-ordinates
- Population figures for major cities and towns and year for determination of the population figures.

  Based on assessments of population growth in the different cities and towns all population figures have been calculated to Year 2005 level.

  The population growth for the different towns are assessed individually, but the following population growth figures are typically used:

  (H) Highly expanding towns (typically larger towns): 5% growth
  (N) "Normal" expanding towns (typically medium size towns): 4% growth
  (R) "Rural expanding" towns (typically small towns): 3% growth

- Types and names of industries with significant wastewater production. Wastewater productions from small scale industries and/or industries with very limited wastewater production are assessed to be included in the municipal wastewater production.

The following methods have been used to quantify the industrial and municipal effluents:

1. Measurements:
   If measurements for industrial and municipal wastewater discharges have been available, these have been used to the extent possible. For most urban centres only limited measurements for wastewater pollution were available as majority does not have sewerage systems, while for industries measurements were taken. However, in isolated cases concentrations for industrial effluents were measured without corresponding discharges. Nevertheless the data quality and reliability have in several cases been high.

2. Standard figures for municipal loads.
   If no measurements have been available the following standard figures have been used for municipal wastewater pollution loads:
   BOD: 30 – 40g/p.e/day,
   Total Nitrogen: 5g/p.e/day,
   Total Phosphorus: 2g/p.e/day,

Total Suspended Solids: 44g/p.e/day
Faecal Coliform: $2x10^9$No./p.e/day.

These values reflect the levels for populations in developing countries with relatively low protein intake.

3. <u>Industrial pollution loads based on production figures</u>
   If no measurements have been available for industrial wastewater production, the assessment of wastewater pollution loads has been based on standard loads per production unit for the particular industry type and the actual production figures. The "World Bank Pollution Prevention and Abatement Handbook. Industry Sector Guidelines"; "World Health Organization (WHO), Rapid Assessment of Sources of Air, Water; Land Pollution, WHO Offset Publication No. 62, Geneva, 1982" and "Bacteriology for sanitary Engineers. D.D. Mara 1974" have been used as the main references for determination of industrial wastewater pollution based on production figures.

4. <u>Rough estimates</u>
   If neither wastewater production nor industrial production figures have been available, rough estimates have been given based on either number of staff, local knowledge or similar.
   Finally some industries have not been taken into account in the determination of wastewater pollution load to Lake Victoria as they have "zero discharge" e.g. mining industries.

Based on the above calculation methods, basic loads (weighted averages) for each of the point sources have been calculated. Basic loads are defined as the actual wastewater pollution production generated at the individual point source, i.e. total wastewater production from towns and industries.

The discharge methods from each of the point sources have been identified or assessed.

The following categories of discharge methods have been used:

- Direct discharge to Lake Victoria, a river or a stream
- Discharge to municipal sewer system
- Discharge to septic tanks or pit latrines
- No sewerage facilities
- Discharge to wastewater treatment facilities
- Discharge to wetlands
- Zero discharge

Where relevant, the fractions of wastewater discharged by different methods have been assessed. For larger towns the wastewater is typically discharged through a combination of more of the above options. As an example, the combination of discharge methods in Mwanza is assessed to be:

- Direct discharge to Lake Victoria, a river or a stream 20%
- Discharge to municipal sewer system 3%
- Discharge to septic tanks or pit latrines 75%
- Discharge to wastewater treatment facilities 3%
- Discharge to wetlands 5%

The sum of the above figures for discharge methods shall not necessarily be 100%, since for example, wastewater discharged through the municipal sewer system is treated at the wastewater treatment facilities and part of the wastewater that is discharged directly to a stream flows through wetlands.

Based on the discharge methods the reduction of the basic wastewater loads before the wastewater pollution reaches the nearest recipient has been assessed.

The resulting reduced load indicates the amount of pollutants reaching the nearest watercourse, i.e. stream, river or Lake Victoria. The further reduction of pollutants through the river system before they reach Lake Victoria is hence not included in the reduction rates.

Using Mwanza again as an example, the following basic loads, reduction rates and resulting loads have been estimated based on an assessed population of 446,623 persons:

	Unit	**Basic load**	**Reduction**	**Resulting load**
Biochemical Oxygen Demand (BOD_5)	Kg/day	13399	60%	5,359
Total Nitrogen (TN)	Kg/day	2233	55%	1,005
Total Phosphorus (TP)	Kg/day	893	55%	402
Total Suspended Solids (TSS)	Kg/day	17865	75%	4,466
Faecal Coliforms (FC)	No./day	8.9E x 14	65%	3.1E x 14

RESULTS AND DISCUSSION

In table 5.1 below the estimate of the resulting municipal point sources is shown. In total 46 large towns have been identified in the Tanzania part of the lake Victoria catchment area, of which 17 are in Mwanza, 11 in Mara and 18 in Kagera Regions.

In the attachment to this chapter detailed figures for the assessment of the municipal point sources are given.

Table 5.1: Municipal pollution Load 2005

Catchment area	Urban Centre	Population/persons	Resulting load (kg/day)				No. FC/day
		(Year 2005)	BOD_5	Total-N	Total-P	TSS	FC
Nyashishi	Mwanza	446,623	5359	1005	402	4466	3.1E+14
Southern Shore Streams	Geita	45,798	412	69	27	183	2.7E+13
Magogo	Ngudu	13,863	125	21	8	55	8.3E+12
Nyashishi	Kisesa	11,123	100	17	7	44	6.7E+12
Simiyu	Magu	19,274	173	29	12	77	1.2E+13
Magogo	Misungwi	13,641	123	20	8	55	8.2E+12
Southern Shore Streams	Nkome	16,875	152	25	10	67	1.0E+13
Southern Shore Streams	Katoro	14,706	132	22	9	59	8.8E+12
Southern Shore Streams	Sengerema	43,222	389	65	26	173	2.6E+13

Eastern Shore Streams	Nansio	31,880	287	48	19	128	1.9E+13
	Total - Mwanza	**657,004**	**7253**	**1320**	**528**	**5308**	**4.4E+14**
Eastern shore streams	Musoma	117943	1061	177	71	472	7.1E+13
Grumeti	Bunda	45449	341	57	23	182	2.3E+13
Grumeti	Mugumu	14116	42	7	3	56	2.8E+12
Eastern Shore Streams	Sirari	18352	165	28	11	73	1.1E+13
Eastern Shore Streams	Tarime	40632	366	61	24	163	2.4E+13
	Total - Mara	**236493**	**1976**	**329**	**132**	**946**	**1.3E+14**
Western Shore Streams	Bukoba	66544	499	83	33	266	4.0E+13
Biharamulo	Biharamulo	10782	81	13	5	43	6.5E+12
Southern shore Streams	Buseresere	10055	75	13	5	40	6.0E+12
Southern shore Streams	Chato	15231	114	19	8	61	9.1E+12
	Total- Kagera	**102611**	**770**	**128**	**51**	**410**	**6.2E+13**
	Total - Tanzania	**996,108**	**9,998**	**1,778**	**711**	**6,664**	**6.3E+14**

Table 5.2: Municipal pollution Loads by Catchments 2005

Catchment area	Population/persons	Resulting load (kg/day)				
	(Year 2005)	BOD_5	Total-N	Total-P	TSS	No. FC/day
Nyashishi	457746	5460	1022	409	4511	3.2E+14
Simiyu	19274	173	29	12	77	1.2E+13
Magogo	27504	248	41	17	110	1.7E+13
Eastern Shore Streams	208808	1879	313	125	835	1.3E+14
Grumeti	59565	383	64	26	238	2.6E+13
Southern Shore Streams	145887	1275	213	85	584	8.8E+13
Western Shore Streams	66544	499	83	33	266	4.0E+13
Biharamulo	10782	81	13	5	43	6.5E+12
TOTAL LOADS	**996,108**	**9,998**	**1,778**	**711**	**6,664**	**6.3E+14**

Table 5.2 above and Fig.1 and Fig.2 below confirms that for Municipal pollution loads by catchments, Nyashishi sub-catchment harbouring Mwanza City and Kisesa has the largest resulting load discharged into the Lake Victoria followed by Eastern Shore Streams sub-catchment nesting urban centres of Musoma, Tarime, Sirari, and Nansio. Southern Shore

Streams sub-catchment follows in the list which is a home of a cluster of urban centres including Geita, Sengerema, Katoro, Nkome, Buseresere, and Chato. While Western Shore Streams sub-catchment is next in the list with urban centre of Bukoba. Sub-catchments of Grumeti, Magogo, Simiyu, and Biharamulo follow the list in a descending order.

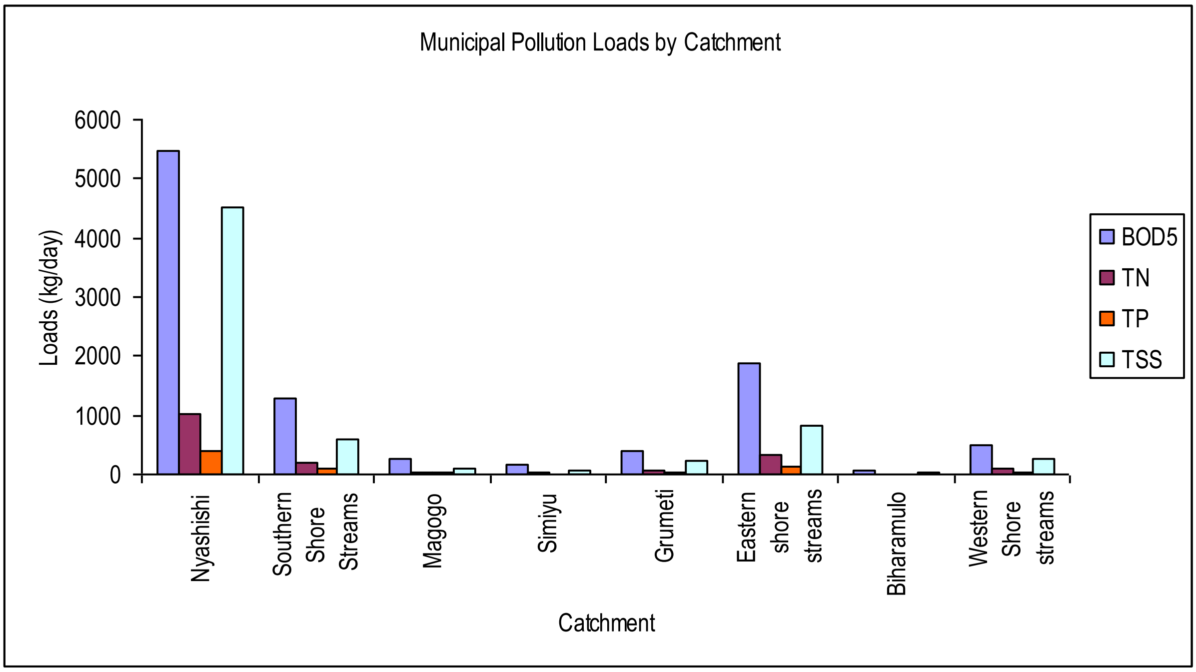


Fig.1: Municipal pollution Loads by Catchment

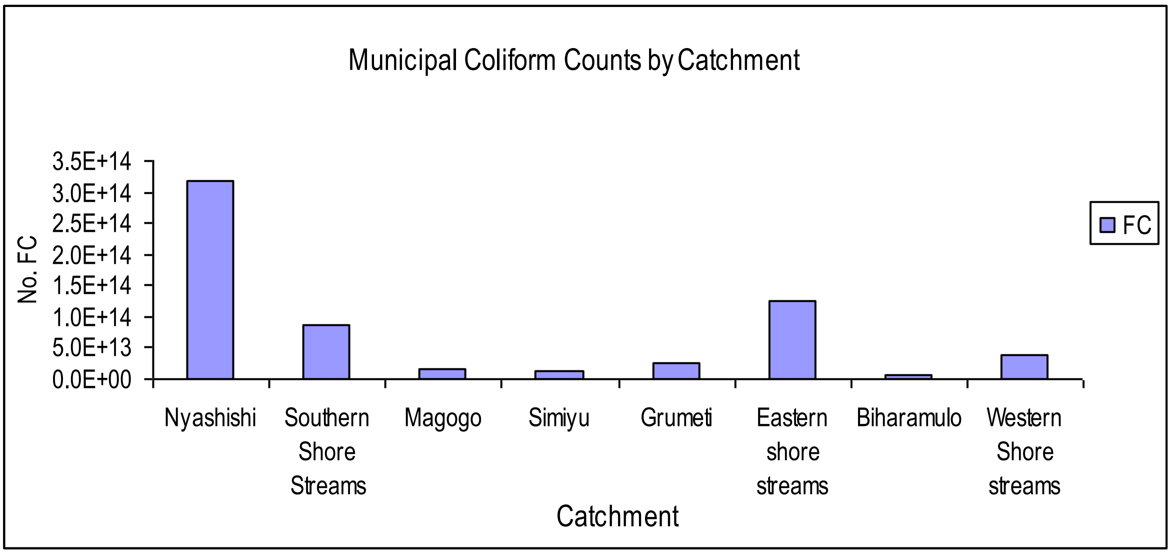
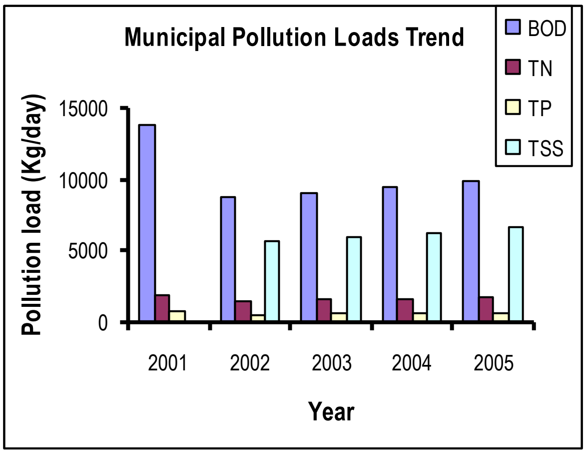


Fig. 2: Municipal Coliform Loads by Catchment

Table 5.3: Municipal Pollution loads Trend

Year	Urban centre's	Resulting load (kg/day)				No. FC/day
	Population	BOD	Total-N	Total-P	TSS	FC
2001	1020613*	13887*	1998*	799*		
2002	875511	8769	1556	623	5817	5.6E+14
2003	913958	9158	1628	651	6086	5.9E+14
2004	954131	9568	1701	680	6368	6.2E+14
2005	996108	9998	1778	711	6664	6.3E+14

Municipal pollution loads show an incremental trend between the year 2002 and 2005 as clearly shown in Table 5.3 above and Fig.3 and Fig. 4 below. This can be explained by the normal population increase and the increase due to rapid growth of the mining and fish industries in the basin and the minimal investment on new installations and or improvement of wastewater treatment facilities. However, data of 2001 shows exaggerated higher figures and should be used with caution as it was a projection from the1988 National Census.



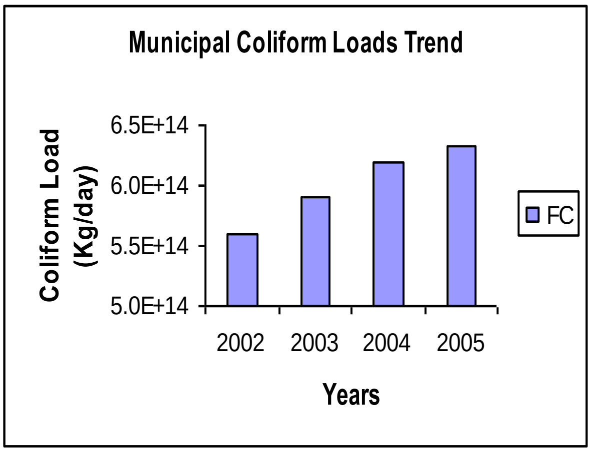


Fig. 3: Municipal Pollution Loads Trend **Fig.4: Municipal Pollution Coliforms Loads Trend**

Industrial Point Sources

Table 5.4: Major Industrial Categories in the Catchment

S/No.	Industrial Category	Number of Establishment	Operating	Closed/Under Construction	Studied
1.	Fish Processing	15	12	3	YES
2.	Abattoirs	3	3	0	YES
3.	Vegetable Oil Refining	11	4	7	YES
4.	Textiles	3	2	1	YES
5.	Soft Drinks	4	4	0	YES
6.	Coffee Processing	3	3	0	YES
7.	Breweries	1	1	0	YES
8.	Cane Sugar Processing	1	1	0	YES
9.	Fish Net	1	1	0	YES

	Manufacturing				
10.	Dairy	4	1	3	NO
11.	Gold Mining	5	5	0	NO
	TOTAL	**51**	**37**	**14**	

The point sources pollution loading to the lake from industries in the Lake Victoria basin is as shown in Table 5.4 below. The number of industries in the catchment area is 31, of which 17 are in Mwanza, 8 in Mara and 6 in Kagera Region.

Table 5.5: Industrial Pollution Loads by Catchment 2005

Catchment area	Town	Resulting load (kg/day)				No. FC/day
		BOD	Total-N	Total-P	TSS	FC
Eastern Shore Streams	Mara Fish Packers (T) Limited	52	0.95	0.45	88	4.4E+08
Eastern Shore Streams	Prime Catch Limited.	29	2	0.53	79	1.7E+06
Eastern Shore Streams	Musoma Abattoir	15	3.3	1.3	25	2.1E+12
Eastern Shore Streams	Musoma Bottlers	12	0.18	0.30	14	9.3E+11
Eastern Shore Streams	New Musoma Textile Ltd (MUTEX)	270	54	36	22	8.9E+11
Eastern Shore Streams	Musoma Fish Processors	103	16	2	15	1.7E+09
Eastern Shore Streams	Mara Coffee Limited	4.3	0.10	0.39	1.00	6.4E+10
Grumeti	Bunda Oil Industries Ltd.	408	10	5	697	2.3E+12
Nyashishi	Vegetable Oil Industries Ltd (VOIL)	240	9	6	612	9.8E+11
Nyashishi	VIC FISH Limited	155	32	5	32	1.9E+12
Nyashishi	Tanzania Fish Processors	163	23	5	49	1.4E+13
Nyashishi	Tanzania Breweries Limited (TBL)	102	19	5	41	1.5E+12
Nyashishi	Tan Perch Limited	136	4	23	167	6.6E+12
Nyashishi	Omega Fish Limited	209	33	6	80	5.9E+12
Nyashishi	Nile Perch	369	78	6	205	1.1E+13
Nyashishi	Mwanza Fishing Industries	133	24	3	28	1.8E+12
Nyashishi	Mwanza Fish Meal	116	3	3	1087	7.0E+12
Nyashishi	Birchand Oil Mill Limited	670	48.76	1.57	402	1.3E+13
Simiyu	Chain Food International	2.0	0.09	0.04	0.76	6.3E+10
Nyashishi	Mwanza Abattoir	49	11	4	46	3.9E+12
Nyashishi	New Era	192	50	24	490	8.8E+11
Nyashishi	Regent Food and Drinks Limited	305	61	16	104	6.6E+10

Nyashishi	Nyanza Bottling Company Ltd.	353	9	2	116	8.3E+12
Nyashishi	Mwanza Fish Net	105	5	0	16	9.7E+10
Nyashishi	Mwatex	336	97	2	71	6.1E+12
Western Shore Streams	SBC Limited	243	6.20	1.20	134.7	8.8E+12
Western Shore Streams	BUKOP Limited. Coffee Curing	4.32	0.10	0.39	1	6.4E+10
Western Shore Streams	Tanganyika Instant Coffee Company Ltd.	8	0.20	0.02	0.50	6.0E+10
Western Shore Streams	Bukoba Abattoir	10	2.20	0.90	9.10	8.8E+12
Kagera	Kagera Sugar	400	50	25	300	7.0E+10
Western shore streams	Kagera Fish Processors	8	1.26	0.20	1.44	1.4E+12
	Total Load (Kg/day)	**5201**	**653**	**185**	**4934**	**1.1E+14**

Table 5.6: Industrial Pollution Loads by catchments

Catchment area	Resulting load (kg/day)				No. FC/day
	BOD	Total-N	Total-P	TSS	FC
Eastern Shore Streams	486	77	41	246	4.0E+12
Grumeti	408	10	5	697	2.3E+12
Nyashishi	3631	506	111	3544	8.3E+13
Simiyu	2.0	0.09	0.04	0.76	6.3E+10
Western Shore Streams	273	10	3	147	1.9E+13
Kagera	400	50	25	300	7.0E+10
Total Loads	**5200**	**653**	**185**	**4934**	**1.1E+14**

Nyashishi sub-catchment demonstrates large industrial pollution loads as compared to other sub-catchments as shown in Table 5.5 above and, Fig. 5 and Fig. 6 below. Nyashishi sub-catchment is a home of Mwanza City, which has many industries of different categories. Eastern Shore Streams sub-catchment harboring Musoma Municipal is next in the list followed by Western Shore Streams sub-catchment of Bukoba Municipal.

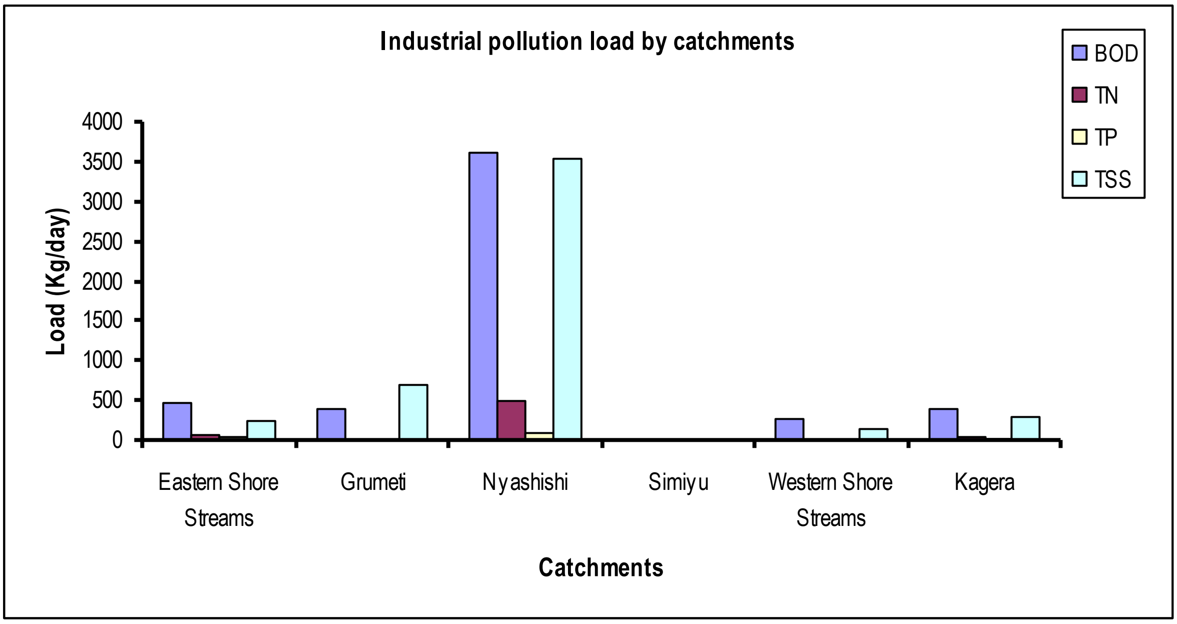


Fig. 5: Industrial pollution Loads by Catchment

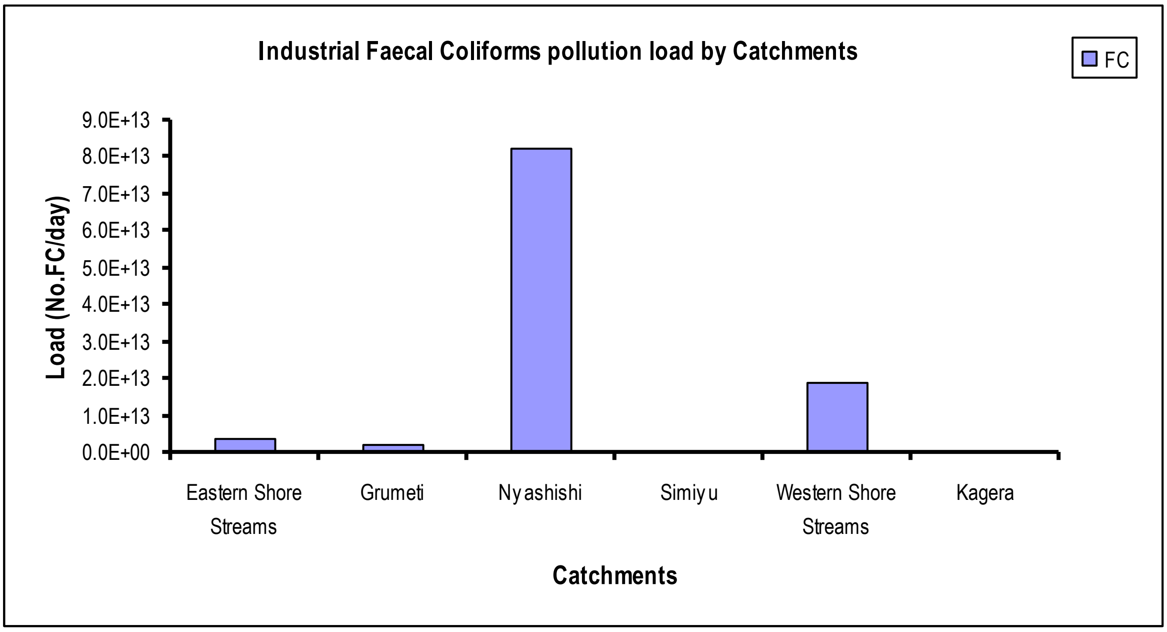
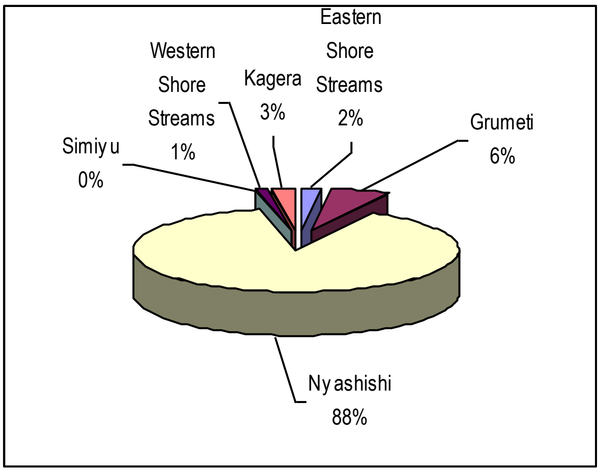


Fig. 6: Industrial Faecal Coliform Pollution Loads by Catchment



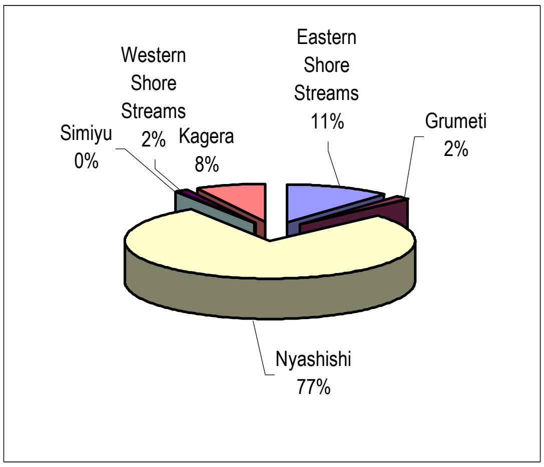
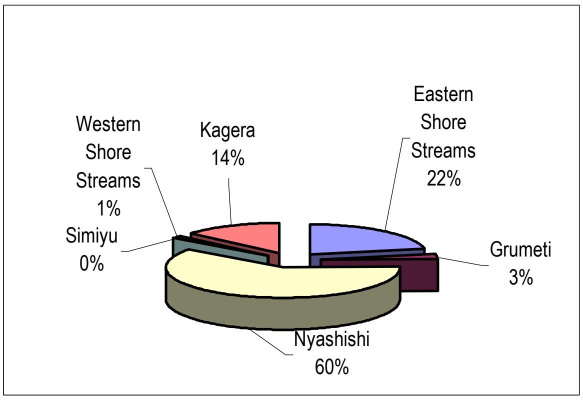


Fig. 7: Industrial Total TSS pollution Loading **Fig. 8: Industrial Total N**
Pollution Loads by Catchment



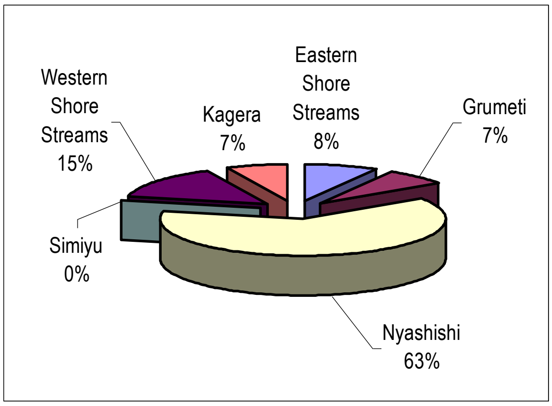


Fig. 9: Industrial Total-P Pollution Load by Catchment **Fig.10: Industrial**
BOD Pollution Loads by Catchments

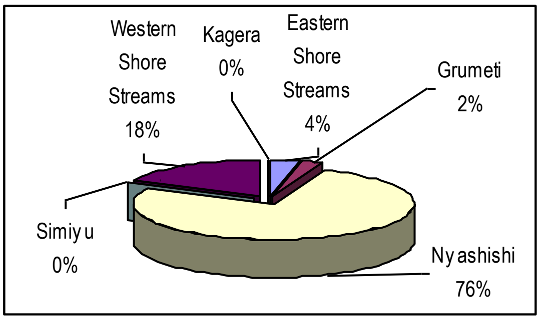


Fig. 11: Industrial Total Faecal Coliforms by catchment

Table 5.7: Industrial pollution Loads by Category

Type of Industry	Resulting load (kg/day)				No. FC/day
	BOD	Total-N	Total-P	TSS	FC
Fish Processing Industries	1475	217.18	52.17	1833	4.9E+13
Abattoir	74	17	6.60	80	1.5E+13
Vegetable Oil	1509	118	37	2201	1.7E+13
Textile	606	151	38	93	7.0E+12
Soft Drinks	913	77	20	368	1.8E+13
Coffee Processing Industry	16	0.40	0.80	2.50	1.9E+11
Breweries	102	19	5	41	1.5E+12
Cane sugar Processing	400	50	25	300	7.00E+10
Fish Net Manufacturing	105	5	0	16	9.7E+10
TOTAL	**5200**	**653**	**185**	**4934**	**1.1E+14**

Table 5.6 above and Fig.12 and Fig. 13 below give the industrial pollution contributions from different categories. With regard to the parameters under study, the fish processing industry category is leading in most of the parameters except in Total suspended solids (TSS), which is

dominated, by the Vegetable Oil Industries (VOIL). Bio-Chemical Oxygen Demand (BOD) is of the same magnitude with the Vegetable Oil and Soft Drink Industries. Coffee Processing Industries have the least contributions to the Lake Victoria among the industrial categories.

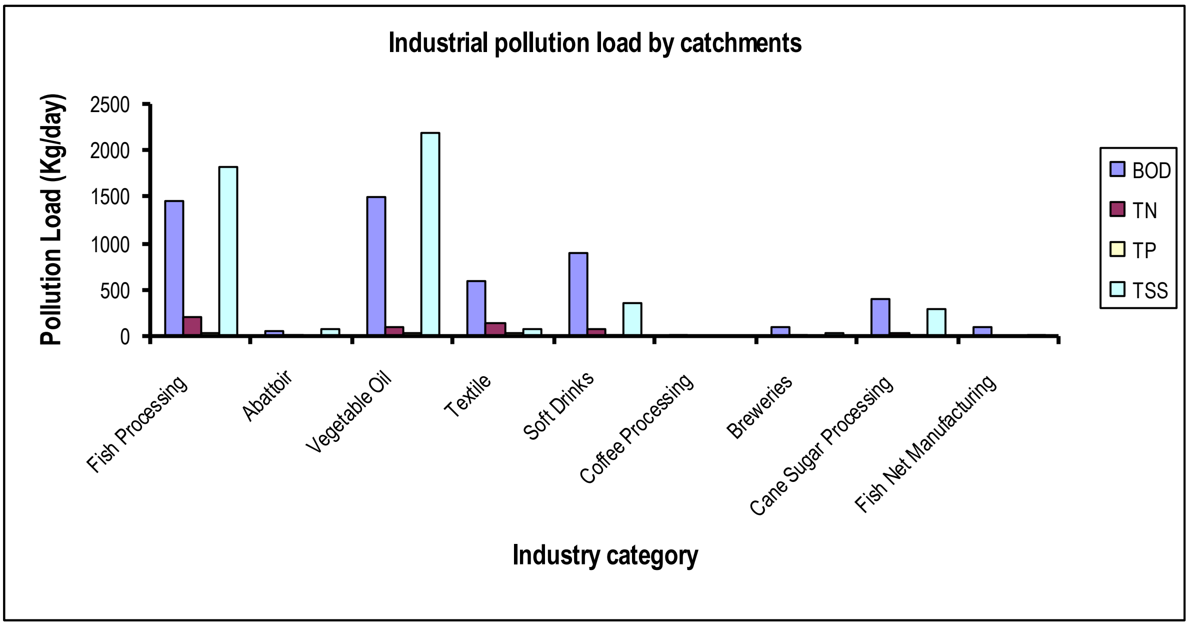


Fig. 12: Industrial Pollution Loads by Category

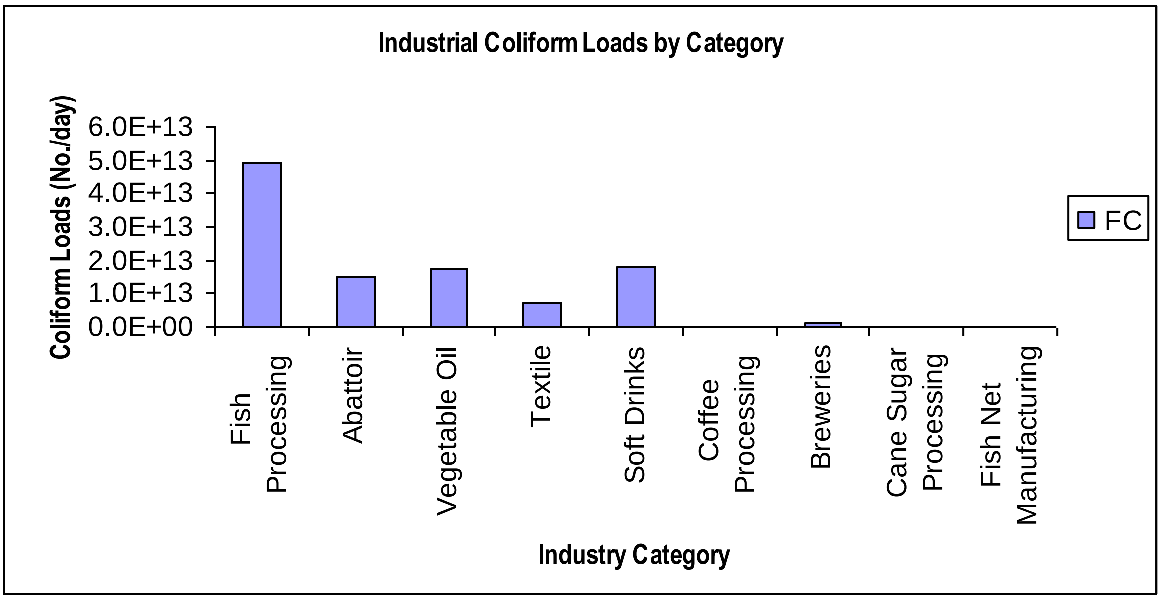
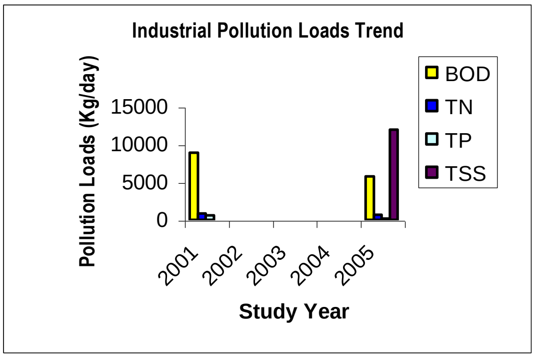


Fig. 13: Industrial Faecal Coliform Loads by Category

Table 5.8: Industrial Pollution loads Trend

Year	Resulting load (kg/day)				No. FC/day
	BOD	Total-N	Total-P	TSS	FC
2001	8930	887	569		
2005	5774	653	185	11948	1.1E+14

Data available on Industrial pollution loads is not enough to make concrete trend conclusions however; with the two sets of data it shows a downward trend. This could be attributed by the different initiatives put in place by different players including LVEMP.



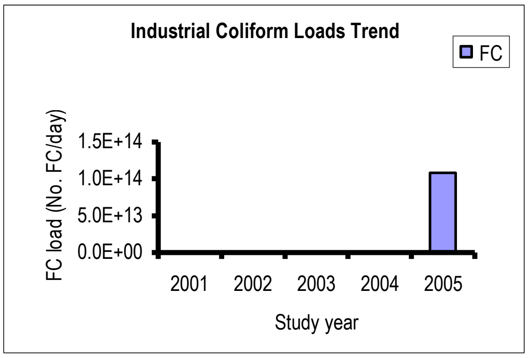


Fig. 14: Industrial Pollution Loads Trend **Fig. 15: Industrial Pollution Faecal Coliforms Trend**

Total Point Sources

Table 5.9: Total Point source Loads (Municipal plus Industrial) by Catchments 2005

Catchment area	BOD_5 (Kg/day)	Total-N (Kg/day)	Total-P (Kg/day)	TSS (Kg/day)	FC No. FCx10^13
Nyashishi	9091	1528	520	8055	403
Simiyu	175	29	12	78	12
Magogo	248	41	17	110	17
Eastern Shore Streams	2365	390	166	1081	134
Grumeti	791	74	31	935	28
Southern Shore Streams	1275	213	85	584	88
Western Shore Streams	772	93	36	413	59
Kagera	400	50	25	300	0
Biharamulo	81	13	5	43	7
TOTAL LOADS	**15198**	**2431**	**897**	**11599**	**748**

Table 5.8 above and, Fig.16 and Fig.17 below shows the total point source (Industrial and Municipal) pollution loads, Nyashishi sub-catchment leading the list followed by Eastern Shore Streams, Southern Shore Streams, and Western Shore Streams sub-catchments.

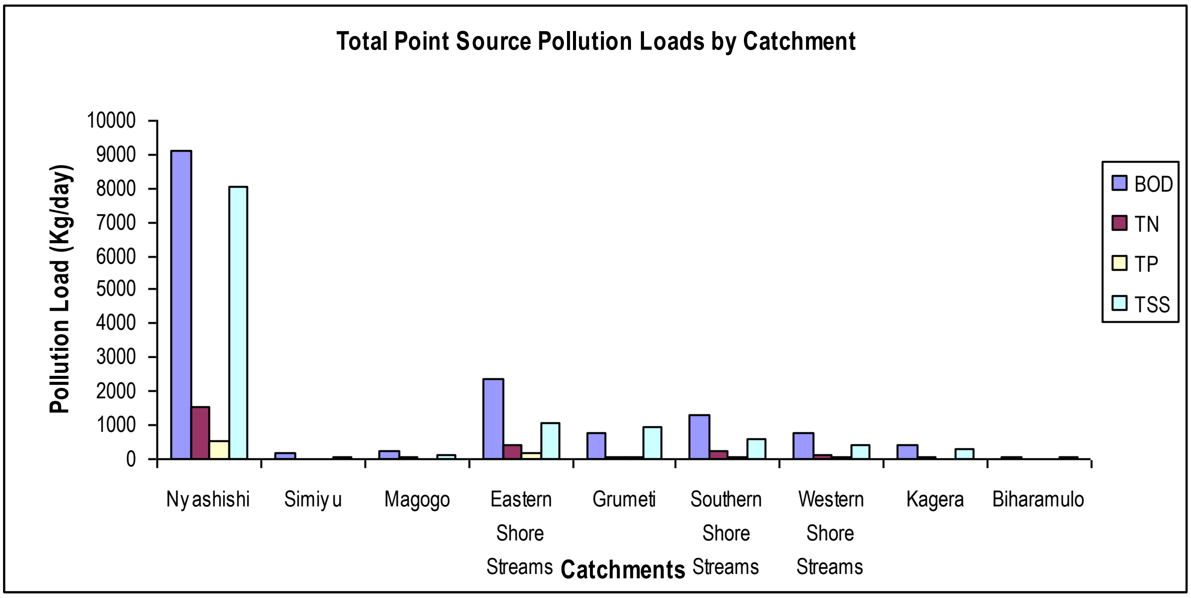


Fig. 16: Total Point Source Pollution Loads by Catchment

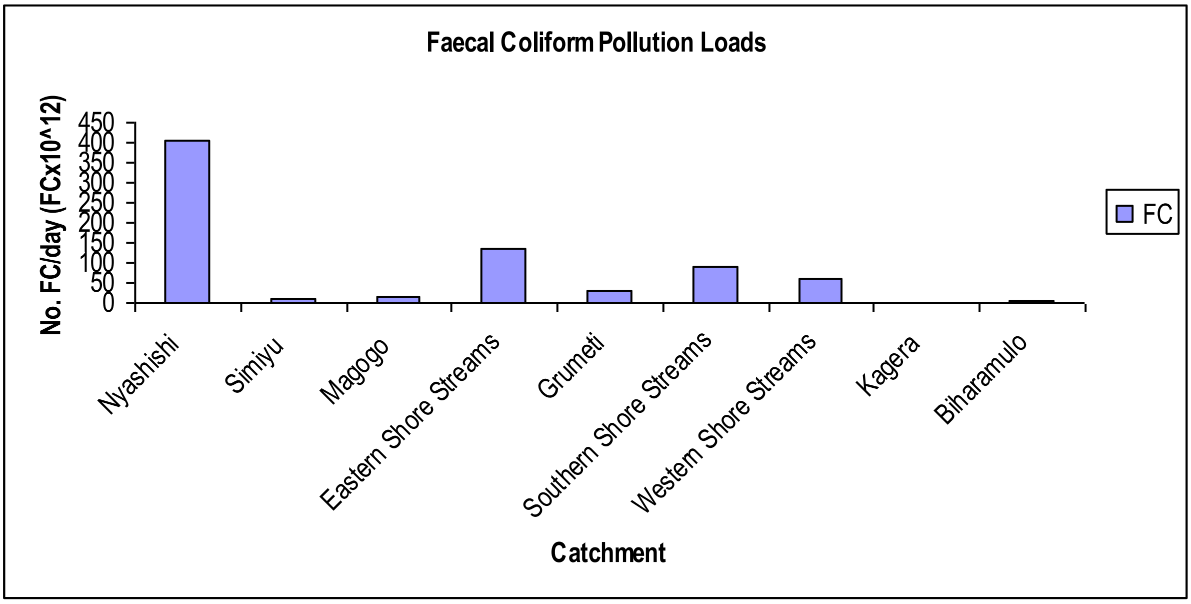


Fig. 17: Total Point Source Coliform Loads by Catchment

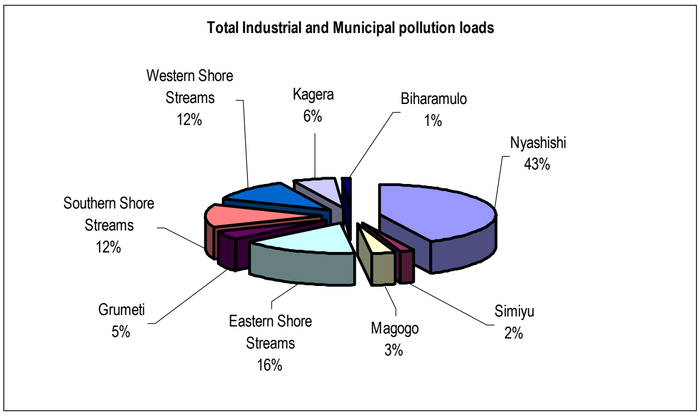
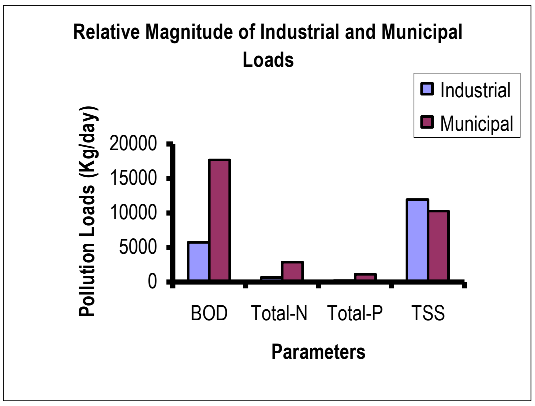


Fig. 18: Total Point Source Pollution Loads by Catchment

Table 5.10: Total Industrial and Municipal load - 2005

Parameter	Industrial	Municipal	Total
BOD	5200	9998	**15198**
Total-N	653	1778	**2431**
Total-P	185	711	**896**
TSS	4934	6664	**11598**
FC	1.10E+14	6.30E+14	**7.4E+14**

From Table 5.9 above and Fig. 19 and Fig. 20 clearly shows that Municipal pollution loads are of greater magnitude as compared to Industrial pollution loads except for TSS. Previous studies, LVEMP (2002) has indicated similar results. Unfortunately, in practice close surveillance and monitoring is mainly done to industries while Municipalities are left unchecked. Today, sewage presents the main point source water pollutant and causes water quality deterioration at an alarming rate all over in Africa (Gijzen 2004).



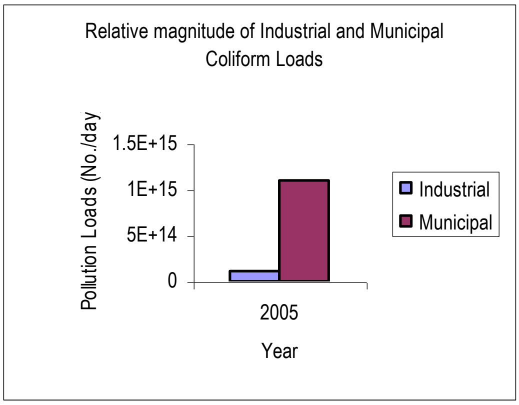


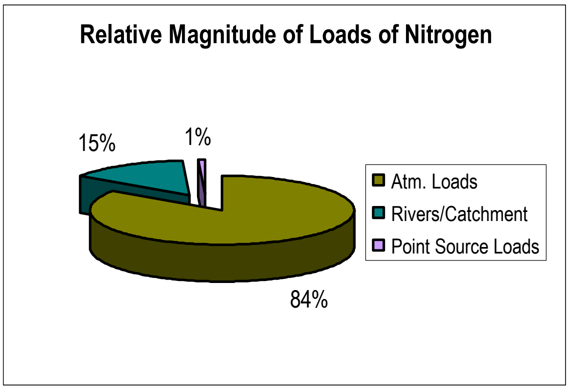
Fig. 19: Relative magnitude of Industrial and Municipal Loads **Fig. 20: Relative Magnitude of Industrial and Municipal Coliform Loads**

Relative magnitude of point sources to total lake loading:

Table 5.11: Relative Magnitude of Point Sources to Total Lake Loading

Source	N	N (%)	P	P (%)	TSS
Atm. Loads	137859	85	80074	92	
Rivers/Catchment	23953	15	6693	8	4905201
Point Source Loads	1290	1	489	1	8094
Total	163102	100	87270	100	4946976

The total pollution loading to the lake is dominated by direct atmospheric deposition over the lake surface. Table 5.10 above and Fig. 21and Fig.22 below shows the relative magnitude of the different components of pollution. The loads from the catchment including the point sources are not critical for the lake as a whole, but they give rise to serious eutrophication in gulfs, bays and some other near-shore areas especially in vicinity of coastal towns and settlements.



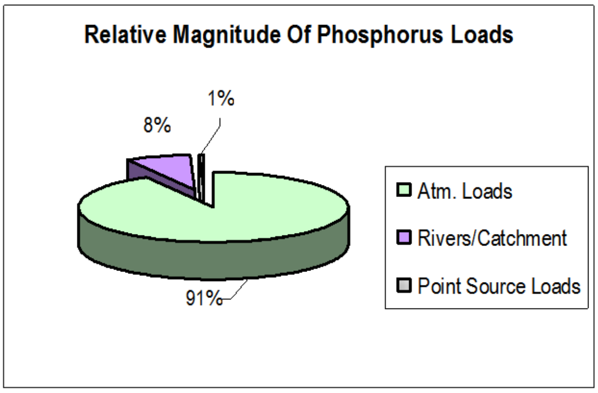


Fig. 21: Relative Magnitude of Nitrogen Loads **Fig. 22: Relative Magnitude of Phosphorus Loads**

Level of compliance:

Very few industries and urban centers in the Lake Victoria Basin have installed onsite wastewater treatment facilities thus discharge raw (untreated) effluent into the existing receiving water bodies including the Lake. Industries, which happen to have treatment systems, make use of waste stabilization ponds as their treatment facilities. When the industries were built, majority of the proprietors were not aware of wastewater problems. To make the matter even worse even some of the City/town Council officials did not either bother or think about the waste management. Among the few with plants, almost all do not monitor their effluents (self evaluation) regularly. However, LVEMP has put in place a monitoring programme with a definite sampling frequency in the Lake Victoria Basin. The results from the monitoring programme indicate that most of the industries do not comply with the set effluents standards. Thus, level of compliance to the effluent standards is very low. The problem is attributed by failure of industries to comply with the laid down legislation, lack of legislation enforcement, lack of experts on environmental issues, inadequacy of appropriate facilities and meagre budget allocated to such activities. Furthermore, awareness on the importance of compliance and knowledge on effluent standards is very low to most industrialists. However, introduction of Cleaner Production Technology by LVEMP into these industries has demonstrated relief on dependence of the expensive, uneconomical and inefficient "end of pipe" (EoP) treatment.

Strategies to reduce effluents:

Several strategies (some at pilot scale) have been applied so far to reduce effluents entering into the lake Victoria: -

(a) <u>Launching of the National Environmental and Water Policies</u>
The Vice President's Office launched the National Environmental Policy in December 1997. The Policy seeks to provide the framework for making fundamental changes that are needed to bring environmental considerations into the mainstream of decision-making in Tanzania. It seeks to provide policy guidelines, plans and give guidance to the determination of priority actions, and provides for monitoring and regular review of policies, plans and programmes. It further provides for sectoral and cross-sectoral policy analysis in order to achieve compatibility among sectors and interest groups and exploit synergies among them (VPO 1997). The environmental management Act. 2004 aims to provide the legal framework necessary for coordinating and harmonizing conflicting activities with a view of integrating such activities into an overall sustainable environmental management system by providing technical support to

sector Ministries. The Act advocate for the establishment of environmental sections in the sector ministries to accomplish the above objective.

The Ministry of Water and Livestock Development in July 2002 launched the National Water Policy. The National Water Policy stipulates that measures should be taken to control environmental degradation and pollution of water sources from increasing discharge of untreated and partially treated municipal and industrial wastewater so that future generations are not deprived of their basic right (MoW&LD 2002). The MoWLD is in the process of finalizing a National Water Development Strategy and new Water laws which address more adequately the implementation of the water policy 2002, and to also conform to the environmental policy and legislation.

(b) Effluent and Receiving Water Standards

Water pollution is regulated through the Water Utilization Act No. 42 of 1974 and its amendments of 1981, 1989 and 1997. Amendments of 1981 included regulations on water pollution. According to this amendment, no person may discharge effluents from commercial, industrial or other waste system into receiving water without consent, duly granted by a Water Officer. The standards prescribed in the Water Utilization Act include Standards for receiving waters, Effluent standards, and Drinking water standards. Other legislations which also play a role in regulation and enforcement of water quality standards include the Fisheries Act, 1970 and its subsequent amendments; The National Environment Management Council Act -1983; The Public Health (Sewerage and Drainage) Ordinance, and Cap. 336; Pesticide Regulations-1984; the Inland Water Transport Ordinance- Cap. 172; Local Government (District Authorities) Act- 1982,'Local Government (Urban Authorities) Act-1982 and the Environmental Management Act -2004. Under the Environmental Management Act 2004, quality standards for all environmental parameters including water and effluent quality shall be prepared by the national Environmental Management Council (NEMC) in close collaboration with the National Environmental Committee of the Tanzania Bureau of Standards (TBS). The environmental council shall maintain a close collaboration with the local Government authority and all other relevant public departments and other institutions for the purpose of enforcement of the environmental quality standards.

(c) Discharge permits system

The discharge Permit instrument, stating effluent limits and in some cases mitigation measures, is a widely used instrument for regulating industrial and municipal wastewater disposed directly or indirectly, into any water body. Application of this system in Tanzania is hampered by inadequate awareness on pollution issues among the polluters and the general public. However, currently there are initiatives to implement this instrument to keep levels of pollution under control. Procedures to grant discharge permits to industries and municipalities have started in the Lake Victoria Basin Water Office by potential polluters filling in application forms (Appendix II and III).

(d) Point Sources Database

Inventories of point sources (industries, urban centers and shoreline settlements) were prepared after undertaking field visits. Questionnaires and structured interviews were administered during the visits to get information from the respondents. Global Positioning System (GPS) references have been established for all point sources visited. The references will be used both for locating the discharges on GIS and for future location of discharges by sampling teams. All point sources information collected has been entered into an ACCESS database named 'Viwanda'.

(e) Harmonization of Effluent Standards

A Regional workshop by LVEMP was held at Mukono, Uganda in October, 2001 with an objective of reviewing existing standards that are critical with the aim of laying strategies for harmonizing these standards to protect the Lake Victoria ecosystem within the region and its sustainability.

(f) Lake Victoria Clean Up Week

The Lake Victoria Clean Up Week is an initiative by the UN-HABITAT and the Lake Victoria Region Local Authorities Cooperation (LVRAC) that encourages environmental action at a local level by supporting and promoting community activities geared towards reviving and preserving a clean environment. Events during the week include paper and plastic waste collection, education and campaigns, drama competitions and sport activities. This year's Lake Victoria Clean Up Week was held from 5th to 9th July, 2005 in Musoma, Tanzania.

(g) Cleaner Production Training and in-plant Demonstrations

One of the specific objectives of the LVEMP is to improve Management of Industrial and Municipal effluents. To implement the task, the project adopted a Cleaner Production Technology (CPT) strategy. The Project is promoting CPT because it minimizes the use of resources and significantly reduces the wastes discharged to the environment. In many cases the adoption of CPT improvements can reduce or even eliminate the need for end of pipe (EOP) investments and therefore can have both financial and economic net benefits. LVEMP launched the "Cleaner Production Training and in-plant Demonstrations Programme for industries along the Lake Victoria (Tanzania side)" in June 2000 with a duration of about one year.

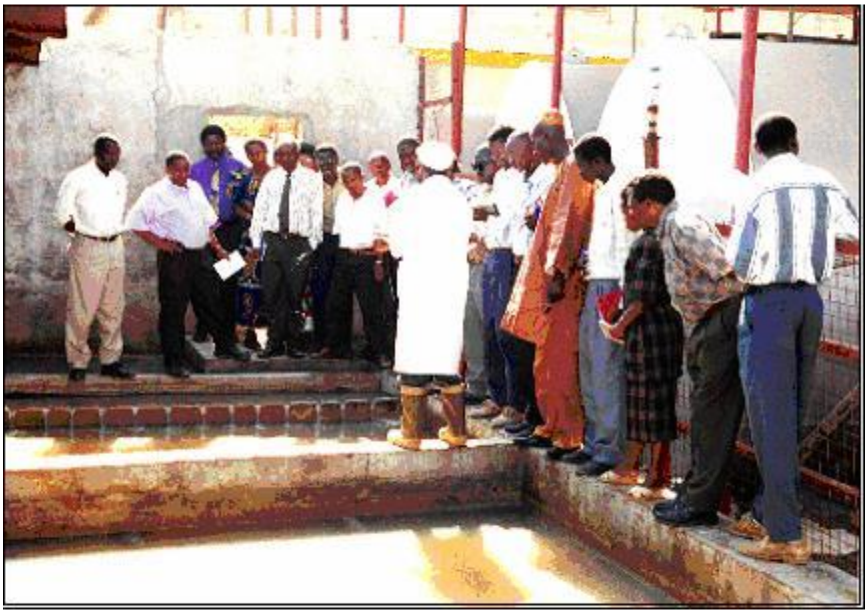


Fig. 23: Cleaner Production Programme Trainees Visiting VICFISH Wastewater Treatment Facility

Out of the fifteen industries selected, twelve of them from Mwanza (7), Musoma (4) and Bukoba (1) participated actively in the entire training course. Industries which participated in the programme included Tanzania Breweries LTD, VOIL, Vicfish LTD, Mwanza Fishing Industries LTD, Nyanza Bottling LTD, Nile Perch LTD and Regent Food and Drinks LTD of Mwanza; Musoma Bottlers, Fish Pak LTD, New

Mara Dairy and New Musoma Textile LTD of Musoma; and Tanganyika Instant Coffee Company LTD of Bukoba.

The enterprises' representatives have been working independently on cleaner production during a period of several months. The participants and the enterprises have been very committed to the training programme and a qualified understanding has been anchored in the enterprises. Furthermore, several CP-solutions identified in the training programme have been implemented in the enterprises leading to considerable environmental, financial and economic net benefits of the initiative. Furthermore, representatives of eight Mwanza industries made a study tour of ten days to Denmark in November 2001 to gain insight of Cleaner Production options identification and implementation. The tour was made possible by LVEMP in collaboration with the Sustainable Mwanza Programme (SMWP) under DANIDA sponsorship. LVEMP appreciates that this is a good start and would like to appeal to all industrialists to take necessary steps in order to protect the environment.

(h) Integrated Tertiary Effluents Treatment
Pilot studies on Constructed Wetlands (Horizontal Sub-Surface Flow) to serve as tertiary treatment system for industrial and municipal effluents downstream the Butuja ponds receiving a diverted portion of the effluent are undertaken. Readily available macrophytes (e.g. typha, phragmites and papyrus) are used for the study. Advocacy of the technology aiming to translate the study findings into management actions is in the pipeline.

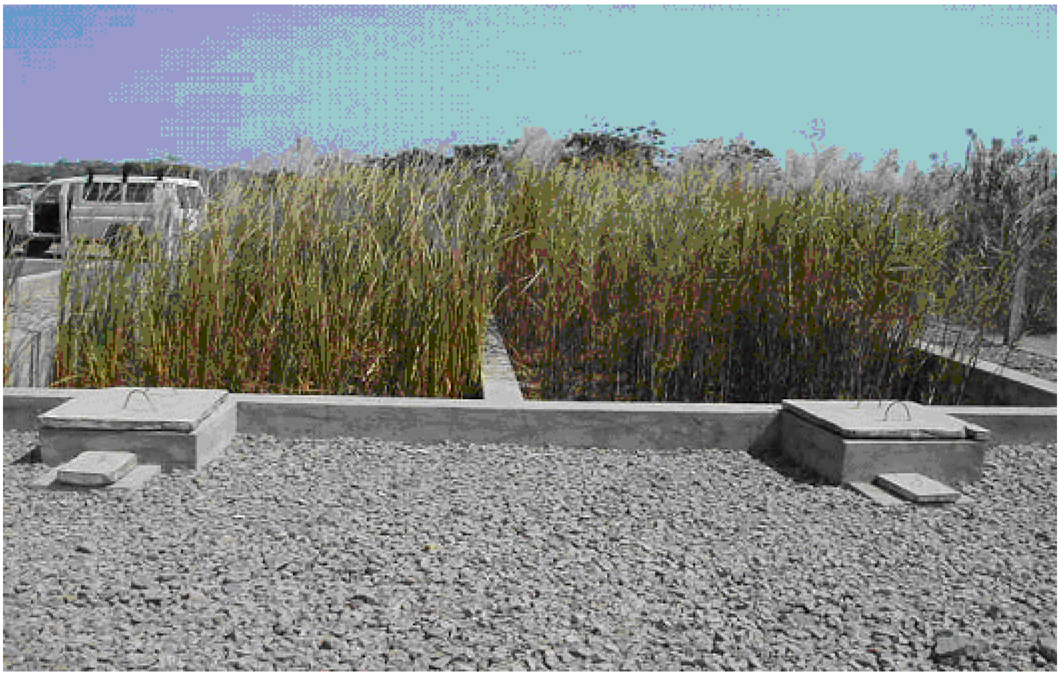


Fig. 24: Constructed Wetland at Butuja, Mwanza City

(i) Community-based Simplified Sewerage Scheme for Igogo Ward, Mwanza City
LVEMP has undertaken a feasibility study and Preliminary design of a Community-based Simplified Sewerage Scheme for Igogo Ward, Mwanza. The detailed design and construction ("Turn-key" Contract) of the facility has been shelved until LVEMP2 implementation, it will complement an expansion of the water supply system financed by the EU. This will be followed by an impact assessment of the scheme to the lake.

(j) Bukoba Sludge Disposal Facility

Bukoba town like most of the urban centers in the Lake Victoria basin has no central sewerage system. Domestic wastewater is discharged into septic tanks coupled with cesspits or in pit latrines while industrial wastewater and wastewater from non-domestic sources is discharged on land, to streams, rivers and directly into lake Victoria. Cesspit emptying services is currently not available in the township. This situation has prompted LVEMP to undertake feasibility study, EIA and Preliminary design with the objectives of establishing a sludge disposal facility to take care of sludge generated in domestic septic tanks, cesspits and pit latrines, and from industrial cesspools in order to save lake Victoria from pollution. Detailed design and construction of the facility has been earmarked for the LVEMP2 implementation.

(k) Water Quality Model for Lake Victoria

Development of a Regional Water Quality Model as a management tool for Lake Victoria has been initiated. Delft Hydraulics and Delft IHE-UNESCO of The Netherlands, and HYRO-QUAL of USA teamed up to develop the model framework. Collected data will be used to calibrate the model. The Water Quality Model training at Delft Hydraulics, in Delft, The Netherlands is still pending.

(l) New and Expansion of Existing Sewerage Systems

The Ministry of Water and Livestock Development through the Mwanza Urban Water Supply and Sewerage Authority (MWAUWASA) and with the assistance from the EU cleaned and expanded sewer line for 5.6 Km and rehabilitated the Waste Stabilization Ponds at Butuja and the pump house at Gandhi Hall in Mwanza. Two new systems to have treatment plants at Igoma and Butimba are to be constructed soon under another EU Project.

Table 5.12 MWAUWASA Future Sewerage Plans

	Year 2004	**Year 2015**	**Year 2025**
Sewer Length (Km)	21.2	92.4	243.7
Connection Fee (Tshs.)	50,000/=		
Connected Population	19,500	69,800	200,300
Max. hour discharge (l/s)	64	265	851
Max. day discharge (l/s)	33	132	475
Max. month discharge (l/s)	30	123	442
Average day discharge (l/s)	28	114	409
Average annual discharge (m^3/a)	880,000	3,590,000	12,900,000

Fig. 25: Raw Sewage disposed into Mirongo River through the Bypass before the Rehabilitation

The French Government through the French Development Fund has shown interest to finance water supply and sewerage schemes for Bukoba, Misungwi and Musoma. Seureca in association with Don Consult Ltd. of Dar-es-Salaam has undertaken feasibility study for the project. At the same time UN-HABITAT has picked six towns to enjoy their support in terms of public toilets, sewerage systems and disposal facilities these are Bukoba, Muleba, Musoma, Bunda, Geita and Sengerema.

(m)Toxic Chemical and Oil Spills Contingency Plan on Lake Victoria
A German consultancy and Training Company HPTI Hamburg Port Training Institute GmbH prepared a Regional Toxic Chemical and Oil Spills Contingency Plan in association with Tanzania Hold Trade. The contingency plan has an objective of minimizing damage resulting from release of oil or hazardous substances, pollutants, or contaminants.

(n) Awareness Creation
LVEMP launched awareness campaigns to educate and sensitize the public on environmental issues. Additionally, dissemination of information on water quality management and research findings was carried out through Radio and Television Programmes, newsletters, brochures, newspapers, scientific publications, stakeholder meetings, conferences, seminars and workshops.

Shoreline Settlements:

Lake Victoria basin has about 600 shoreline settlements which include fishing villages, fish landing sites, piers, beach resorts etc. Sanitary conditions in the shoreline settlements are very poor and the Lake water along the settlements show high feacal coliforms counts (indicators of recent feacal pollution). In many places the “in-law taboo”, high construction costs and lack of awareness forces people to defecate in the bush (free range) or in the Lake.

Household's structure toilets, but they are nicknamed as "choo cha daktari" meaning doctor's toilet, which is shown when health inspectors go around inspecting the situation of health and sanitation in household (Mnyanga 2002). Fish camp owners and those with semi-permanent/permanent homes in the settlements provide limited and rudimentary sanitary facilities. While some members of the communities appreciate that the Lake is a finite resource, others view it as indestructible and inexhaustible and care the least about preventing pollution (LVEMP 2001c). Fish cleaning waste, and liquid and solid waste from eating areas, market, households etc. find its way to the lake as collection methods are not always effective. Nevertheless, the lake is recognized by most people as being the source of their livelihood. The formation of Beach Management Units (BMUs) and introduction of micro-projects co-managed by the local communities and LVEMP in these settlements is a way forward in the improvement of the sanitary conditions.

Urban run-off

Urban run-off carries untreated domestic and industrial waste and uncollected garbage into the river and wetland systems, and eventually into the Lake Victoria. Mirongo River in central Mwanza for about 12 years (1991-2003) received and conveyed raw sewage from the Municipal Sewerage system into the Lake (Mnyanga 2001). Mwisenge stream in Musoma continues to convey all Municipal sludge into the Lake as it is dumped on its banks. River Kanoni in Bukoba collects almost all municipal wastewater including the notorious waste from "magereza" and empties into Lake Victoria. There are 57 urban run-off stations on streams conveying wastewater into the lake including Mwanza 27, Musoma 20 and Bukoba 10.

CONCLUSIONS

Three Inventories of industries, shoreline settlements and urban centres with their global positions have been compiled and quantities of the point sources established. An ACCESS database has been prepared and documented and can be used for management purposes.

Hazardous waste from industries does not (yet) poses a severe pollution problem for the Lake Victoria. Oxygen demanding organic waste, suspended solids, pathogenic bacteria and nutrients are the major pollutants of the lake environment. Mwanza City, Musoma and Bukoba Municipalities are the main sources of urban domestic waste. Total Municipal waste loads are larger than total industrial waste loads. Most of the industries in the Lake basin are concentrated in the urban centers of Mwanza, Musoma and Bukoba which have better infrastructure and much needed services e.g. roads, power, water etc. Nyashishi sub-catchment is the main wastewater polluter in terms of point source pollution. Fish and vegetable oil industries categories demonstrated high BOD levels. While, Vegetable oil industries category has demonstrated high levels of TSS. Generally the industrial and municipal pollution loads show an incremental trend as population and number of industries increases over the years respectively. An assessment of treatment plants revealed that most if not all don't comply with the Tanzanian Effluent Standards. Environmental protection measures were until very recently apparently not mandatory. Even for new industrial projects, Environmental Impact Assessment studies have been instituted as part of the industrial or project development cycle only in the past eight years. However, at individual industrial level there is a decrease in pollution loads due to different mitigation measures. Industrial loads could be significantly reduced if industries could practice cleaner production technology and properly operate well-designed wastewater treatment plants as “end of pipe” treatment; they probably lack motivation to incorporate environmental considerations in their production processes.

The organic pollution load from urban domestic sources is about four (4) thousand Tons of BOD per year which is twice the industrial load. The total resulting pollution loads (tons/year) from all point sources into Lake Victoria were: BOD_5 5,757; TN 887; TP 327; TSS 6793 and FC $2.7x10^{14}$ No. /year.

RECOMMENDATIONS

(a) Study Recommendations

To support a future system for management of the water quality of the lake it is recommended to regularly repeat gross or “rapid” estimations of the urban centers and industries pollution. This implies a basin updating of population data, industry data etc. For this purpose, it is recommended to improve on the data collection i.e. establish more complete data sets bearing in mind that the “forcing” factors are the urban population, the industries’ production and the discharge methods. Moreover, locally established (and verified) estimates of standard figures such as person equivalent loads, reduction efficiency of discharge system, industrial production related load figures etc. would improve the validity of the overall load estimates.

In the “rapid assessment” the determination of the wastewater pollution loads from municipal point sources, i.e. major cities and towns, is based on wastewater production standard figures per person equivalent and assessed reductions via the discharge methods. In order to improve and verify these estimates it is recommended to carry out measurements for some urban areas where it is possible to establish a well-defined relation between number of persons and actual pollution load. It is important to establish a measurement programme with several measurements over a long period in order to establish a measurement programme with several measurements over a longer period in order to establish well-documented figures. A possibility is to carry out programmes for selected towns located along a relatively small stream in order to determine the net pollution load.

Due to the high resources input required for sampling and analyses, it is recommended considering carefully the need for such studies and e.g. concentrating future measurements of industrial pollution loads on industries with significant wastewater production, sites with significant local problems, or studies necessary to determine production/load factor. For the selected industries overflow weirs or similar devices should be established in order to determine the wastewater flows. Some of these costs could be part of licensing i.e. the polluter pays-problem is the Municipalities resting to charge for services. Analyses should be based on flow-proportional samples. Analyses should be limited to a few central and important parameters, which are relatively easy to analyze, for instance COD, Total Suspended Solids, Faecal Coliforms, Ammonia, Total-Nitrogen, and Total Phosphorus. For specific industries it might, however, be necessary to supplement with additional parameters as pH, relevant heavy metals or specific hazardous chemicals.

(b) Policy Recommendation

Control of point sources of pollution from municipalities and industries should always be given priority as it is generally the most cost-effective measure. However, though the diffuse source control is more difficult to achieve yet, in many cases, effective prevention of eutrophication, or restoration of eutrophic waters cannot be achieved without such control.

In Lake Victoria basin situations where onsite sanitation is the technology most widely used, nutrient contributions from septic tanks are important. Potential contributions from such sources should be carefully assessed, although no generally applicable methodology exists to control septic tank leaching. The issue here is the contamination of private wells and their health risks. However, when septic tank effluent is emptied promptly with vacuum tankers and dumped to a sludge disposal facility for a considerable time to dry before sludge cakes are used as potential fertilizer products in agricultural fields or disposed on a landfill, a high degree of nutrient removal can be achieved.

Fish industries in addition to the classic approach of utilizing solid fish wastes in the production of fish meal and oil, should aim at reducing wastes as much as possible by better fish handling and processing and by a rational use of water (Cleaner Production) and search for wastewater treatment processes that could offset the costs involved, totally or in part, through the recovery of substances, in particular protein and fat, from wastewater. This can be achieved by proper wastewater treatment plant siting and design, and tertiary treatment through constructed wetlands and aquaculture

The microbial pollution of Lake Victoria, which is predominantly onshore rather than whole lake pollution problem, indicates the need for improved sanitary conditions around the lake. Discharges of sewage to any receiving water body (e.g. streams, rivers, lakes) should be forbidden until when there is an adequate treatment of those effluents. Also, as individual industries and municipalities appear to have failed to treat their wastes ‘onsite’, well-designed centralized water borne sewerage systems operated by private entrepreneurs/Water Authorities are recommended.

Industrial development is essential for economic growth but industries are major users of resources and producers of waste. To minimize pollution and damage to the Lake Victoria environment, it is recommended that national administrative, social and economic measures be taken, where appropriate, that will encourage industry to: increase resource and material efficiency, install pollution abatement technologies, and reduce wastes. A mix of economic incentives and legal measures should be used to promote these goals. However, penalties for pollution sited in the respective legislations are needless to say, are totally inadequate. The water utilization Act amendment No. 17 of 1989, raised the penalties for polluting to Tshs. 50,000/= or two years imprisonment for the first offence and Tshs. 100,000/= or three years imprisonment, for a second or subsequent conviction. These fines neither compensate the people by the harm created by this waste nor provide a meaningful financial incentive to industry to improve its performance. Fines imposed for polluters by the Fisheries Act and the Public Health ordinance are equally low and considered not deterrent enough.

Though the Government has enacted legislation aimed at protecting the environment, it is generally recognized that ‘policing’ the compliance of industry to environmental legislation is not an easy task in view of large number of industries and the limited resources at disposal of the enforcement agencies. Voluntary adherence by industries to ISO 14000 is highly recommended which can go a long way toward ensuring compliance with the legislation and continual self-monitoring and improvement of their environmental performance.

The Lake Victoria Basin Water Office (LVBWO) and the National Environmental Management Council (NEMC) should collaborate with industries in performing the industrial environmental auditing and assist them in introducing the Environmental Management Systems (EMS), which is a sustainable approach for proper industrial environmental protection. They should also put in place Programs to increase awareness and education, with the long-term objective of changing the behavior of manufacturers and consumers towards minimizing waste generation.

The Legislation should have a provision to allow any person(s) 'aggrieved' by a decision to issue a waste discharge permit to appeal to the Water Basin Board. The Board should have mandate to hear evidence, and decide whether to confirm government's decision, impose conditions in the permit to better protect the environment, or revoke a decision to issue a permit. Only a small fraction of permits are expected to be appealed in this way, but if a significant reduction in the number of permits means that important checks and balances are not in place.

It is clearer now and never before that industrialists and Municipal officials should not consider the project (LVEMP) and themselves as two opposing forces. They share in common the future of the Lake Victoria basin and the judgment of future generations. The goal is to establish partnership with a common stand of maintaining the business while protecting our environment. For any intelligent person, it is obvious that the cost of pollution is much higher than the cost of prevention. But unless and until top management is involved and is willing to provide necessary inputs (resources) environmental goals cannot be achieved.

In addition to other remedial measures (e.g. Cleaner Production and 'end-of-pipe' treatment) to reduce pollution in Municipal and Industrial wastes, the government should consider imposing regulations limiting or eliminating phosphorus from detergents sold for use within the Lake Victoria basin. After reduction of phosphorus from point sources, the relative role of phosphorus from diffuse sources will increase. This means that measures against diffuse sources may become necessary if improvement of water quality cannot be achieved by further elimination of phosphorus point sources.

In order to develop and inculcate better attitudes and understanding of the environmental Health awareness and management to the communities with the long-term objective of changing the behavior of manufacturers and consumers towards minimizing waste generation, it is recommended that training of the communities should start at tender age, hence the Ministry of Education and Culture should see to it that Primary schools, and Secondary Schools' curricula are modified to accommodate the environmental issues facing the Lake Victoria.

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APPENDIX 1

BRIEF ON INDUSTRIAL SECTORS

1. Gold Mining (5):

The gold mining sector has been dominated by four foreign professional companies namely Geita Gold Mine (GGM) at Geita, Buhemba Gold Mine at Buhemba, Placerdome at Nyamongo, and Kahama Mining Cooperation Limited (KMCL) at Bulyanhuru and Tulawaka. With the exception of KMCL, which use floatation method, the remaining mines use cyanide for gold extraction. They have all been omitted in this study as they are categorized as "zero discharge" industries. Artisanal mining dominated by small local companies and individuals who use mercury for gold extraction are in Mwanza, Mara, Kagera and part of Shinyanga regions in the gold potential areas. However, in this study they were also omitted, as they are small and scattered over the area hence considered to be non-point sources.

Artisanal Miners in Mugusu Area Processing Gold on the banks of Mugusu Stream

2. **Fish processing (15):**

Fish processing is a water-intensive industry where Nile perch fish are processed into fish fillets. Fish processing involves cutting of fish in order to produce fish fillets. Typically, the process uses large quantity of water with liquid waste generation of $20m^3$/ton (Scheren et al., 1994). Process water is used for washing fish, cleaning process area, cooling and production purposes and hence large quantities of wastewater are generated. Similar to most processing industries, fish processing operations produce wastewater, which contains active organic contaminating organisms in soluble, colloidal and particulate form. Depending on the particular operation, the degree of contamination may be small (e.g., washing operations), mild (e.g., fish filleting), or heavy (e.g., blood water drained from fish storage tanks). Fish processing is a growing industry around lake Victoria. At the time of the study twelve industries were operative, namely Vicfish Ltd, Tanzania Fish Processors (TFP), Omega Ltd, Mwanza Fishing Industries, Mwanza Fish meal, Tan Perch, Nile Perch and Chain Food in Mwanza; Musoma Fish Processors, Prime catch Ltd, and Mara Fish Packers in Musoma; and Kagera Fishing Industry in Bukoba. One industry owned by Vicfish is under construction in Bukoba. Two industries have closed business namely Victoria Fisheries in Mwanza and Musoma Fish Filleters in Musoma. All fish processing industries have treatment systems as part of the environmental and EU requirements. Efficiencies of the treatment systems leave a lot to be desired. With the exception of Tanzania Fish Processors and Prime Catch Ltd. all fish processing industries use readily available and affordable technology, biological treatment (WSPs), unfortunately due to land constraint they are designed with very short detention times and as a result they produce raw or semi treated effluents.

Tanzania Fish Processors and Prime catch Ltd. use mechanical and chemical treatment respectively.

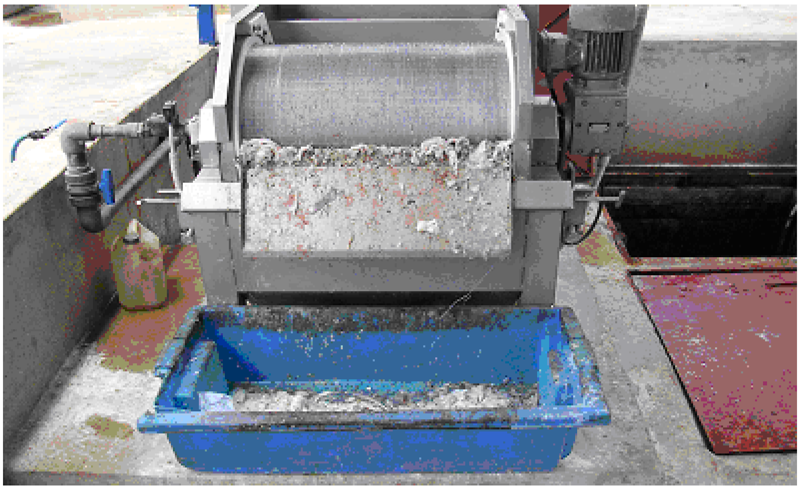


Fig.1 Screens at Prime Catch Ltd. (MUSOMA) Wastewater Treatment Facility

3. **Vegetable oil refining (4):**

Vegetable oil processing industry involves the extraction and processing of oils and fats from vegetable sources. The extraction processes are generally mechanical or involve the use of solvent such as hexane. Crude oil refining includes degumming, neutralization, bleaching, deodorization, and further refining. Four mainly cotton seed oil industries namely Vegetable oil industries (VOIL), Birchand and New Era in Mwanza; Bunda Oil Industries in Musoma were operative during the study. Dynamic, Farai and Bibiti Oil Mills in Mwanza; Mara, and Mugango Oil Mill in Mara, and Biharamulo oil mill in Kagera stopped production due to various reasons. Wastewater from these industries is high in organic content and dissolved solids, oil and fat residues, organic nitrogen, and ash residue. All industries don't have proper treatment systems for their wastewater; instead they dump it into pits threatening the surface and ground waters. Bunda oil Industries being the largest is producing more raw wastewater to the environment as compared to the rest. However, its distance from the Lake Victoria makes it have a high reduction factor and reduces its pollution to be more of a local problem.

Fig.2 Soap Stock Flowing out of the Bunda Oil Ltd. (BUNDA, MUSOMA)

4. **Soft drinks (4):**

Four bottling Industries can be found in the area. Largest is Nyanza Bottling Ltd processing Coca-Cola products in Mwanza followed by smaller ones, Musoma Bottlers in Musoma; Regent Food and drinks Ltd in Mwanza and SBC in Bukoba. Chemicals such as Chlorine, caustic soda used in the bottle rinsing process, fruit and vegetable residues, and spilt syrup, easily end up in wastewater.

Fig.3 Bottle Washing at Nyanza Bottling Ltd. (MWANZA)

5. **Coffee processing (3)**

Coffee beans from Kagera and Mara plantations are processed at Bukoba Coffee curing (BUKOP) Ltd and Mara Coffee Co. Ltd respectively. The process involves the removal of the coffee husks to expose the bean. Hardly any wastewater is produced as a “dry processing” technique is used. Only a small part of the solid organic waste ends up in wastewater, for example from cleaning practices. The Tanganyika Instant coffee Co. Ltd. (Tanica) is processing cured coffee beans to get instant coffee.

6. **Abattoirs (3):**

Three major slaughterhouses serve the three major urban centers of Mwanza, Musoma and Bukoba. Of recent, services and revenue collection of the slaughterhouses have been privatized. These point sources are located at Nyakato – Mwanza, Rwamishenye – Bukoba and Bweri-Musoma. The wastewaters from the slaughterhouses contain blood, manure, hair, fat and bones. They generate large quantities of wastewater with a biochemical oxygen Demand (BOD_5) level of 600-8000 mg/l and suspended solid level of 800mg/L and higher as well as, in some cases, offensive odours. The wastewater contains organic material and nitrogen content. It may contain pathogens including Salmonella and Shigella bacteria, parasite eggs, and amoebic cysts. Pesticide residue may (not analysed due to lack of Chromatograph) be present from treatment of animals or their feed. No wastewater treatment systems in the slaughterhouses and as a result raw wastewater are being discharged to the environment.

Fig.4. Poorly Managed Abattoir in Mwanza City. Watch out the Bio-indicators hovering around the area and the stream of blood!

7. **Breweries (1):**

   There is only one Brewery in the area namely Tanzania Breweries Ltd (TBL) located at Bwiru in Mwanza City. The brewery is very near to the shoreline and has made big investment on five WSPs though treatment efficiency is low. Originally it was designed to make use of surface flow constructed wetlands but water hyacinth, the designed macrophytes was later discouraged as chances were high to find its way to the lake from the last (fifth) pond. The fifth pond was turned into another maturation of the ponds system.

8. **Textiles (2):**

   There are two cotton textiles in the area namely MUTEX in Musoma and MWATEX in Mwanza. They used to be Government Parastatal Organizations before they were privatized. MUTEX has changed hands twice since it was privatized. MWATEX stayed for a long period before it was privatized in 2003. While MWATEX has completed constructing a “non-performing” new treatment facility, MUTEX is yet to rehabilitate the old facility it acquired from the previous investors. The stages in textile production include fibre production, fibre processing and spinning, yarn preparation, bleaching, dyeing, printing and finishing. Cotton textile wastewater has a high content of pollution compounds the sources of which are the natural impurities extracted from the cotton fiber, the processing chemicals and the dyes. It is typically alkaline and has high BOD and Chemical Oxygen Demand (COD) approximately 2 to 5 times the Biochemical Oxygen Demand (BOD level), solids, oil and possibly toxic organics including phenols (from dyeing and finishing) and halogenated organics (from processes such as bleaching). Dye wastewaters are frequently highly colored and may contain heavy metals such as copper and chromium. The discharge of this wastewater to the environment causes aesthetic problems due to the remaining colour (from the dyestuff used) and also damages the quality of the receiving water. (Georgiou´ et al. 2003).

Fig.4 Treatment Facility at NEW MUTEX Ltd. (MUSOMA)

9. Cane sugar manufacturing

Kagera sugar Ltd is the only sugar industry in the Basin located in Kagera near the Ugandan border. It used to be a Government Palastatal before it was privatized in 2001. The factory was seriously hit during the 1978/9 Tanzania/Uganda wars, which ousted President Idd Amin Dada of Uganda. However, the new factory built under the government palastatal has of recent been rehabilitated to accommodate the current activities under the new private investor. Sugar canes are generally washed and then juice is extracted from them. This juice is then clarified to remove mud, evaporated to prepare syrup, crystallized to separate out the liquor, and then centrifuged to separate molasses from the crystals. Sugar crystals are then dried and may be further refined before bagging for shipment. Wastes generated from cane sugar processing comprise bagasse, fuel oil, mud, molasses and some sugar losses during production.

10. Dairy Industry

This is an industrial category which has been hit with a lot of problems as a result, almost all major industries are closed including New Musoma Dairy and Makilagi Dairy in Musoma and Nyanza Dairy in Mwanza. Mara Dairy is the only industry in this category which operates however, it does so intermittently. In this study it was omitted due to its size (volume of waste generated), method of waste disposal and style of operation. New Mara Dairy is one of the industries participating in the Cleaner Production Training Programme and has succeeded in waste minimization. Dairy industry involves processing of raw milk into consumer milk, butter, cheese, yogurt, dry milk, and ice cream. The dairy industries in the Lake Basin produce mainly consumer milk, butter and to some extent fermented milk with fruit concentrates. The wastewater generated from the raw milk processing contains dissolved sugar and proteins, fats, fruit concentrate residues and pathogens.

11. Fish Net manufacturing

Mwanza Fish Net is the only industry in the category and the only fish net manufacturer in the basin. The industry is located in Igogo industrial area, Mwanza City.

APPENDIX II

G.N. No. 370 **Form H**

MINISTRY OF WATER

WATER LAW ADMINISTRATION OFFICE

The Water Utilization (Control and Regulation) Act. 1974

APPLICATION FOR A GRANT OF CONSENT TO DISCHARGE WASTE OR EFFLUENT INTO RECEIVING WATER

The Water Officer

P.O. Box ……………………………

………………………………………

1. Name of Application…………………………………………………………..
2. Address ………………………………………………………………………….
3. Particulars of Water Right…………………………………………………….
4. Source of Water where the Effluent is to be discharged…………………………
5. possible Persons to be affected downstream…………………………………….
6. The quality of Effluents to be Discharged ………………………………………
7. Application Fee of Tsh. ………………………………………… is hereby enclosed

………………………………….. ………………………… ……………….

Date **Name** **Signature**

(Applicant)

APPENDIX III

LAKE VICTORIA BASIN WATER OFFICE

ASSESSMENT OF WATER USES AND WASTE WATER TREATMENT FACILITIES FOR DOMESTIC, INDUSTRIES, MINING AND COMMERCIAL SECTORS

General Information

1. Name of Organization …………………………………………………………………..
2. Address …………………………………………………………………………………
3. Name of Contact Person……………………………….. Designation…………………
4. Region……………………………District…………………… Location………………
5. Telephone No……………………… Fax No…………………………………………..

Technical Information:

1. Does your organization have a Water Right………….. What is the number…………..
2. Does your organization have a Discharge Permit ……… What is the number………..
3. What is the main source of Water?……………………………………………………..
4. For what purpose is the Water being used for………………………………………….
5. What is the main source of Water?
6. What type of Effluent treatment facilities do you have…………………………………
7. What is the quantity of Waste Water discharged per day………………………………
8. What are the Major Pollutants generated………………………………………………
9. What is the level of treatment achieved ……………………………………………….
10. What is the Distance of Discharge point from the Water Source………………………

…………………………. **………………………………**

Date **Signature**

(Water User)

THE HYDRAULIC CONDITIONS OF LAKE VICTORIA (TANZANIA PART OF

By: O.I Myanza, D.K. Rutagemwa, and F. Mwanuzi

ABSTRACT

One of the processes or input which is the driving force to the lake water quality changes is the hydraulic conditions of the lake. To account for this it was required to measure patterns of water circulation in selected parts of the lake in order to determine the interaction between the vertical and horizontal circulation components as well as develop simulation models of the dynamics of nutrients, phytoplankton, benthic biota, suspended sediments and dissolved pollutants. Monitoring in the selected gulfs or bay could give detailed information in a more refined situation; however the whole lake circulation is meaningful. The consequence of the lack of large scale circulations is that the spreading of pollutants from the nearshore areas to the centre of the lake during most of the year is mainly caused by dispersion and not by advection.

Since the ADCP to measure the currents/circulation is not yet available study of the hydraulic conditions is based on the measurements of vertical water temperature profiles at the lake monitoring stations. These data were established by the water quality component for the period from September 2000 to March 2005. Current/velocity variations are simulated by the Lake Model.

Based on the available monitored data of temperature, it can be concluded that, for most of the year, there does not seem to be any recognizable, large-scale horizontal circulation pattern in Lake Victoria. However, it is possible that strong winds in July - Aug (the cause of the total vertical mixing) could also cause large scale circulations.

Keywords: Water Quality, Hydraulic Conditions, Driving Forces, Water Circulation Pattern

Introduction

This section discusses the characteristics of the physical limnology of Lake Victoria with the overall objective of providing background for addressing questions related to movement of materials in the lake. The transport processes of the particulate and dissolved constituents in water are related to water motion and currents that are induced by several factors, which include river inflow and outflow and wind induced currents. Differential heating and cooling of surface waters as well as influents can cause conventional currents. However, mixing of surface waters, by convection is weak and insufficient to produce long-term stratification patterns commonly observed in most lakes.

Mixing in lakes is largely controlled by stratification (Scott et al, 2004), which arises from temperature, dissolved solids and suspended particulate variations. However, according to Scott (2004), the latter two components (chemical and particulate stratification) are generally negligible. Thus stratification is dominantly dependent on temperature variations, which in turn are a function of the overall energy balance and the internal mixing processes of the lake

Thermal stratification in the water column is an important physical feature in many tropical lakes. The vertical stratification, which results from density changes with temperature, has a strong influence on the rates of biological and chemical processes in the lake.

Generally, recognized movements of water in lakes, include, surface movements caused by surface waves and surface currents, internal movements such as Langumuir circulations and seiches and other water movements which includes circulations caused by thermal bars and currents generated by inflows such as rivers

The surface waves are generally caused by frictional wind movement over water surface resulting not only to water motion (wind drift), but also sets an oscillation (traveling waves), which are however, restricted only to the surface and do not cause large water displacement. Surface current are also induced by winds and are generally non periodic movements.

Of the internal movement, Langumuir circulations are prominent. These are circulations that tend to move in vortices which result in "microzones" of upwelling and downwelling water. Convention from these vertical motions generates streaks that are approximately parallel to the direction of wind. Others internal water movements include seiches which are stationery oscillations of the lake.

Other important water movement includes currents generated by influents (e.g. rivers). When rivers enter the lake, the incoming waters will have density (due to temperature, dissolved materials and suspended load) that differs from that of the lake. When density of the river is less than that of the lake, the water will flow over the surface but rapidly mixed by wind generated turbulent movement. When river is denser, it will descend to the floor of the lake.

Scientists are particularly interested in the water movement or water mixing because it has the potential to influence oxygen in the water column, water temperature changes, nutrients within the water column and disruption of bottom sediment.

Methodology

The Tanzania part of the harmonized water quality monitoring network consists of thirteen (13) littoral stations and sixteen (16) pelagic stations (Fig.1). During the monitoring period (September2000- June 2005), measurements of temperature profiles has been carried out insitu using Data sonde series 4a (Hydrolab) fixed with pH, EC, temperature, DO, DO % saturation and depth sensors. The instrument is always carefully calibrated at the laboratory before the start of each field work using standard solutions. At the monitoring station, data are captured continuously at one depth until a more or less constant value of parameters monitored is obtained. The Hydrolab is then lowered to another depth for further data capturing. To make sure that quality data representing the actual field situation are collected, the instrument is frequently checked for consistency during data capturing process. After the field work, the mean values at each depth are calculated and stored in a simple EXCEL based database for further analysis.

Wind speed data has been obtained from meteorological stations from Mwanza, Musoma and Bukoba airport.   No current measurements have been carried out due to lack of Acoustic Doppler Current Profiler (ADCP).

The analysis of the vertical temperature profile data has been made in two ways to determine the thermal stratification pattern in the lake, which include the analysis and the development of vertical

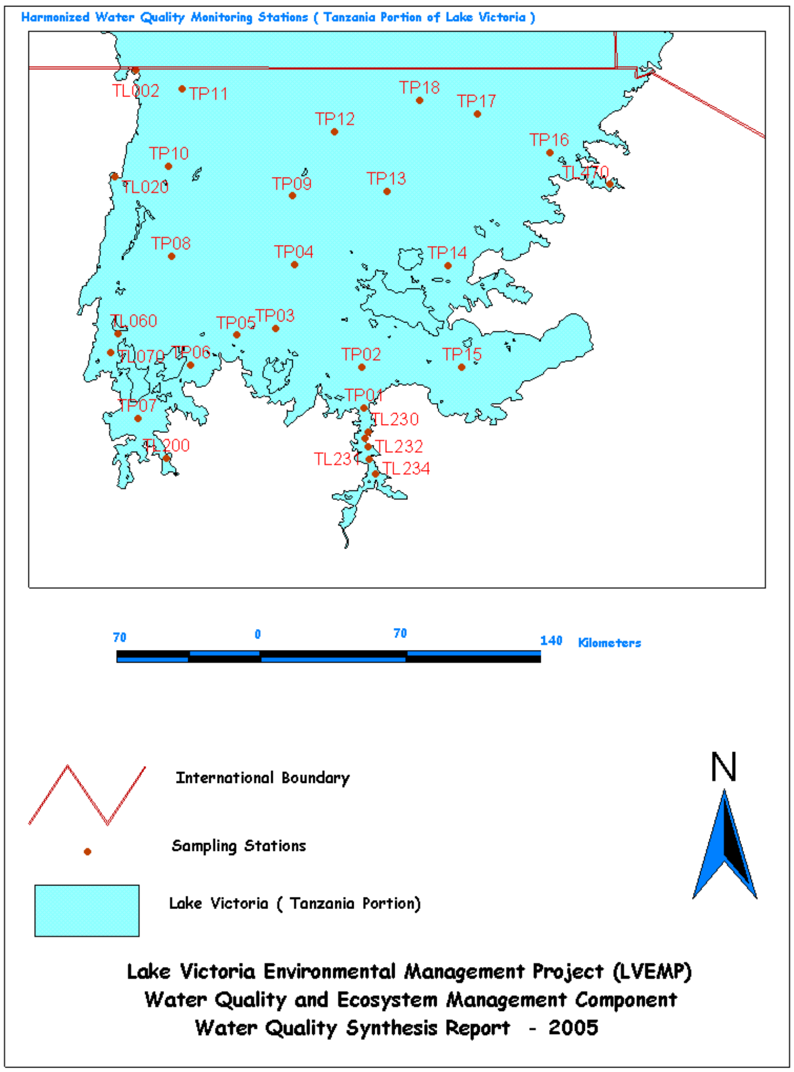


Fig 1: Harmonized Water Quality Monitoring Stations (Tanzania)

profiles at each station during the year i.e. time series of vertical profiles at each station and analysis of the vertical along some transects across the lake to give an instantaneous picture of the vertical temperature profile.

The data collected were quality checked, graphical presentation and visual analysis and comparisons with previous studies made.

RESULTS AND DISCUSSIONS

Seasonal Stratification in Lake Victoria

Changes in the temperature profile with depth within the lake system are called thermal stratification. This profile changes from one season to the next and creates a cyclical pattern that is repeated from year to year. It has been noted that in southern part of Lake Victoria, thermal stratification begins in January to May, coinciding with the period observed by Talling in 1964 (Fig. 6), although the settings differ from one location to the other. The thermocline in this part of the lake may develop at depths of 50 to 60m in pelagic stations (Fig. 6), and with the surface temperatures reaching its maximum in March after which cooling starts. Earlier report by LVEMP (2002) predicted that thermal stratification seems to exist in most of the time in Mwanza gulf, but the current information indicates that, mixing in the gulf seems to occur in most of the time except in late March to late May. However, the stratification seems to be shallow and weak. It is not very clear that this is likely to cause a vertical circulation with the cooler water flowing in from the lake at the surface to give a significant flushing of the gulf. This condition is possibly due to the fact that most but not all part of the Mwanza gulf is protected from strong winds that cause mixing elsewhere. Periodic inflows from rivers could also be the cause of flushing of Mwanza Gulf if at all this phenomenon proved to exist.

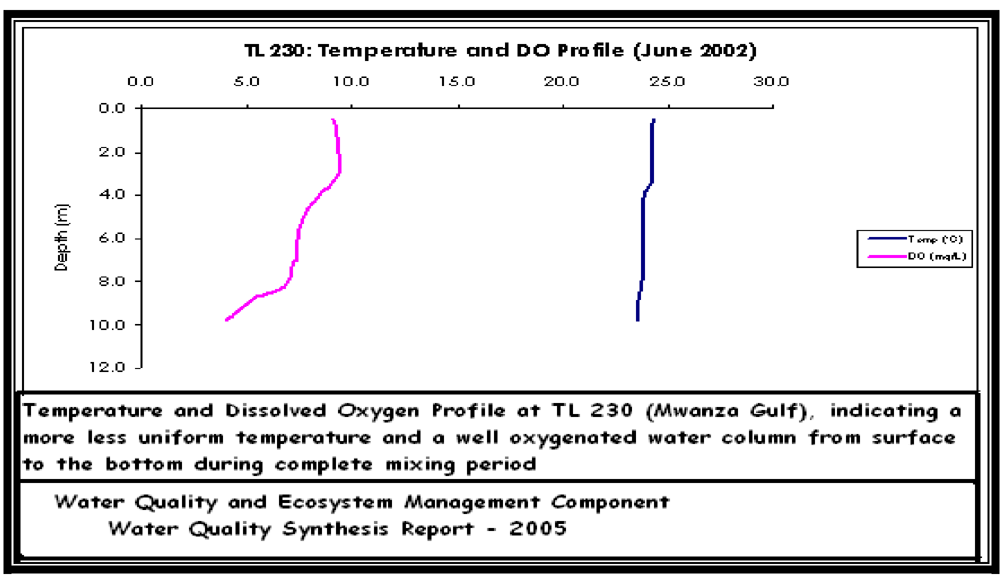
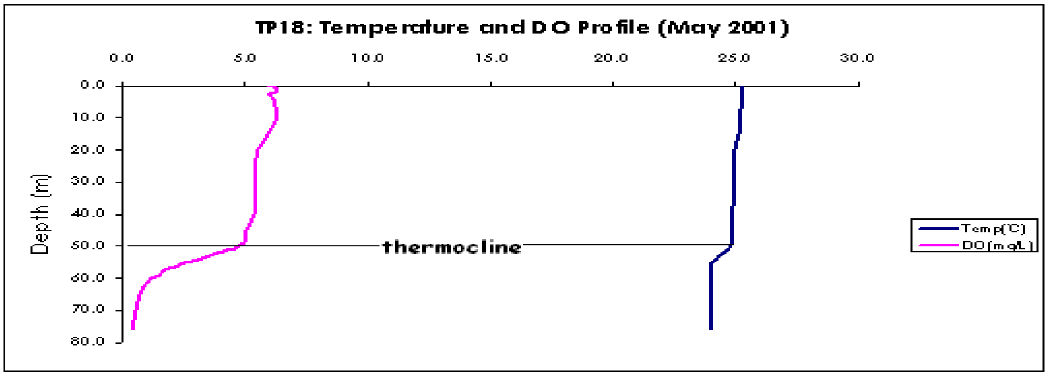


Fig.2 : Temperature and Dissolved Oxygen Profile during complete mixing period



Temperature and Dissolved Oxygen Profile at TP 18 (Pelagic), indicating formation of thermoclice at about 50m. Note that the bottom of the lake is anoxic.

Lake Victoria Environmental Management Project (LVEMP)
Water Quality and Ecosystem Management Component
Water Quality Synthesis Report- 2005

Fig.3 : Temperature and Dissolved Oxygen Profile during stratification period

This circulation pattern in the lake system is very important because it allows relatively large amount of oxygen to reach the bottom of the lake, otherwise, oxygen will have to reach the bottom by relatively slow process of diffusion. The mixing of the lake water at this time of the year is called overturn. According to Manahan (2000), during overturn, physical and chemical characteristics of the water body become much more uniform, resulting into a number of physical, chemical and biological changes in the lake system.

Examination of the temperature profiles for both littoral and pelagic stations show no significant variations in temperature along the column. A typical example of temperature profiles in pelagic and a littoral station are as shown (Fig. 2 and 3). High temperature differences have been noted in littoral stations (TL230), with the maximum temperature obtained in the month of October and minimum in June. While the difference of about 3.5°C have been noted in littoral stations, in pelagic station, the difference of about 2.1°C have been recorded between the two periods.

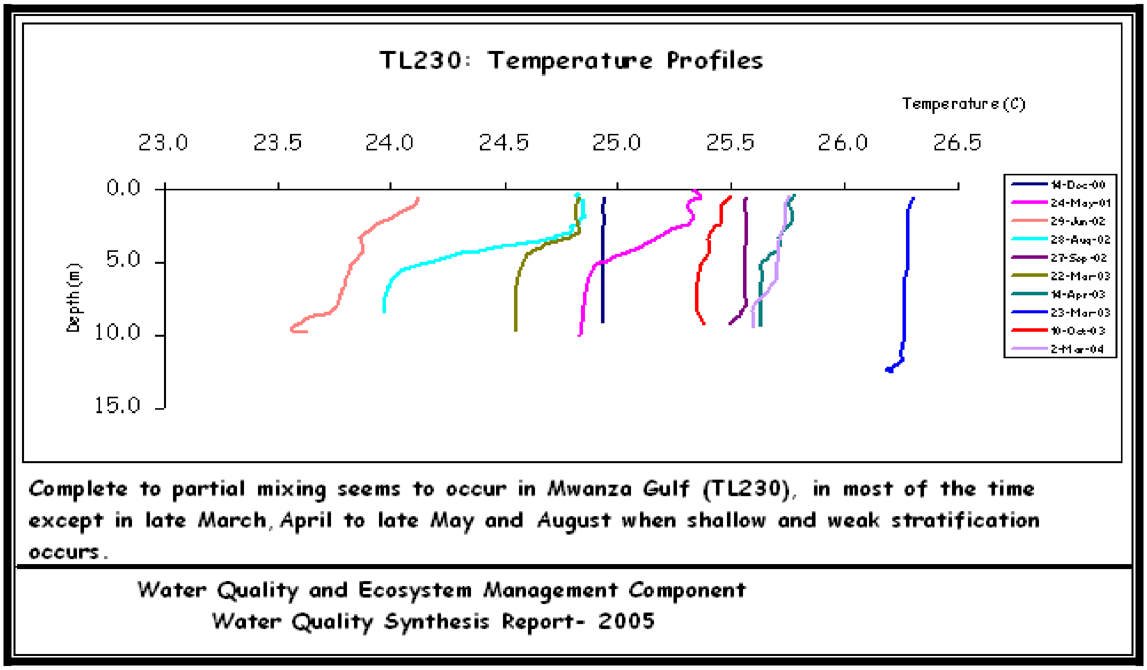


Fig.4. Temperature Profiles at TL 230 (Mwanza Gulf)

Other stratification patterns observed (Fig. 4 and 5)and which are similar to those observed by Talling (1964) are observed in September to December (Fig. 6), where gradual warming of water column takes place. During this period, no strong thermoclines are observed, but gradual decrease in temperature from the surface downwards. Cooling and almost complete mixing of the water column is observed between June and August coinciding with the global winds blowing from E-W. .

In some parts of the lake, it has been noted that cooling and almost complete mixing occurs also in January, supporting earlier observations made by Fish (1957) and Newell (1960).

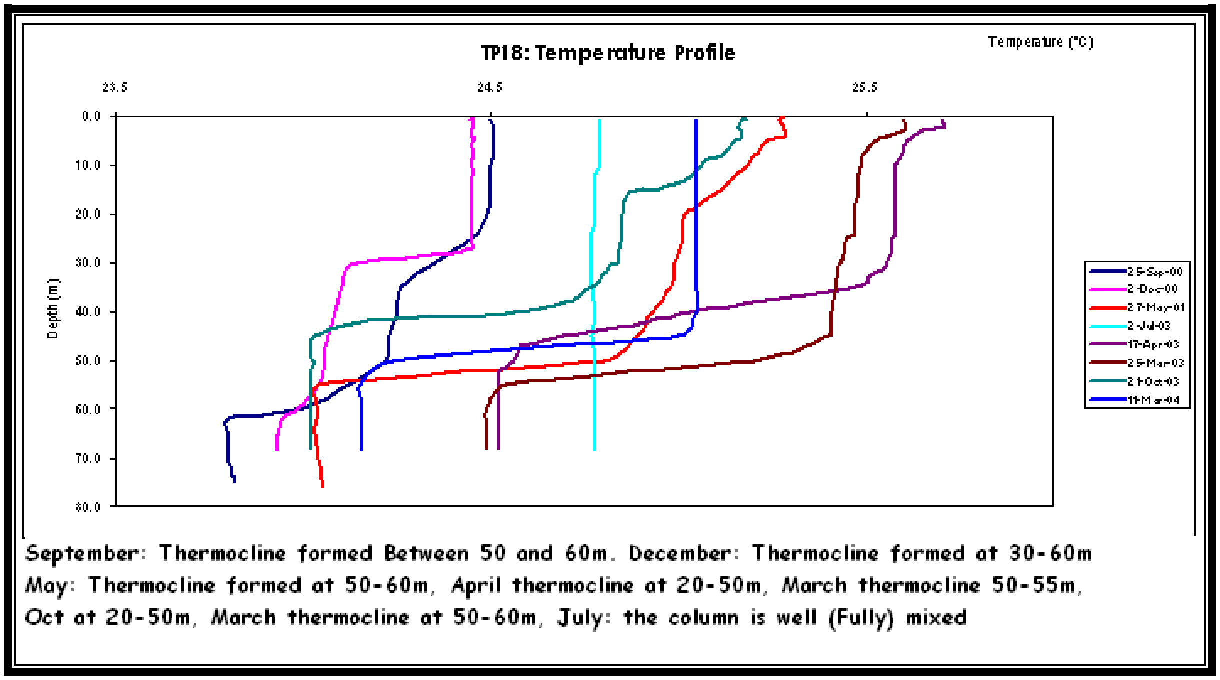


Fig.5 : Temperature variation with months

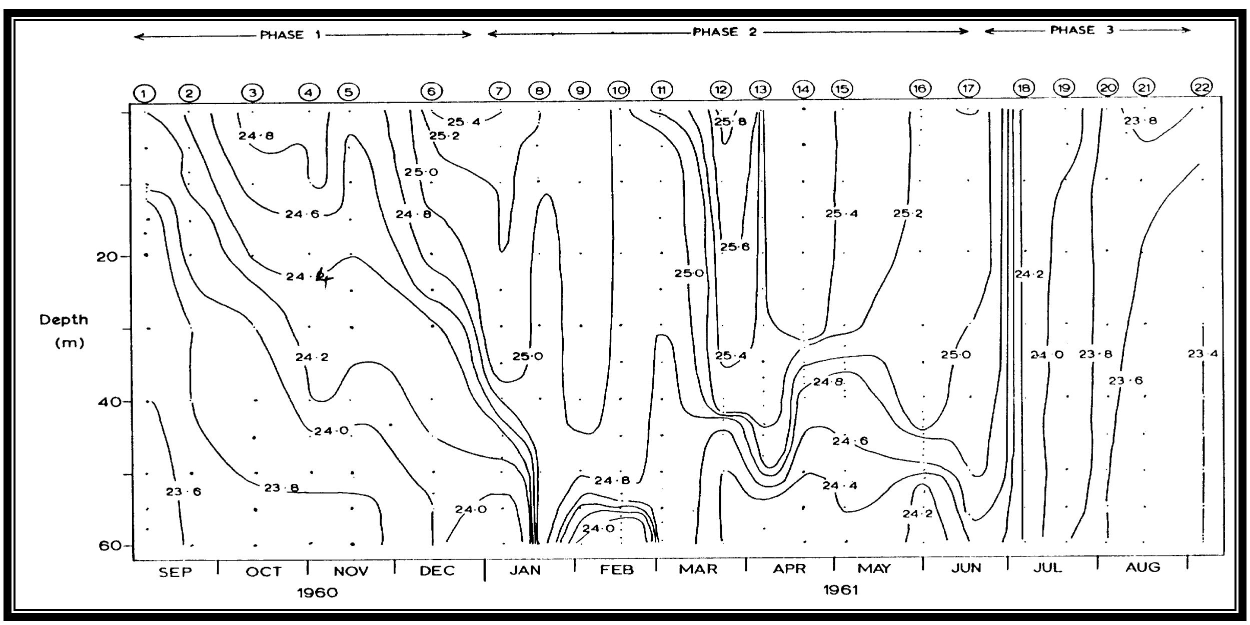
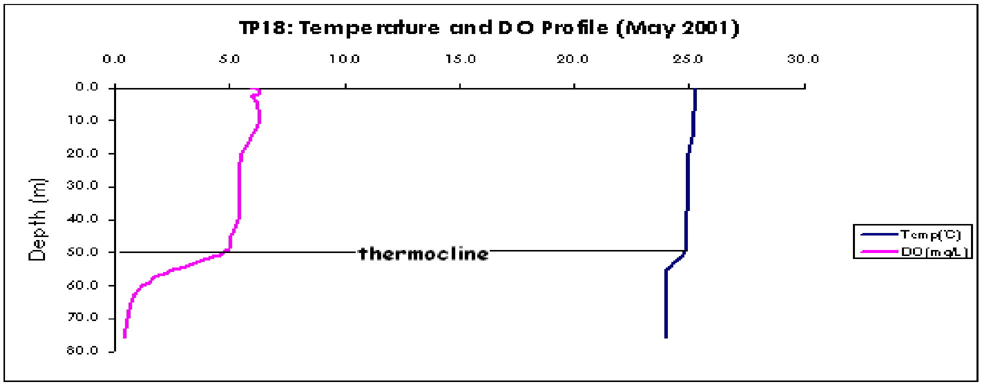


Fig. 6. Time series of temperature profiles at Bugaia Islands (UP2) 1960-61, adopted from Talling (1961)

The effects of thermal stratification

Warmer water has the ability to hold more suspended particles; this is a big part of the reason why water clarity is reduced during stratification periods. As the water picks up more suspended particles, it losses the ability to hold dissolved gases such as oxygen. The difference in water density eventually becomes so great that nutrients and oxygen can not pass from one layer to the other (Fig.7).

The water in the hypolimnion slowly begins to run out of oxygen as oxygen breathing organisms such as fish consume the available supply. Fresh oxygen can not pass through the density gradient of the thermocline and hypolimnion become anoxic. This process has great effect on fish location during because they are forced out of the cool water of the hypolimnion.



Temperature and Dissolved oxygen Profile at TP18 (Pelagic), indicating formation of deep thermocline at about 50m. Note that fresh oxygen can not pass through thermocline and hypolimnion has become anoxic.

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Water Quality Synthesis Report- 2005

Fig. 7: Fresh Oxygen can not pass through the thermocline and the hypolimnion has become anoxic

Cool water fish are also forced into warmer water than they prefer. Warm water increases fish's metabolism so fish have to feed more. Cool water species often survive the stratification by suspending near the thermocline. Fish which are sensitive to temperature become lethargic during the stratification's temperature peak. They often suspend over very deep water with their bellies lying in the cool thermocline. They occasionally eat a large prey item and seek cool water, where it may take days to digest it.

Oxygen loss in the hypolimnion is much more serious for cold water fish. These fish has narrow temperature tolerance range and the hypolimnion is often warmer than the fish's upper tolerance temperature limit. As oxygen run out in the deep water, the fish are caught in a temperature /oxygen squeeze. Summer kills occurs as fish succumb to either heat or stress or suffocation.

The southern part of Lake Victoria, areas which are badly hit by low oxygen concentration (Figure 8), and therefore likely to cause migration of fish to other areas of higher oxygen concentrations includes

Wind mixing and Water Movements

The global wind pattern shows that from March to May and October to December the winds approach the lake from South East moving at very high altitude and as they cross the lake, they turn towards the north. This wind meets another stream of wind from Congo approaching the lake from southwest (Fig.8) .These two wind streams meet in a convergence zone along the western side of the lake creating very strong surface waves on the western part of the lake. From January to February and June to September the main global winds flow from East to West. By the time these winds

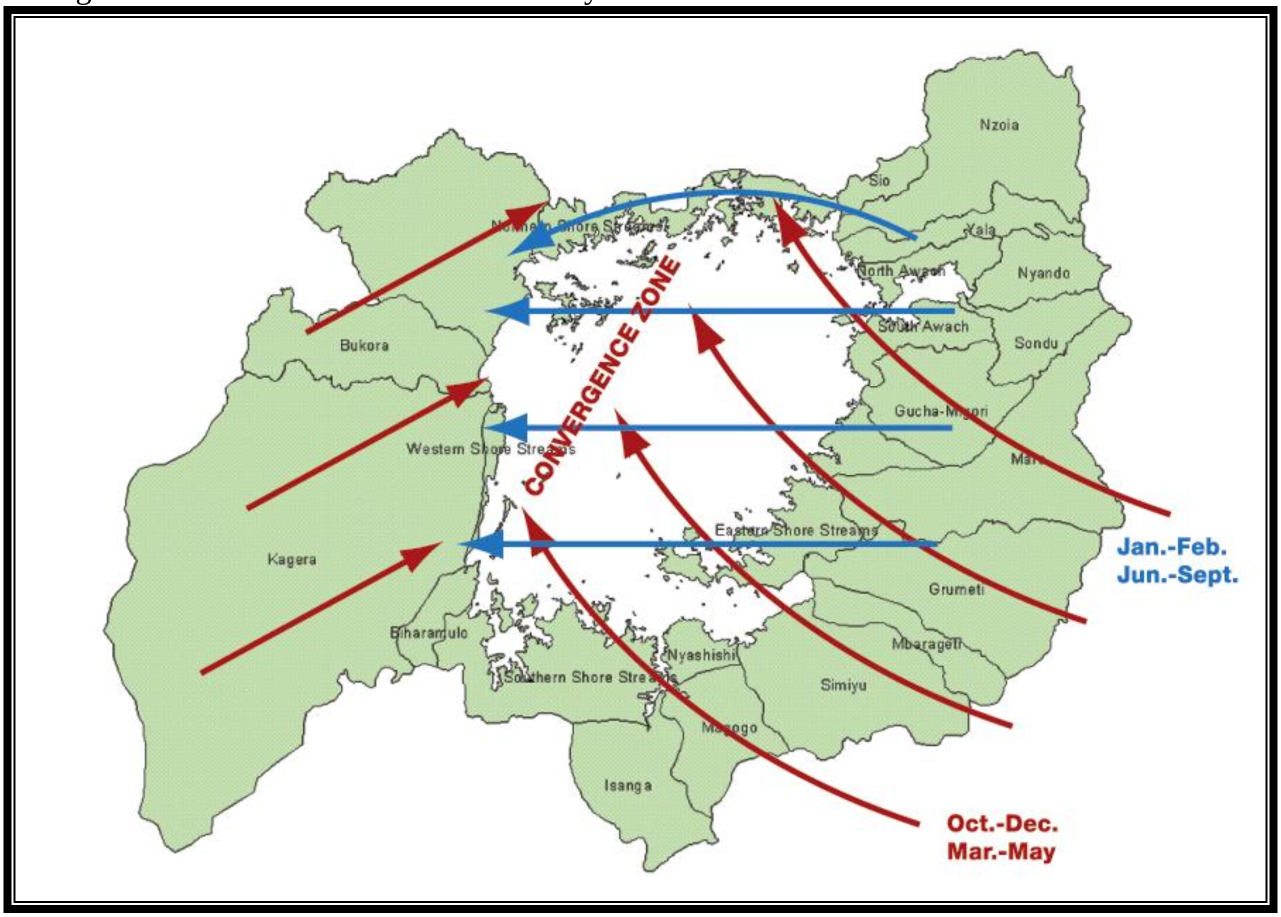

Fig.8. Global wind patterns over Lake Victoria (Source LVEMP-2002)

reach the western part of the lake, they have long fetch (uninterrupted movement by land).These winds are capable of creating very high waves on the western part of the lake. This accounts for the mixing of the water column on the western part of the lake for most period of the year. These strong movements cause very turbulent water mixing that reach the bottom of the lake and thus possible re suspension of bed materials. The turbulent mixing coupled with cold rains in this period of the year results in cooler water profiles in the western part of the lake. The strong currents force the suspended solids in rich waters of river Kagera to move along the northern shores of the lake to join with other inflows in Uganda of the lake.

The speed over the lake is generally gentle to moderate; with maximum wind speed during storms rarely exceeding 12m/s. the waves generated are correspondingly low, with maximum (1-100 years) significant wave heights of 2.5m. The daily waves generated by the on shore – offshore breezes normally not exceeding 1m, and can cause mixing of the surface waters of Lake Victoria to depths of 5-15m (LVEMP, 2002)

CONCLUSIONS

The examination of the temperature profiles and wind pattern in the lake leads to the following conclusions;

Thermocline in the southern part of Lake Victoria develops in the period between February to May. Total mixing has been found to occur in July to August. Gradual warming of the water column is observed mainly between September and December, although less obvious i.e. gradual warming of the water column is weak. An almost total mixing occurs in December to January in some stations. This is observed in TL D , TPX and TPG. The above observations confirm the existence of phase 2 and 3 as earlier observed by Talling (1964), i.e. development of deep thermocline in periods of February to may and the existence of total mixing in the months of july to August.

Large temperature variations exist within the lake at any instant, indicating that the south differs from the north, while the east differs from the west in terms of temperatures, contrary to what was assumed by early researchers (Talling, 1964), that the lake is homogeneous, and therefore the profile at UP2 (i.e Bugaia) can be used to represent the situation in the whole lake. It is now concluded that the lake is inhomogenous and that Bugaia profile does not represent the situation of the whole lake

Less vertical mixing observed in the eastern part of the lake including southeastern corner can possibly be explained by the fact that global winds that cause the mixing come from the east and southeast and adjacent areas are more protected than the western part.

Stratification in the southern part of the lake including Mwanza gulf is not pronounced compared to the central part (TP9, 18) of the lake. The observation of temperature profile also indicates that the water column is slightly warmer in the north than in the south.

Mwanza gulf seems to have quite different thermal stratification characteristics from remaining part of the lake (TP1 TP2). In most cases, there are significant spatial temperature differencies between the upper most part of the lake (TL234) and the mouth of the gulf.

RECOMMENDATIONS

Procurement of an ADCP is very necessary in order to make continuous observation of currents in order to fully understand the forces that drive the generation of and govern decay of the variable flow for various embayment and the almost closed bays within central lake

More emphasis is required on the implementation and training on hydrodynamics model available so that management issues can be investigated and potential solutions discussed

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LAKE MONITORING

By: D.K., Rutagemwa, O.I Myanza, and F. Mwanuzi

ABSTRACT

To date there are several studies carried in the Lake Victoria a number of conclusions being made but most of these studies are based on either single location or single data thus not representative for the entire lake and situation. During the period September 2000 through March 2005, the Water Quality and Ecosystem Management Component in Tanzania undertook an in-lake Water Quality Monitoring in the Tanzanian part of the harmonized in-lake water quality-monitoring network designed jointly by the Water Quality and Ecosystem Management Components of the three Lake Victoria riparian states. The monitoring design involved defining of objectives, selection of monitoring stations and parameters to be monitored, and agreement on field equipment and procedures. It also involved cruise planning, and on-board training. Apart from the harmonized network, eighteen (18) impact-monitoring stations were established to determine trends and how the near-shore areas of the lake are affected by release of contaminants and other human activities carried out in the urban centres of Mwanza, Bukoba and Musoma.

This chapter provides the achievements made and challenges and problems encountered during the period in question and recommends the way forward. During the four and a half (4½) years of monitoring, a total of 16 cruises were undertaken and 4314 profiles were obtained and 1688 water, 284 sediment trap, 3403 zooplankton and phytoplankton samples were collected and analysed in the laboratories of Mwanza, Bukoba and Musoma. Also since 1998, a total of 6,044 water samples have been collected from the urban impact stations and analysed in the three laboratories. The experience gained during the period has led to recommendations for improving the monitoring and research including *interalia*: retaining the current 29 stations of the harmonized network and 18 impact stations until a more complete picture of the lake is obtained; retaining the current sampling frequency and ensuring it remains interruption free for a period of one to two years so as to confirm the observed temporal variations in the state of the lake; putting in place a mechanism to sustain an efficient monitoring and research program; putting in place contingency plans for rescue operations in the event of an accident or problem; and procurement of a fast research vessel.

INTRODUCTION

The Tanzanian part of Lake Victoria occupying an area of above 35,720km^2 (MoL) forms about 51% of entire lake and lies entirely in the southern, hemisphere with the latitude 01º 00'S forming the northern border with both Uganda and Kenya. This part of the lake is very important for the lake basin and the areas beyond for providing freshwater for domestic, agricultural and industrial use, transport, recreation, tourism and biodiversity reservation. However, since the early 1960s the lake water quality has increasingly degenerated. The changes were driven by high population increase and their associated activities and economic development (Hecky, 1993). Nutrient inputs have increased to three fold, concentrations of phosphorus have risen markedly in the deeper lake water, and nitrogen around the edges. Stimulated by these and other nutrients, the five-fold increase in algal growth, and the shift in its composition towards domination by blue-green algae, is causing deoxygenation of water, increased sickness for humans and animals drawing water from the lake, clogging of water intake filters, and increased chemical treatment costs for urban centres. A side from the near total loss of the deep water species, the deoxygenation of the lake's bottom waters now poses a constant threat, even to fish in shallower portions of the lake, as periodic upwelling of hypoxic water causes massive fish kills (World Bank, 1996). Nonetheless, these conclusions were based on the monitoring activities carried out in the northern segment of the lake in Uganda and Kenya. Some few locations were studied by foreign and local researchers and thus until the start of this monitoring programme not much could be said about the general lake water characteristics. Thus, the lake monitoring programme is meant to evaluate the variability of the various water quality problems indicators within the lake with the intention to come up remedial measures. The specific objectives are to obtain data for determination of the present state of the lake water quality and ecosystem; analysis of the relative importance of the biological processes and limiting factors in the eutrophication of the lake; calibration of the Lake Victoria Framework Model; and in the long term, monitoring the changes in the lake.

To achieve these objectives a programme for monthly and quarterly sampling on the lake was agreed on by the three lake Victoria riparian countries of Kenya, Uganda and Tanzania. The lake model consists some 8000 (20 vertical x 400 horizontal) grid cells with 38 state variables and bearing in mind that a proper model calibration requires about 1000 data per state variable a sampling programme would need careful planning. During the first one year of monitoring programme implementation a consultant (COWI) was contracted to provide advice and assistance in planning of monitoring cruises for the three countries; preparing on-board procedures and field forms for recording of field observations; and providing hands-on training by participation in sampling cruises (LVEMP, 2002)

METHODS

Study area

The Study area is the Segment of Lake Victoria covering an area of about 35720 km^2, with a maximum depth of 73m, mean depth of 40m, and a volume of about 1,429km^3. It lies between latitude 01º and 03'S and longitude 31º 51.5' and 33º 54.7'E.

Monitoring stations:

The in-lake water quality monitoring stations fall into two categories namely the Harmonized Water Quality Monitoring network designed jointly by the Water Quality and Ecosystem Management Components of the three Lake Victoria riparian countries, and the Urban lake (impact) stations located along the three major Tanzanian lake Victoria riparian urban centres of Mwanza, Bukoba and Musoma.

Harmonized Monitoring Network

The study area was divided in two main zones namely the open waters herein referred to as pelagic are (P) and the near shore areas herein referred to as the littoral zone (L). This classification is based on the depths with pelagic area having depths greater than 15 metres and littoral area having depth less then 15 metres. Again based on its large surface area and shallow depth, and the fact that some of the bays are sheltered while others are open, and the variation in climatic conditions between the east and west and the preliminary hydraulic and thermal conditions established by earlier research, the desk design came up with 18 pelagic stations and 11 littoral stations. Each of the stations was located in such a way it fell on a transect joining the Ugandan or Kenyan stations of the harmonised monitoring network. This is meant to examine the temperature profiles along and across the lake at a number of instants in time. This can illustrate for example the variations from north to south and east to west at any one instant.

The naming convention for the stations is as follows:

First letter: Country. T=Tanzania,.
Second letter: L = Littoral (inshore). P = Pelagic (offshore).

The locations of the stations were chosen so that, as near as possible, they lie on transects along and across the lake.

Parameters: Based on the earlier identified water quality issues the following parameters were selected. These are: Temperature, pH, EC TDS, Turbidity, TSS, Total Alkalinity, Total Hardness, Calcium, Magnesium, Chloride, PBSi, LOI, TPP, TPC, TP, SRP, TDP, Ammonia (NH_4^+-N), Nitrite Nitrogen (NO_2^--N), Nitrate Nitrogen (N_3¯N), Dissolved Reactive silicon, Chl-a.

- Physical: light attenuation, secchi depth, temperature, PH, Conductivity turbidity, current speed and direction

- Chemical: Chlorophyll, alkalinity, PO4, NH4, NO2+NO3, SI, TPN, TPP, TPC, PBSi, DON, DOP.

- Biology: Counts on phytoplankton, zooplankton and benthos with necessary information on sample size.

- Sediments: trap measurements of DW, TPC, TPP, TPN and TBSi with necessary data on exposure time, depth and dimensions of traps.

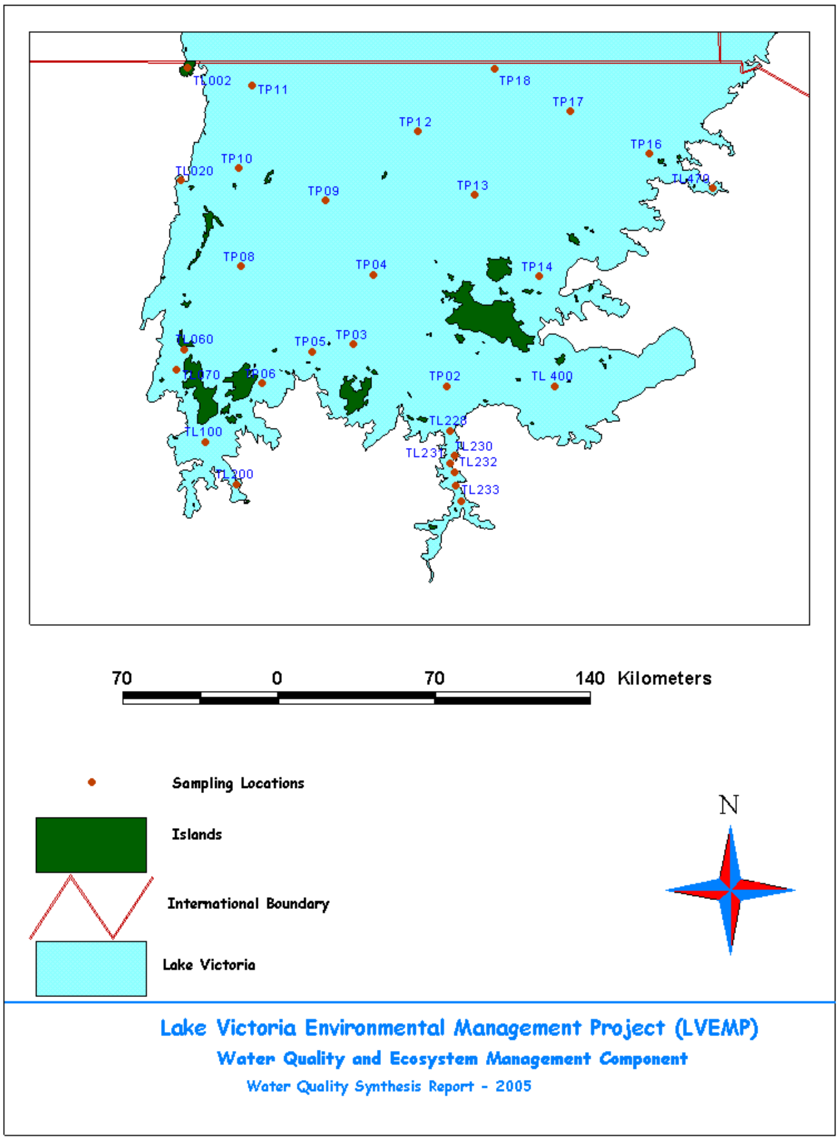

Figure 01. Monitoring Stations in Lake Victoria (Tanzania)

Research Vessel

The research vessel RV TAFIRI II (Figure 2) was made available by the Tanzania Fisheries Research Institute (TAFIRI) after signing a memorandum of understanding with the component on 22 August, 2000.

The research vessel basically designed for trawling task was modified to accommodate the new task of water quality monitoring. It is equipped with a video sounder, VHF radio, hydro graphic winch, a compartment for laboratory work, a deep freezer for storage of samples, kitchen facilities, toilet and bathroom and ten (10) beds. Others are a standby generator, radar, global position receiver, navigation compass, and a life raft.

The Tanzania stations forming the Southern part of the Harmonized-monitoring network are presented in table 01.

Figure 02: RV Tafiri II, TAFIRI, Tanzania.

Urban lake station (impact) monitoring

The in lake impact stations are located along the three urban centres of Mwanza, Bukoba and Musoma with six stations each. (Table. 02, 03, and 04). Selection of the stations was based on influences that caused water quality to vary from place to place and from time to time. Some are located near entrances of streams, effluent outfalls, river mouths.

The selected parameters are: Colour, Turbidity, Alkalinity (Total), and Chloride; Permanganate value, Total Hardness, Calcium, Magnesium, pH, and E. Conductivity; Total dissolved solids, Total phosphorus, Dissolved Reactive phosphorus, Dissolved $O_{2,}$ and Feacal coliform; Total Coliforms, Nitrite $–N_{2,}$ Nitrate – $N_{2,}$ Ammonia – $N_{2,}$ Suspended solids (T.S.S), Silicon (SiO2, DRSi), and Chlorophyll-a.

Table 01: In-lake Water Quality Monitoring Network Tanzania

STATIONS	LONGITUDE	LATITUDE	AV. MAXIMUM DEPTH (m)	NUMBER OF TIMES VISITED (n)
TL-002	31º 51' 30" E	01º 00' 40" S	9.4	6
TL-020	31º 46' 02" E	01º 28' 51" S	11.0	6
TL-060	31º 52' 59" E	02º 06' 39" S	7.0	5
TL-070	31º 44' 54" E	02º 14' 43" S	11.5	6
TL-100	31º 51' 32" E	02º 32' 05" S	11.0	6
TL-200	31º 59' 29" E	02º 42' 19" S	4.6	5
TL228	32º 50' 58" E	02º 29' 26" S	17.5	14
TL-230	32º 52' 06" E	02º 35' 26" S	9.5	15
TL-231	32º 51' 12" E	02º 37' 04" S	8.0	13
TL-232	32º 50' 22" E	02º 39' 26" S	5.5	14
TL-233	32º 52' 06" E	02º 42' 42" S	4.8	12
TL-234	32º 53' 51" E	02º 46' 26" S	4.8	14
TL-400	33º 16' 16" E	02º 18' 37" S	21.5	6
TL-470	33º 43' 31" E	01º 30' 43" S	3.5	6
TP-02	32º 50' 18" E	02º 18' 36" S	43.1	14
TP-03	32º 27' 53" E	02º 08' 27" S	52.4	7
TP-04	32º 46' 51" E	01º 51' 39" S	60.0	10
TP-05	32º 16' 11" E	02º 07' 44" S	50.2	7
TP-06	32º 05' 42" E	02º 17' 59" S	27.0	7
TP-08	32º 07' 12" E	01º 49' 36" S	50	8
TP-09	32º 21' 07" E	01º 33' 54" S	59	13
TP-10	31º 59' 58" E	01º 25' 51" S	41.7	6
TP-11	32º 03' 31" E	01º 05' 46" S	38.0	7
TP-12	32º 43' 24" E	01º 16' 56" S	68.6	11
TP-13	32º 12' 00" E	01º 51' 52" S	70.0	1
TP-14	32º 12' 34" E	01º 51' 57" S	43.6	6
TP-16	33º 39' 12" E	01º 22' 17" S	48	6
TP-17	33º 20' 16" E	01º 12' 11" S	70.5	4
TP-18	33º 05'18’’ E	01º 08' 36" S	68.5	9

Table 02: Mwanza Littoral Impact Stations

S/No.	Name of Location	Station Code	Latitude	Longitude
1.	Butuja		S02º 02026.996	E032054.920'
2.	Mahina		S02º 028.713	E032052.649'
3.	Mirongo river mouth		S02030.489	E032053.741'
4.	Capri point		S02031.666	E02053.098'
5.	Nyashishi river mouth		S02038.926	E032053.436'
6.	Tilapia		S02311966	E03253739'

Transport facilities

The transport facilities used include the water transport consisting of fibreglass boats and dinghies and outboard engines. Hand-held global positioning receivers for exact station location and life vests are other important facilities.

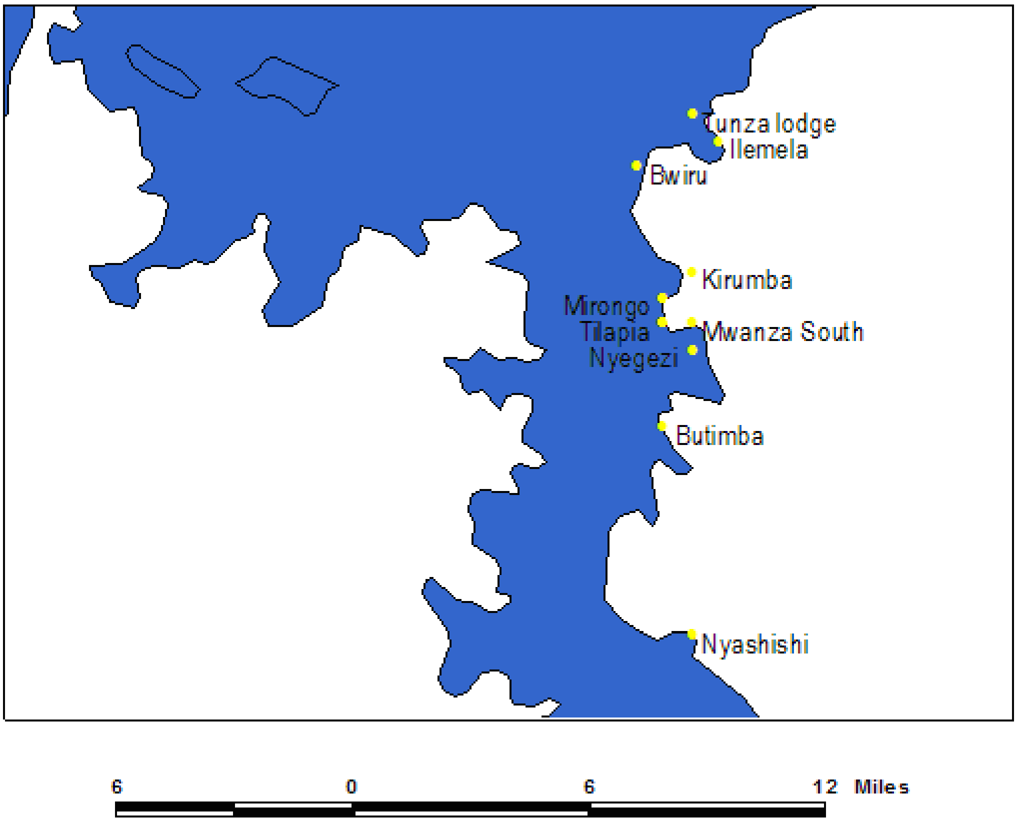

Fig. 03: Mwanza impact stations

Table 03: Bukoba Littoral Impact stations

S/No.	Name of Location	Station Code	Latitude	Longitude
1.	Nyamkazi River mouth	TL 4	31.820	-1.330
2.	Nyamkazi Fishing mouth	TL 6	31.828	-1.333
3.	Kanoni river mouth	TL 9	31.820	-1.340
4.	Bukoba W/S Pump house	TL 10	31.815	-1.346
5.	Kemondo Wharf	TL 18	31.751	-.1478
6.	Kyetema River mouth	TL 16	31.763	-1.460

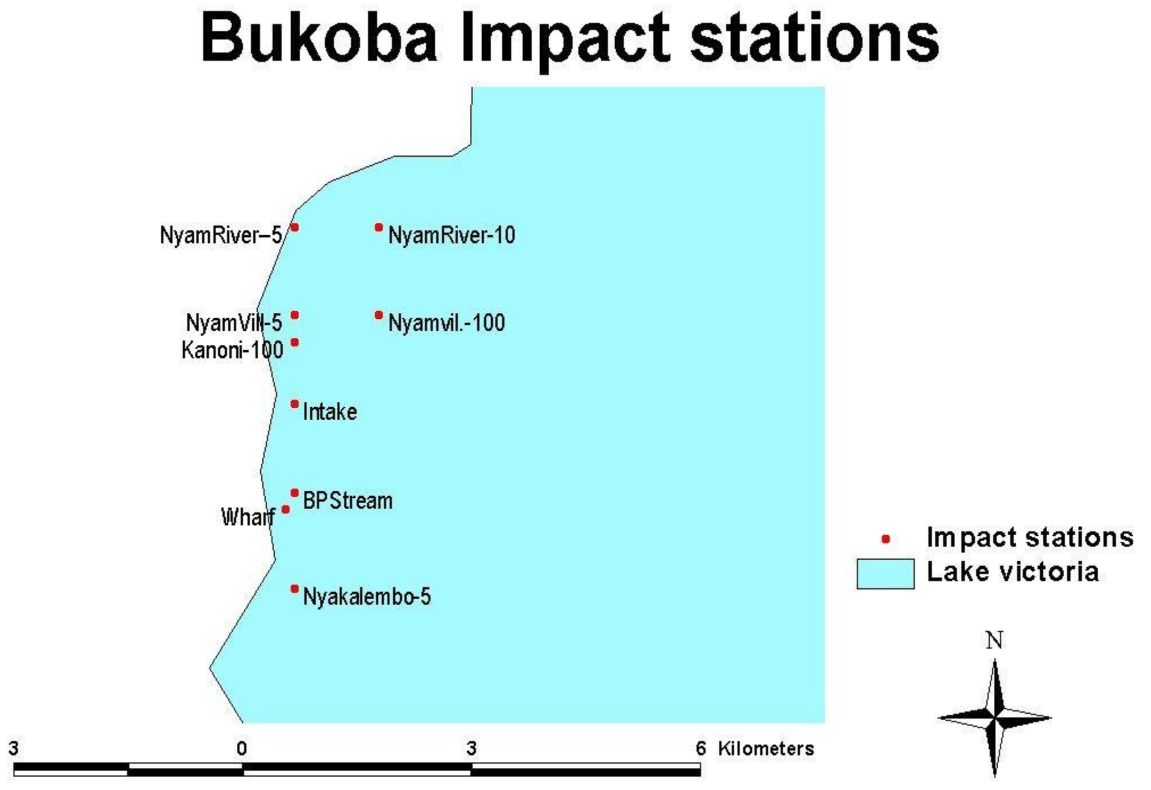

Fig. 04: Bukoba Impact Stations

Table 04: Musoma Littoral Impact stations

S/No.	Name of Location	Station Code	Latitude	Longitude
1.	Makoko Point	TL 456	-1.149	33.79
2.	Mwisenge Point	TL 457	-1.49	33.80
3.	Water Pumping Station	TL 458	-1.48	33.81
4.	Mwigobero	TL 462	-1.50	33.82
5.	Machinjioni	TL 467	-1.52	33.84
6.	Mara Mouth	TL 471	-1.52	33.97

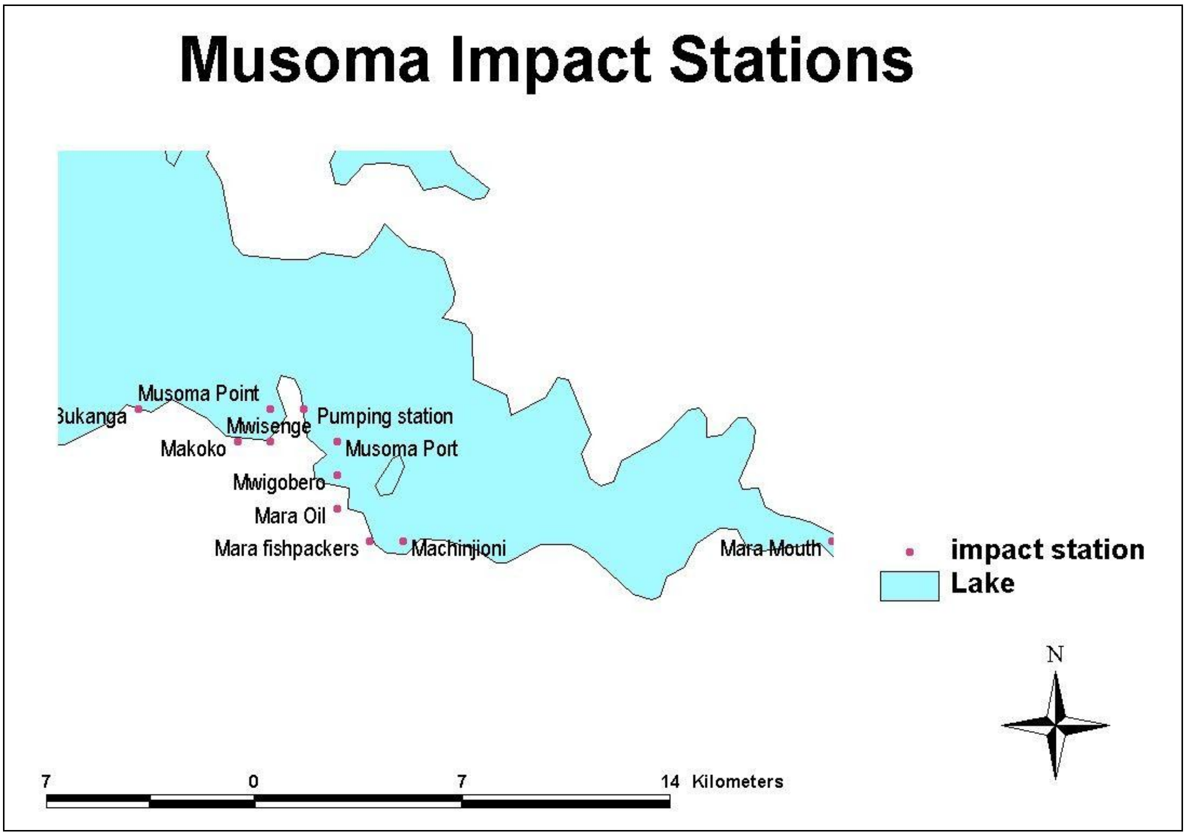

Fig. 05: Musoma Impact Stations

Cruise planning

A monitoring programme consisting of monthly and quarterly sampling cruises was agreed upon by the three countries with assistance of the consultant during a workshop held in Entebbe Uganda in November, 2000. The monitoring stations are shown in Figure 01 and a summary of the number of cruises in Table 1.

Monitoring Frequency

During the Seminar conducted by the consultant at Entebbe – Uganda in November, 200, a harmonized monitoring programme consisting of monthly and quarterly sampling cruises was agreed upon by the three countries. The number monitoring stations are indicated in Figure 01 and a summary of the number of cruises in table 05

Table 05:Summary of the planned cruises.

Stations	Tanzania
Near shore monthly	8
Near shore quarterly	8
Offshore monthly	5
Offshore quarterly	18?
Total annual profiles	108

During the monthly cruises all eleven (11) littoral stations and five (5) offshore station were covered, and the quarterly cruises involved all eleven (11) littoral and eighteen (18) stations.

The urban lake stations (impact) were monitored in the beginning and later monthly

It was planned that a relatively limited number of key stations should be visited on the monthly cruises, and all stations on the quarterly cruises.

Monitoring of the offshore stations was interrupted by the need to return to Mwanza for refuelling and to seek overnight accommodation on islands and near-shore towns.

The total of 500 annual profiles each consisting 5 - 10 samples depending on depth and the measurement of 15 - 20 nutrient and biota parameters provided a balanced monitoring programme according to the project objectives and the field and laboratory capacity of the WQ Components.

TABLE 06. Summary of the monitoring cruises carried out from 2000-2005.

	Tanzania		
Hydrodynamic phase	No. of cruises	No. of profiles	No. of samples
Stable deep thermocline	5	1146	1279
Beginning of destratification	2	436	596
Complete mixing	3	818	956
ng-stratification establishment	8	1914	2114
TOTAL	18	4314	4947

In-situ measurements and sample collection

At each sampling site recording of position was done using a GPS instrument. Other determinations included depth, wind speed, wind direction, air temperature, wave height, wave direction and wave period. *In-situ* measurements of Secchi depth and recording of profiles for temperature, dissolved oxygen, conductivity, pH, light and current speeds and directions were also determined. Water column depth and temperature, dissolved oxygen (DO) using Hydrolab and/or Seabird (CTD) instruments, and light profiles were used to determine the appropriate depths for collection of samples for phytoplankton and zooplankton.

Samples were collected at the following depths:

1. 0.5 m below surface
2. Secchi depth or 10% surface light
3. 2.3 x Secchi depth or 1% surface light
4. Start of DO- or temperature gradient
5. 1 m below start of gradient
6. 1 m above bottom
7. 0.5 m above bottom
8. Every 5 - 20 m between (3) and (4)

Water samples were filtered through glass fibre filters (1μm) for determination of total particulate nitrogen (TPN), total particulate phosphorus (TPP) and total particulate carbon (TPC). Water samples for chlorophyll-a determination were filtered through membrane filters (0.45 μm pore size) and for total biogenic silica (PBSi) 0.2μm membrane filters were used. The filters and filtrate were stored by freezing to 4^{0}C or below.

Phytoplankton samples for determination of abundance (and calculation of biomass) and species composition were collected with a 5 litre Schindler trap at the surface (0.5m), at Secchi depth of 2.3 times Secchi depth and 5m intervals up to 1m above the bottom in deep waters. The samples were fixed with 1% acid Lugol's iodine solution (APHA, 1995 and 1998). Few drops of formalin (4%) were added to the samples to keep them longer in case of delay in analysis or if samples were desired for archiving. The samples were kept in darkened containers to avoid photolysis of the iodine. Primary production experiments were conducted by incubating for about two hours a set of light and dark bottles filled with lake water from the monitoring stations. This was done by immersing the bottles secured to a retrievable device into the same water column where the samples were collected. A comparison of dissolved oxygen concentrations in the light and dark samples was then done. The difference in dissolved oxygen concentration was used to calculate the photosynthetic rate as a measure of primary production.

Both the Schindler trap and vertical net hauls were used to collect zooplankton samples. Schindler samples were collected at different depths and sieved through 60 µm mesh. The nets consisted of 100 µm mesh size with a mouth diameter of 25 cm. The samples were preserved in 5% formalin for examination later in the laboratory. Zooplankton average densities were derived from triplicate counts taking into consideration the sample volume (S), sub-sample volume (s) and the volume of water filtered along the water column. The densities were expressed in numbers per litre. Benthos samples were taken with Ekman and Ponar grab samplers for quantification and sediment traps were deployed and retrieved according to standard procedures (APHA, 1995).The microbiology of pelagic, littoral and urban lake waters was determined with respect to coliform organisms. Water samples were collected using sterile glass bottles (autoclaved for 15 minutes at 15 lb/in^2 at 121^{0}C) (APHA 1995).

Laboratory Activities

In the laboratory, samples were allowed to attain room temperature and divided into appropriate aliquots for use in the analysis of nutrients using spectrophotometric methods as outlined in Wetzel and Likens (1991) and APHA (1995, 1998). Phosphate-phosphorus was analyzed as Soluble Reactive Phosphate (SRP) using Ascorbic acid method; nitrate-nitrogen using cadmium reduction and diazoic complex method and silica (DRSi) using the heteropoly blue method. Samples for analysis of total and dissolved organic nutrients were digested and analyzed as outlined in APHA (1995, 1998). Total phosphorus (TP) and dissolved organic phosphorus (DOP) were analyzed as PO_4-P whereas total nitrogen (TN), and dissolved organic nitrogen (DON) were analyzed as NO_3-N. For the analysis of particulate biogenic silica (PBSi), the filtered content was digested using wet alkaline method (2 ml of 0.5 M NaOH added and heated in an oven for 15 minutes at 85^{o}C) to release the bound silica. The digest was then analyzed as silica (SiO_2-Si). Chlorophyll-*a* pigment was extracted in the laboratory using 90% ethanol and analyzed using spectrophotometric methods as recommended in Wetzel and Likens (1991). For the analysis of total suspended solids (TSS), appropriate sample volume was filtered through a pre-weighed glass fiber filter paper (nominal pore size 0.45 μm), the filter paper with the content dried in an oven for 24h at 105 $^\circ$C and weighed to calculate the TSS.

Phytoplankton samples were shaken and sub-samples of 1-2ml were introduced in Utermol sedimentation/counting chambers (Utermol 1958) and phytoplankton was allowed to settle for at least three hours. Phytoplankton cells were identified to the species level wherever possible, and counted by the Utermohl method using LEICA DMlL inverted microscope equipped with phase contrast and bright field illumination as needed. Standard literature, including algal taxonomy keys, was used for identification of species. Biovolumes of phytoplankton was estimated using the formula given by APHA (1995) to estimate total algal biomass. Triplicate counts of zooplankton were made and the zooplankton identified to possible taxonomic levels. Samples for benthos and water microbiology were examined in the laboratory using methods recommended in APHA (1995).

Data Quality Control

Comparability of data among national laboratories and national programs was undertaken by using a common protocol for analytical quality assurance amongst the three laboratories located in Kisumu, Entebbe and Mwanza participating in the lake monitoring programme. Quality control also included inter-laboratory comparison schemes and consistency of calibration of instruments. More information on laboratory quality assurance activities are given in the capacity building chapter

Data Storage, Treatment and Reporting

Data were stored in digital format in databases to facilitate statistical analysis, trend determinations and presentation and dissemination of results. These databases will increase in value as monitoring data are acquired over time and trends over time can be confirmed or identified.

Data Interpretation

Following the implementation of the monitoring activities the next step was data interpretation. This involved comparison of water quality data between stations, analysis of water quality trends, and development of cause-effect relationships between water quality and environmental data, and judgments of the adequacy of water quality for various uses. Publication and dissemination of water quality reports to relevant authorities, the public and the scientific community was undertaken through workshops, seminars and international peer-reviewed journals.

On-board training

Initially, the Consultant participated in one-day cruises from Mwanza, to be orientated about capacities and instrumentation of the vessels, sampling equipment and procedures for sampling and facilities for storage of samples. These demonstrations were important background for the further planning and the adjustment of procedures later agreed on. Further consultancy consisted in participation in one sampling cruise from Mwanza.

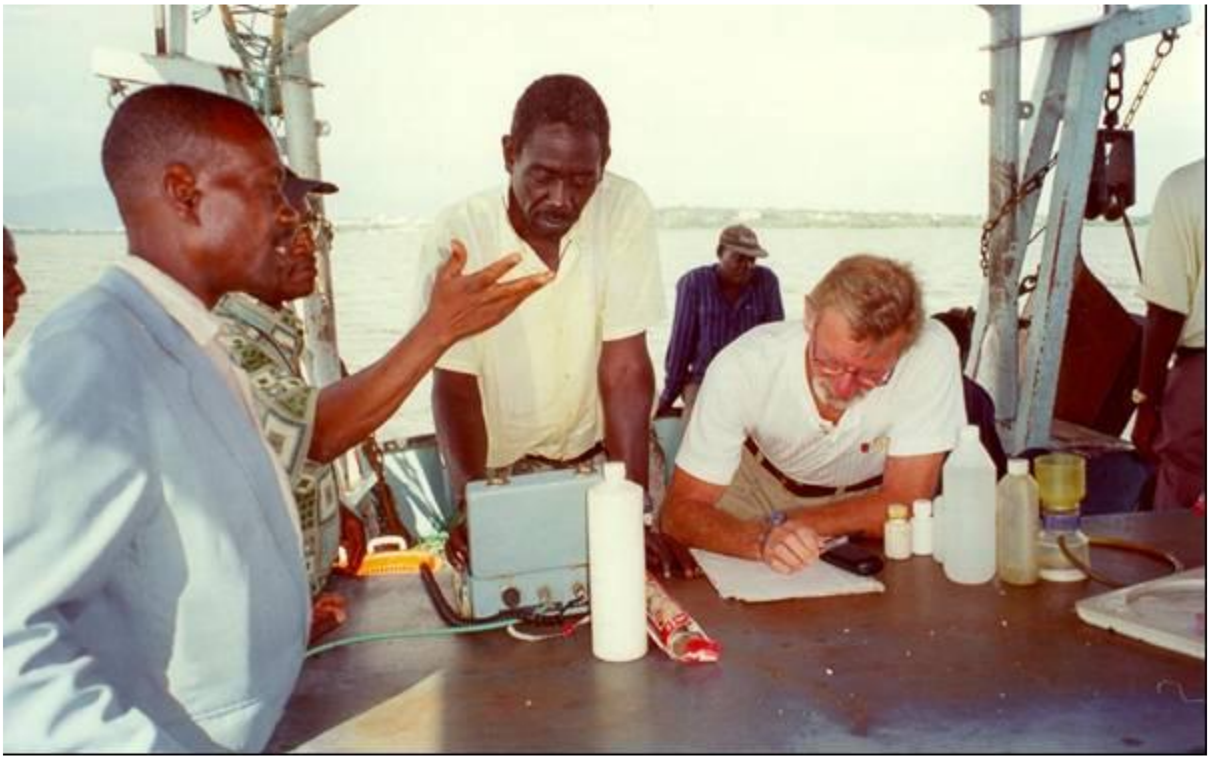

Figure 06: On-board training

CONCLUSIONS

The data that has been generated during LVEMP show significant ecosystem changes that include:

- Presence of high levels of nutrients in the lake;
- Occurrence of frequent algal blooms enhanced by high nutrient levels in the lake
- Algal biomass increase as evidenced by high chlorophyll a levels and primary productivity;
- Increased turbidity resulting from land inflows and biological activity within the lake;
- Reduced water transparency as a result of increased turbidity in the water
- Depletion of oxygen levels with severe cases (anoxic conditions) in pelagic bottom waters;
- Reduced silicon levels as demand by Si requiring algae such as diatoms has exceeded the re-supply of Si from the catchment;
- Rise in P concentrations has been driven by multiple changes in the catchment that have led to increased P loading including deforestation, biomass burning, soil erosion, urbanization, increasing fertilizer;
- Deteriorating oxygen conditions and visibility in the lake has led to loss of fish habitat and possibly other beneficial uses of the lake.

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SEDIMENTATION STUDIES

By: F. Mwanuzi, D.K., Rutagemwa, and A. Mathayo

ABSTRACT

Sediments consist of the input of suspended solids with river discharges, the autochthonous produced particulate matter in the water column and the settled material on the lake bottom. The loading, transport, formation and decay of the sediments entering the Lake Victoria from Tanzanian side was monitored for the period 2000 to 2005

The sedimentation study focused on; quantification of settling fluxes of particulate nutrients at the offshore and near shore monitoring stations. Quantification of diffusive fluxes of oxygen, carbon and nutrients across the sediment-water interface at the offshore and near shore stations and net deposition of carbon and nutrients, and the available pools of these components in the sediment at the offshore and near shore stations.

Monitored data on sedimentation rate and settling velocities of TPP, TPC and TBSi has been sampled and analysed in the period **November 2000 to March 2005**. The results show that sedimentation rates are highest at the littoral stations compared to pelagic stations, but the differences are smaller than the variations in chlorophyll concentrations and Secchi depths. The differences in settling velocities indicate that the settling material consists dead and living material with a contribution of diatoms. The laboratory results on sedimentation status are going to be among of the input in assessment of lake water quality and development of the Water Quality Model.

INTRODUCTION

Sedimentation refers to settling of suspended particles when turbulence from water motion is no longer strong enough to keep them in suspension. When suspended solids exceed natural levels, they can become part of pollution, hence detrimental effect on water quality. With nutrient enrichment the biological production of organic particles is accelerated and that can lead to increased sedimentation (fig: 2).

Human activities are the major cause of sedimentation because of accelerating soil erosion (from agricultural area), urban run-off and failure of wastewater treatment systems. Further more, depending on physical characteristics of the water body, erosion from catchments, airborne inputs and biological activity contributes in sedimentation processes.

The Lake Victoria has terrestrial catchment area of about 197,500km^2, out of which 69,500km^2 is the lake itself, fifty one percent (51%) of the lake area (35,720 km^2) is found in Tanzania side while Kenya and Uganda share the rest part (Fig.1). The Lake under discussion, which is the second largest in the world, is serving about thirty million people of the three riparian counters namely Kenya, Tanzania and Uganda.

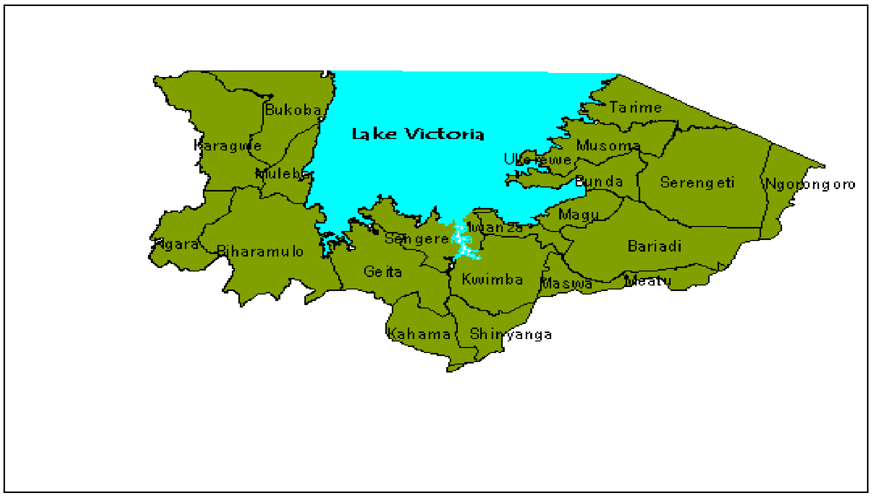


Fig. 1: Lake Victoria Tanzanin side.

However, because of urban areas population increase and rapid growth of industries on the shoreline, poor agricultural system, deforestations and bushfires, the lake is experiencing environmental stress which in turn threats the future beneficial uses of the lake.

Sources of sediments

(i) Autochthonous (the produced particulate matter in water column)

The production of macrophytes (aquatic plants) and phytoplankton (free-floating algae) leads to organic debris that eventually sinks to lake bottom

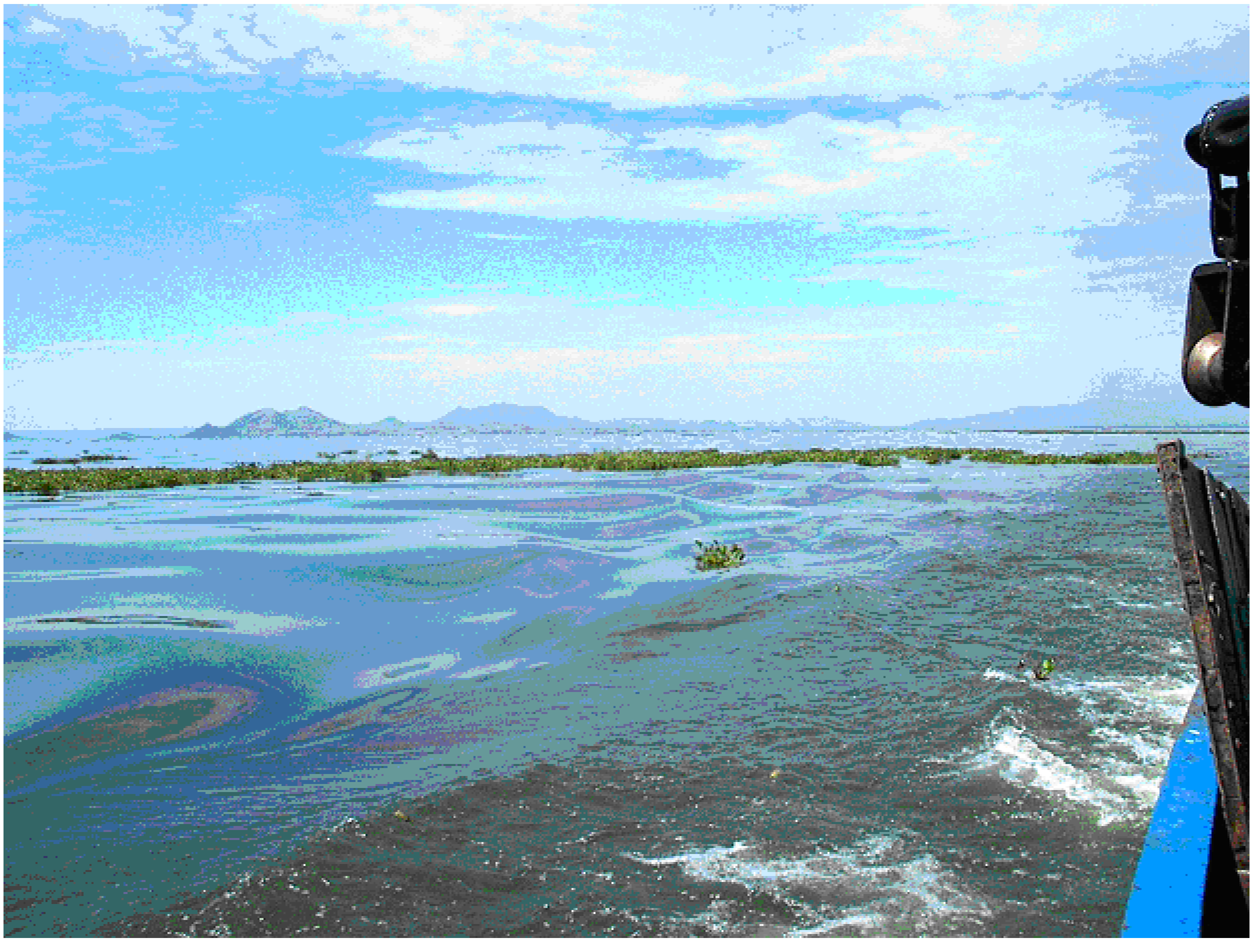


Fig. 2: A mat of algal bloom and water hyacinth.

(ii) Allochthonous (Input of sediments through rivers and surface run off discharges)

Soil erosion in Lake Victoria Catchment has been amplified by human activities including poor land use in agricultural areas, overgrazing of large heard of domestic animals (particularly cattle, goats and sheep) and bush fires. Present agricultural practice accelerates soil erosion that adds to the sediment load into lake Victoria (Fig.3a - b)

Fig. 3a: Widened valley due to accelerated soil erosion that adds to the sediment load into lake Victoria (Nyamatoke Village – Bunda).

Fig. 3b: Chipped soil due to erosion at valley mouth that adds to the sediment load into lake Victoria (Nyamatoke Village – Bunda).

Sediments are responsible and connected to Eutrophication.

When sediments are in suspension alter the native aquatic habitat by blocking light penetration, affecting water chemistry and changing the substrate where it is deposited. When plant material and other organic matter decompose, the process uses up dissolved oxygen required by native flora and fauna for their survivor. Decomposition of organic matter, which always accompanied by sedimentation, eventually goes to the bottom of the lake and causes the lake to undergo natural aging and in the long term fills in the lake basin. Lake Victoria, which is typically shallow and warm, is susceptible to sedimentation effects and aging because data collected so far with reference to human activities that take place around and within the lake favours the enrichment of nutrients hence high rate of sedimentation. Lake sedimentation study is important for the reason that it is an essential link in the chain of eutrophication processes and the nutrient mass balance.

Quantitative assessment of sedimentation is always difficult because sediment concentrations and settling rates are extremely variable, depending on the detailed history of rain, wind, and waves at each site. One popular approach is to put out settling tubes (traps), vertically oriented cylinders from which trapped material is periodically collected and analysed.

Following the alarming changes, Water Quality and Ecosystem Management Component of the LVEMP began the Sedimentation studies section, to obtain comprehensive information on fluxes of particulate and dissolved nutrients between the water phase and the sediment. At Tanzanian side, the lake is fed by three major rivers namely Kagera in western part, Mara in eastern part and Simiyu in southeast part. All these rivers contribute sediments and nutrients to stimulate biological production by aquatic plants especially the microscope algae and cyanobacteria.

METHODOLOGY.

(i) Sampling stations design

The selected sampling stations were divided into two zones namely; littoral (TL) and pelagic (TP) waters whereby arbitrarily transects were established (Fig.4) and samples were collected at designated stations named TLs, and TPs for Tanzania littoral and pelagic waters respectively. During the fieldwork, sampling locations were geo-referenced for ease of identification for subsequent lake data collection. In Tanzanian part there are twenty-eight stations of which eleven (11) are at shallow waters (littoral stations) and seventeen (17) at open waters (pelagic stations).

The exercise on data collection for sedimentation studies was done between November 2000 to March 2005 whereby one hundred ninety (190) samples were collected from littoral stations and three hundred and two (302) from pelagic waters respectively.

Initially the plan was to collect sediment samples from all 28 stations on quarterly basis, but because of a number of reasons, we could not make it, instead we were able to collect four hundred ninety two (492) samples which was much less than what would be achieved.

Further more, according to quick and simple formula for estimation of minimum number of samples to be collected for sedimentation studies for most lakes (Kelderman, 1995) shows the same concern.

$$N = 2.5 + \sqrt{AF/2} \quad \text{……………………} \quad 1$$

Where, N = number of estimated samples.

A = area of the lake (km^2)

F = shore development (shore length: normalized area)

Therefore, according to the above formula, for the period of LVEMP phase one ………. samples were expected to have been collected and analysed.

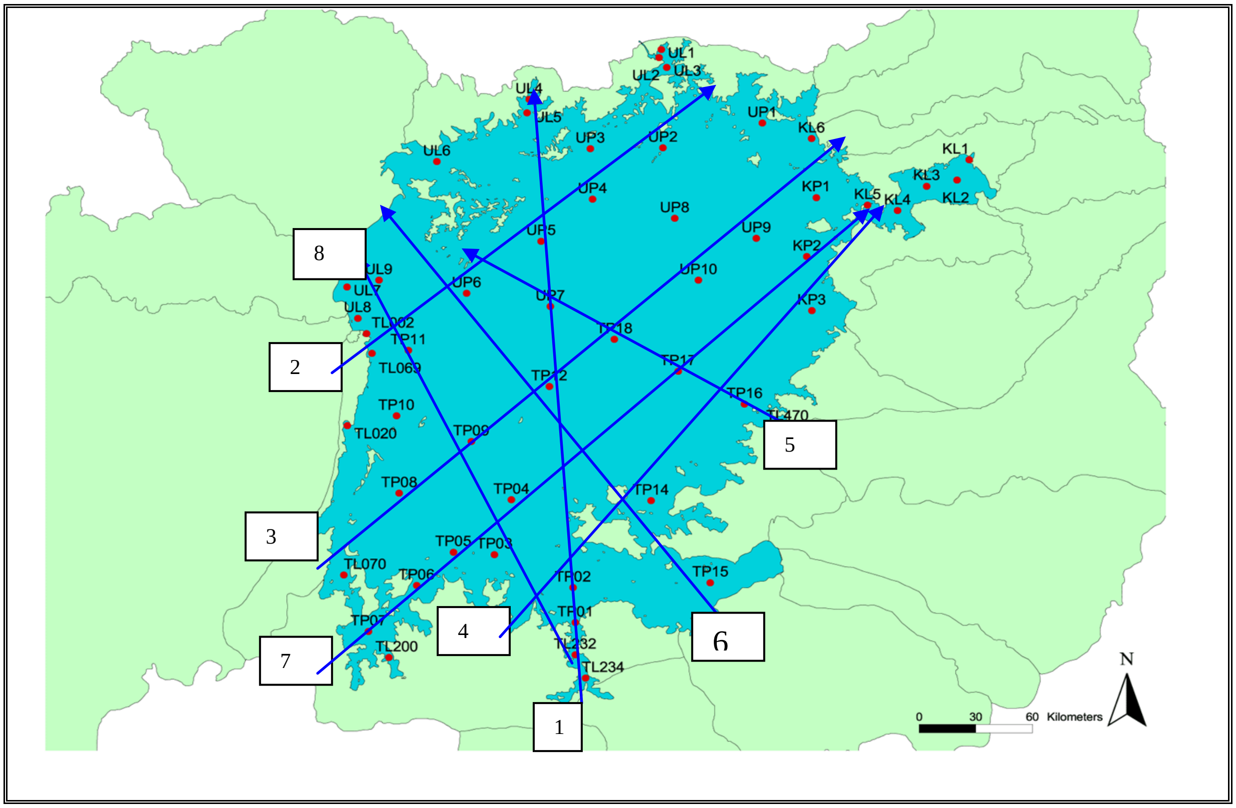


Fig. 4: Selected transect for coordinated water quality monitoring stations in Lake Victoria (1,2, 3, 4, 5, 6, 7, 8………).

(ii) Sampling procedure

Three sets of sediment traps with diameters of 4.5 cm to 8.4 cm and an aspect ratio >5, were vertically configured at three depths with open tops exposed to settling particles of which the first set fixed closer to the end of pre-determined photic zone ((2.3 x Secchi depth) the second set at two meters (2m) from the bottom while the third one fixed at the mid between the first and second sets. Traps were attached to fixed vertical line (rope), anchored at the bottom with weight and subsurface buoy at the upper part of water column to keep line vertically and attached at the top to buoys (Fg.5). After 1 - 2 days of exposure the traps were retrieved (Fig.6) and the volume of water in the traps was measured using a measuring cylinder and reserved in plastic sampling bottles ready for transportation to the laboratory for analysis. The trapped particles were sub sampled and collected on GF-C glass fibre filters (pore size 1 um) to be analysed for parameters of interest, such as TSS, LOI, TPP, PBSi and TPC.

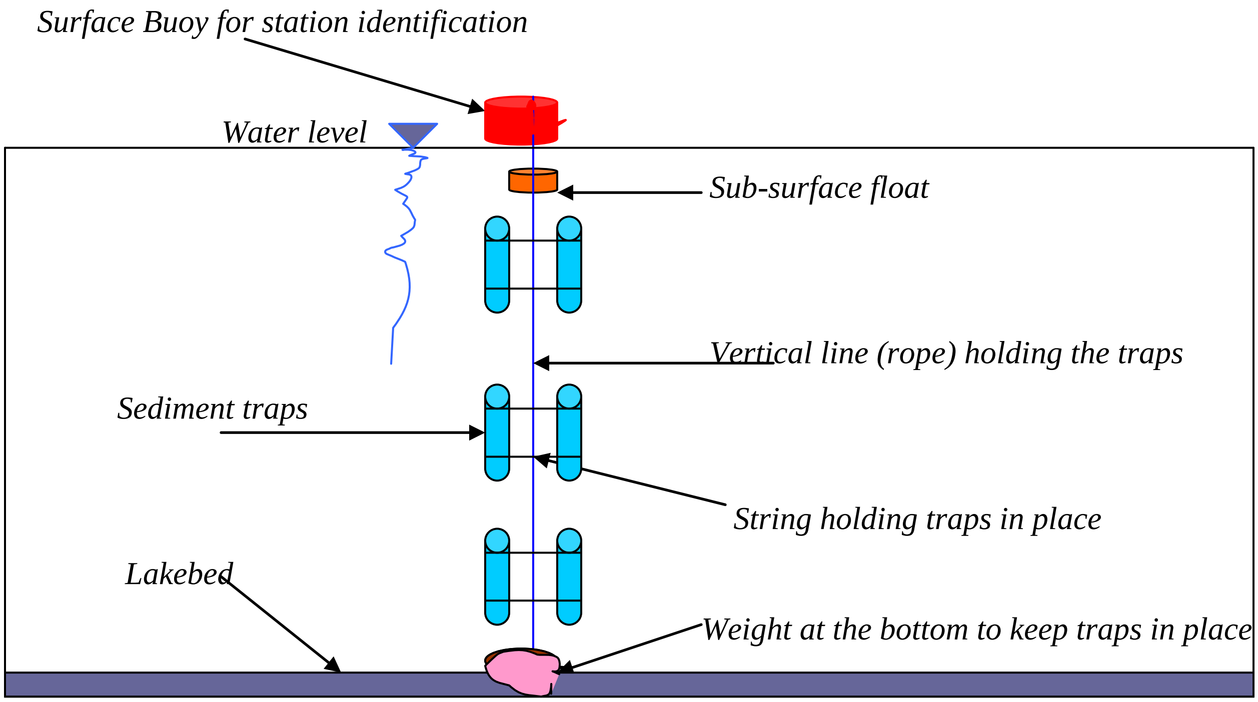


Fig.5: Sketch of sediment traps configuration.

Initially, duplicate traps were exposed at depths 0.2, 0.4, 0.6 and 0.8 m above the bottom, as the results resuspension from the bottom were trapped. After correction the results indicate that re-suspension is not interfering if traps are exposed from 2m above the bottom

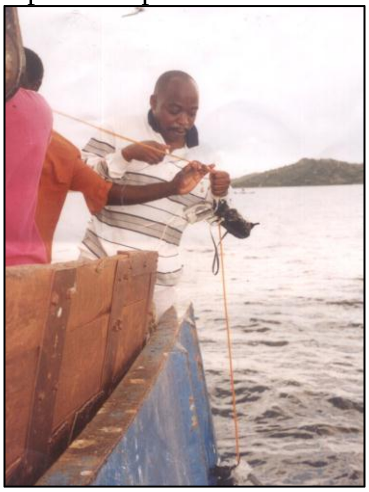


Fig.6: Recovering sediment traps.

ANALYSIS RESULTS AND DISCUSSION.

Sediments being inorganic or organic are deriving from erosion in the catchments, by chemical precipitation or they are produced by primary production and further metabolised through the food chains in the catchments and in the lake. Studies show that sediments play an important role in elemental cycling in the aquatic environment and are responsible for transporting a significant proportion of many nutrients and contaminants (Bartram and Ballance, 1996).

Particles with a density higher than lake water sink to the sediment floor and can be captured by sediment traps. During sinking the particles are mineralised and the primary settling flux decreases with the trap exposure depth. By reducing the exposure time to 1 - 2 days the mineralisation in the traps becomes negligible compared to the mineralisation during the sinking. Close to the sediment floor the traps will also catch resuspended particles from the sediment dependent on the shear stress from waves and currents and the cohesive forces between the sediment particles.

In the sediment, mineralisation continues and dissolved nutrients are released to the pore water and by control of sorption equilibriums and molecular diffusion along concentration gradients the dissolved nutrients can move upwards or downwards participating in further microbial processes like bacterial uptake, remineralisation, nitrification and denitrification. The relative importance of sedimentary processes compared to processes in the water phase increases with hydraulic residence time and decreases with water depth. Lake Victoria has a long residence time ~ 100 years and has a relatively low average depth ~ 40 m. Consequently, sedimentary processes become very important in Lake Victoria justifying the comprehensive sediment sub model as an important part of the Lake Victoria Model. Pore water concentrations, labile and stable particulate nutrient fractions and diffusive fluxes are state variables and processes constituting important parts of the sediment model.

In lakes like Victoria with very long flushing times, sediment burial dominates the loss term of those elements except for those elements that have a gaseous phase. For example gaseous nitrogen can enter the lake from biological nitrogen fixation of atmospheric nitrogen, but it can also be lost from the lake by denitrification processes. Likewise, carbon (C), which is fixed into particulate form by photosynthesis of carbon dioxide, can be returned to gaseous carbon dioxide by respiration and decomposition of particulate organic matter. On the contrary, elements like phosphorus (P) and silicon (Si) can only be lost by sedimentation to permanent burial or at the outflow. Because of the long flushing time, losses at the outflow are minimal, and sediment burial dominates loss of P and Si from Lake Victoria

Short term exposures of sediment traps at depths where resuspension is expected to be negligible and short term experimental determination of sediment-water fluxes at aerobic and anaerobic conditions are combinations of field and laboratory efforts to monitor the essentials of the sediment water interactions. Since September 2000 to March 2005, a total of four hundred ninety two (492) samples for sedimentation studies were collected and analysed.

Sediments interact with lake water and soluble constituents in such a manner that they give many unique insights into limnological processes. As a consequence they provide important basic information on the geochemical origin, dispersion throughout the lake, and limnological fate of soluble and particulate constituents (Chapman, 1998).

Sediment concentrations and settling rates are variable; this indicates that Lake Victoria is not homogeneous. In data interpretation, the sedimentation rate, SR, defined as a mass of dry material deposited per unit area per unit time, is expressed in $mgm^{-2}day^{-1}$. Thus average settling rate during the exposure time T becomes:

SR = (M x C)/AT……………………………………………………………………………..2

Where, M = the dry mass of the whole sample

C = the concentration of the chemical of interest, and

A = the trap collecting area.

Mean values of Flux Rates, TPC /TPP and TBSi/TPP sedimentation rate ratios.

The tables below show that mean sedimentation rate at littoral stations for total particulate phosphorous (TPP) was about twice as compared to pelagic stations. The same situation was observed for total particulate carbon (TPC), however, total particulate silica did not show a clear pattern of variability between littoral and pelagic stations though there was a general tendency of decreasing towards the pelagic stations. Mean value for TPC /TPP sedimentation rate ratio was 117.61 for littoral and 90.74 for pelagic stations respectively compared to TBSi/TPP which was 3.15 for littoral and 2.10 for pelagic stations. The study suggests that organic material is high at the shoreline compared to offshore areas. These values are comparable with what was found by Machiwa *et al* in 2003 at Magu Bay in Speke Gulf, the author found that the C/N ratio values were decreasing with distance away from the shoreline. These results indicate contribution of organic material to the lake by plants and possibly due to anthropogenic and other natural inputs into the lake from the catchments.

Flux Rates

	TPP $mg/m^2/d$	TBSi $mg/m^2/d$	TPC $mg/m^2/d$
Littoral Stations	5.78	7.65	422.333

	TPP $mg/m^2/d$	TBSi $mg/m^2/d$	TPC $mg/m^2/d$
Pelagic Stations	3.48	6.72	210

TPC /TPP and TBSi/TPP sedimentation rate ratios

Littoral Stations	TBSi/TPP ratio	Pelagic Stations	TBSi/TPP ratio
Ratio	0.16 – 22.86	Ratio	0.20 – 8.75
Mean ratio	3.15	Mean ratio	2.10

Littoral Stations	TPC/TPP ratio	Pelagic Stations	TPC/TPP ratio
Ratio	71.88 – 207.73	Ratio	1.00 – 190.74
Mean ratio	117.61	Mean ratio	90.74

Mean value of C/N ratios, total accumulation rate (TO-AR in g/m^2/yr), accumulation rates for organic carbon (OC-AR in gC/m^2/yr) and nitrogen (N-AR in gN/m^2/yr) for various short cores collected from the Magu Bay.

CORE	C/N	Mass-AR (g/m^2/yr)	OC-AR (gC/m^2/yr)	N-AR (gN/m^2/yr)
LV 4	13.41	33.40	8.82	0.77
LV 5	14.67	59.98	28.36	2.27
LV 11	11.98	22.17	12.00	1.15
LV 15	15.89	23.35	11.65	0.83
LV 22	14.40	240.66	57.25	4.37
LV 24	15.98	20.50	6.92	0.51
LV 30	15.86	92.59	27.39	2.02
LV 31	16.10	134.49	25.53	1.90
LV 36	18.94	62.88	21.93	1.36

Data source: Machiwa at el, 2003 (*Sedimentation Studies at the Simiyu River Mouth - Magu Bay, Speke Gulf, Lake Victoria, Tanzania).*

Littoral Stations

StNo	Date	Depth (m)	TPPsed mg/m2/d	TPPw mg/m3	PBSised mg/m2/d
TL 002	17-Oct-03	1.0	9.17	49.640	6.84
TL 002	17-Oct-03	4.0	8.66	43.408	8.68
TL 002	17-Oct-03	7.0	8.07	28.823	8.55
TL 002	28-Jun-03	2.3	15.13	42.952	12.43
TL 002	28-Jun-03	5.45	9.76	40.769	3.01
TL 230	11-Oct-03	5.0	1.25	49.462	28.58
TL 230	11-Oct-03	7.0	0.42	40.444	4.98
TL 231	23-Jun-03	3.5	2.89	28.844	4.72
TL 231	23-Jun-03	5.4	3.91	60.558	5.04
TL 231	23-Jun-03	7.4	3.59	57.675	6.26
TL 231	24-Mar-03	4.3	1.75	65.471	2.01
TL 231	24-Mar-03	6.0	7.53	49.473	2.10
TL 231	24-Mar-03	2,5	0.45	48.407	0.78
TL 231	30-Jun-02	4.2	10.37	70.508	6.80
TL 232	23-Jun-03	2.8	3.63	74.110	2.25
TL 232	23-Jun-03	3.9	4.79	64.611	2.11
TL 232	23-Jun-03	5.0	6.62	68.773	1.45
TL 232	30-Jun-02	3.0	18.33	57.038	17.27
TL 233	11-Oct-03	1.4	1.24	52.917	3.46
TL 233	11-Oct-03	2.6	1.37	30.167	4.69
TL 233	11-Oct-03	3.7	1.49	29.750	5.90
TL 233	23-Jun-03	3.4	13.47	51.909	8.43
TL 234	11-Oct-03	1.4	1.48	28.769	18.01
TL 234	11-Oct-03	2.5	2.61	28.583	21.47
TL 234	11-Oct-03	3.5	2.51	27.917	12.70
TL 234	23-Jun-03	1.8	11.35	54.783	1.77
TL 234	23-Jun-03	3.6	8.88	51.900	12.81
TL 234	23-Jun-03	4.3	1.22	48.755	1.09
		Mean	**5.78**	**48.09**	**7.65**
		STD	**4.89**	**14.06**	**6.86**
		Max.	**18.33**	**74.11**	**28.58**
		Min	**0.42**	**27.92**	**0.78**

1.1 Pelagic Stations

StNo	Date	Depth (m)	TPPsed mg/m2/d	TPPw mg/m3	PBSised mg/m2/d
TP 01	12-Oct-03	4.1	6.04	23.667	6.91

TP 01	12-Oct-03	9.5	8.27	34.154	13.81
TP 01	12-Oct-03	14.8	0.52	42.560	3.88
TP 01	24-Jun-03	10.8	8.90	23.072	20.44
TP 01	24-Jun-03	10.8	3.46	19.384	5.58
TP 01	24-Jun-03	16.1	3.83	19.781	2.50
TP 01	24-Mar-03	4.6	2.33	105.326	2.00
TP 01	24-Mar-03	13.1	4.59	59.971	0.92
TP 01	24-Mar-03	21.5	0.72	49.875	0.19
TP 02	12-Oct-03	6.9	6.20	42.800	16.82
TP 02	12-Oct-03	24.0	5.46	20.715	10.25
TP 02	12-Oct-03	41.0	5.41	58.238	19.61
TP 02	24-Jun-03	24.35	2.96	10.926	3.91
TP 02	25-Jun-03	41.8	0.09	20.760	0.15
TP 06	13-Oct-03	25.0	4.33	47.024	6.26
TP 07	25-Jun-03	3.5	5.10		4.20
TP 07	26-Jun-03	10.0	1.07		0.58
TP 07	27-Jun-03	6.75	4.70		4.26
TP 09	21-Oct-03	11.0	4.66	46.700	7.86
TP 09	21-Oct-03	34.0	3.43	45.104	11.43
TP 09	22-Oct-03	56.8	4.71	60.300	23.32
TP 09	27-Mar-03	7.0	0.75	17.214	1.73
TP 09	27-Mar-03	31.9	1.85	19.917	2.32
TP 09	27-Mar-03	56.8	0.55	6.000	0.40
TP 12	02-Jun-02	10.0	4.60	11.408	15.90
TP 12	02-Jun-02	67.0	3.03	285.592	16.68
TP 12	26-Mar-03	36.5	0.88	8.009	0.86
TP 12	26-Mar-03	66.0	0.19	10.768	0.39
TP 15	06-Jul-03	6.2	2.74		0.81
TP 15	06-Jul-03	13.1	2.95		1.74
TP 15	06-Jul-03	20.0	2.59		1.09
TP 15	24-Oct-03	3.5	8.56		17.46
TP 15	24-Oct-03	12.0	5.28		12.54
TP 15	24-Oct-03	20.0	4.30		4.44
TP 18	24-Oct-03	10.4	0.07	46.575	0.60
TP 18	24-Oct-03	38.4	0.05	57.248	0.15
		Mean	**3.48**	**44.19**	**6.72**
		STD	**2.45**	**53.21**	**7.00**
		Max.	**8.90**	**285.59**	**23.32**
		Min	**0.05**	**6.00**	**0.15**

Littoral stations

	StNo	Date	Depth (m)	PBSiw mg/m3	PBSised mg/m2/d
	TL 002	17-Oct-03	1.0	21.600	6.84
	TL 002	17-Oct-03	4.0	37.300	8.68
	TL 002	17-Oct-03	7.0	33.500	8.55
	TL 002	28-Jun-03	5.45	113.200	3.01
	TL 230	11-Oct-03	5.0	95.700	28.58
	TL 230	11-Oct-03	7.0	45.000	4.98
	TL 231	23-Jun-03	5.4	36.700	5.04
	TL 231	04-Mar-03	4.3	11.100	2.01
	TL 231	04-Mar-03	6.0	15.400	2.10
	TL 231	04-Mar-03	2,5	14.000	0.78
	TL 231	30-Jun-02	4.2	100.900	6.80
	TL 233	11-Oct-03	1.4	23.200	3.46
	TL 233	11-Oct-03	2.6	63.600	4.69
	TL 233	11-Oct-03	3.7	64.400	5.90
	TL 234	11-Oct-03	1.4	105.200	18.01
	TL 234	11-Oct-03	2.5	83.200	21.47
	TL 234	11-Oct-03	3.5	102.500	12.70
	TL 234	23-Jun-03	1.8	93.700	1.77
	TL 234	23-Jun-03	3.6	85.300	12.81
	TL 234	23-Jun-03	4.3	178.800	1.09

1.2 Pelagic Stations

	StNo	Date	Depth (m)	PBSiw mg/m3	PBSised mg/m2/d
	TP 01	12-Oct-03	4.1	15.700	6.91
	TP 01	12-Oct-03	9.5	18.300	13.81
	TP 01	12-Oct-03	14.8	41.100	3.88
	TP 01	24-Jun-03	10.8	70.000	5.58
	TP 01	24-Jun-03	16.1	34.100	2.50
	TP 01	04-Mar-03	4.6	6.300	2.00
	TP 01	04-Mar-03	13.1	3.700	0.92
	TP 01	04-Mar-03	21.5	3.400	0.19

	TP 02	12-Oct-03	6.9	22.900	16.82
	TP 02	12-Oct-03	24.0	22.900	10.25
	TP 02	12-Oct-03	41.0	35.600	19.61
	TP 02	24-Jun-03	24.35	43.900	3.91
	TP 02	24-Jun-03	41.8	41.200	0.15
	TP 06	13-Oct-03	25.0	99.100	6.26
	TP 07	26-Jun-03	3.5	22.900	4.20
	TP 07	26-Jun-03	10.0	31.700	0.58
	TP 07	26-Jun-03	6.75	23.600	4.26
	TP 09	21-Oct-03	34.0	30.500	11.43
	TP 09	21-Oct-03	56.8	36.000	23.32
	TP 09	07-Mar-03	7.0	5.100	1.73
	TP 09	07-Mar-03	31.9	8.000	2.32
	TP 09	07-Mar-03	56.8	6.100	0.40
	TP 12	06-Mar-03	36.5	6.800	0.86
	TP 12	06-Mar-03	66.0	4.100	0.39
	TP 15	06-Jul-03	6.2	22.400	0.81
	TP 15	06-Jul-03	13.1	24.500	1.74
	TP 15	06-Jul-03	20.0	28.400	1.09
	TP 15	24-Oct-03	3.5	34.800	17.46
	TP 15	24-Oct-03	12.0	70.700	12.54
	TP 15	24-Oct-03	20.0	47.900	4.44
	TP 18	21-Oct-03	10.4	47.900	0.60
	TP 18	01-Oct-03	38.4	76.500	0.15

Pelagic Stations

	StNo	*Date*	*Depth (m)*	*TPPw mg/m3*	*TPPsed mg/m2/d*
	TP 01	12-Oct-03	4.1	23.667	6.04
	TP 01	12-Oct-03	9.5	34.154	8.27
	TP 01	12-Oct-03	14.8	42.560	0.52
	TP 01	06-Feb-05	10.8	23.072	8.90
	TP 01	24-Jun-03	10.8	19.384	3.46
	TP 01	24-Jun-03	16.1	19.781	3.83
	TP 01	04-Mar-03	4.6	105.326	2.33
	TP 01	04-Mar-03	13.1	59.971	4.59
	TP 01	04-Mar-03	21.5	49.875	0.72
	TP 02	12-Oct-03	6.9	42.800	6.20
	TP 02	12-Oct-03	24.0	20.715	5.46
	TP 02	12-Oct-03	41.0	58.238	5.41
	TP 02	24-Oct-03	24.35	10.926	2.96
	TP 02	24-Oct-03	41.8	20.760	0.09

	TP 06	13-Oct-03	25.0	47.024	4.33
	TP 09	21-Oct-03	11.0	46.700	4.66
	TP 09	21-Oct-03	34.0	45.104	3.43
	TP 09	21-Oct-03	56.8	60.300	4.71
	TP 09	07-Mar-03	7.0	17.214	0.75
	TP 09	07-Mar-03	31.9	19.917	1.85
	TP 09	07-Mar-03	56.8	6.000	0.55
	TP 12	06-Feb-05	10.0	11.408	4.60
	TP 12	06-Feb-05	67.0	285.592	3.03
	TP 12	06-Mar-03	36.5	8.009	0.88
	TP 12	06-Mar-03	66.0	10.768	0.19
	TP 18	21-Oct-03	10.4	46.575	0.07
	TP 18	21-Oct-03	38.4	57.248	0.05

Littoral Stations

	StNo	***Date***	***Depth (m)***	***TPCw (mg/m3)***	***TPCsed mg/m2/d***
	TL 231	23-Jun-03	3.45	4600.000	305.43
	TL 231	23-Jun-03	5.4	3360.000	368.85
	TL 231	23-Jun-03	7.4	4320.000	257.74
	TL 231	04-Mar-03	4.3	2000.000	363.04
	TL 231	04-Mar-03	6	6000.000	816.60
			Mean	4056.000	422.333
			STD	1487.978	225.046
			Max	6000.000	816.603
			Min.	2000.000	257.737

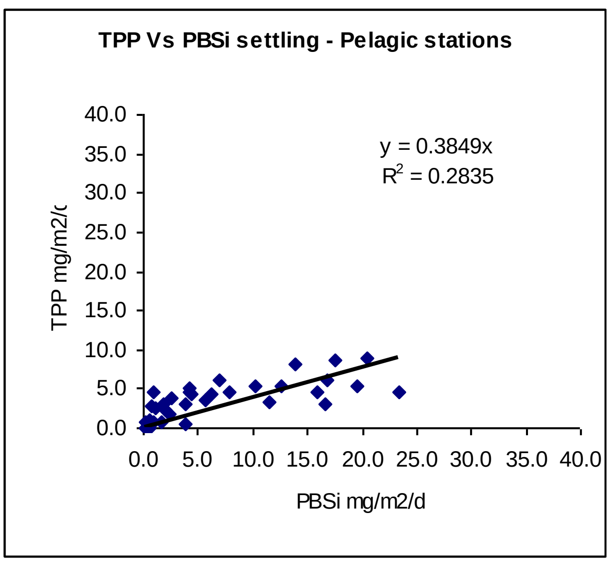
Pelagic Stations

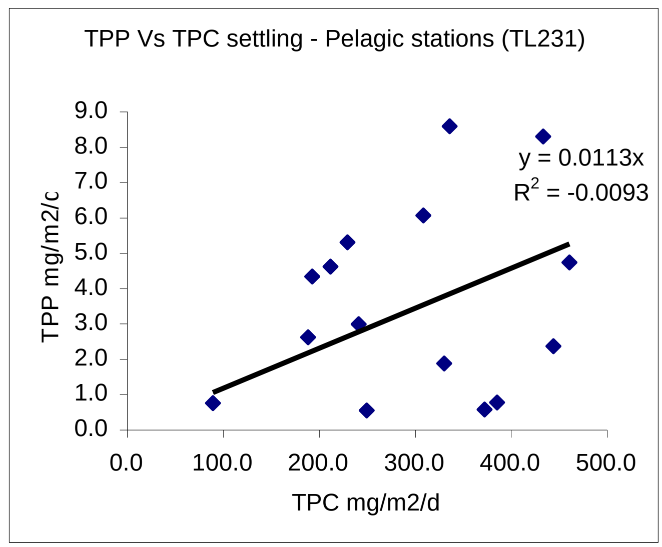
	StNo	***Date***	***Depth***	***TPCw (mg/m3)***	***TPCsed mg/m2/d***
	TP 01	12-Oct-03	4.1	1760.0	309.6
	TP 01	12-Oct-03	9.5	1440.0	434.5
	TP 01	12-Oct-03	14.8	4252.0	250.8
	TP 01	24-Mar-03	4.6	1400.0	445.3
	TP 01	24-Mar-03	13.1	860.0	212.9
	TP 01	24-Mar-03	21.5	1600.0	90.5
	TP 02	24-Jul-03	24.35	2720.0	242.3
	TP 07	24-Jul-03	6.75	2560.0	461.9
	TP 09	27-Mar-03	7	1140.0	386.5
	TP 09	27-Mar-03	31.9	1140.0	331.3
	TP 15	06-Jul-03	20.0	4960.0	189.7

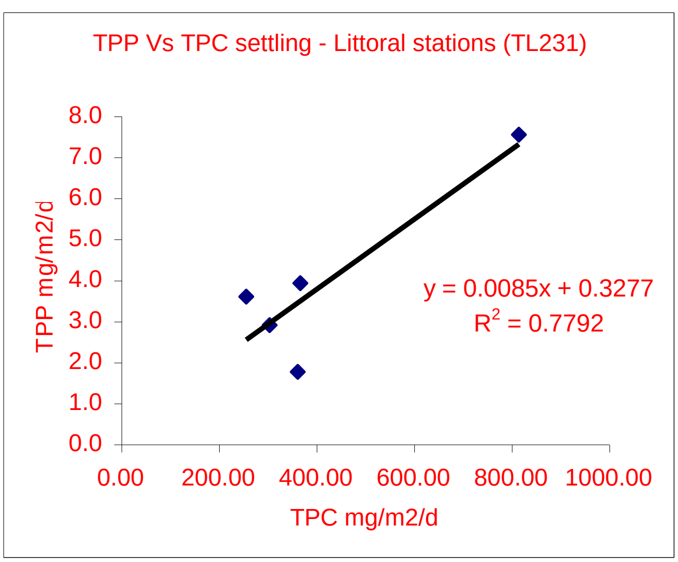
	TP 15	24-Jul-03	3.5	1680.0	337.1
	TP 15	24-Jul-03	12.0	2600.0	230.6
	TP 15	24-Jul-03	20.0	3656.0	194.1
			Mean	**2269.143**	**294.080**
			STD	**1256.543**	**68.667**
			Max	**4960.000**	**337.146**
			Min.	**860.000**	**189.736**

Composition of Sediments (nutrients).

To determine the settling rates, regressions curves were performed and the results show that silica has high sedimentation rate compared to phosphorous. In contrary, phosphorous and carbon were of the same magnitude especially in littoral stations, while phosphorous dominated in open waters Fig.7 (a. – d).



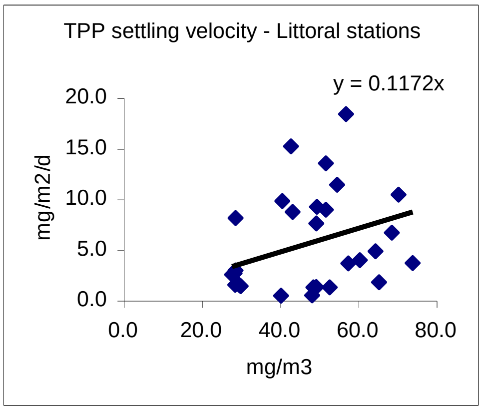


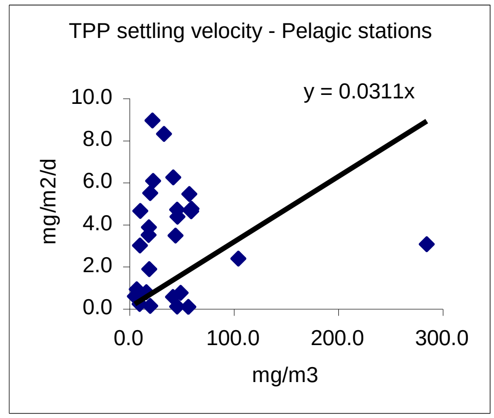


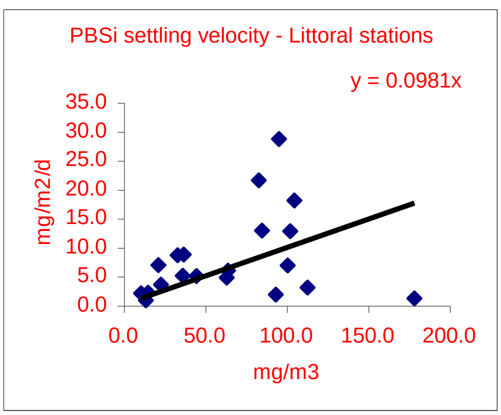
Sedimentation velocity

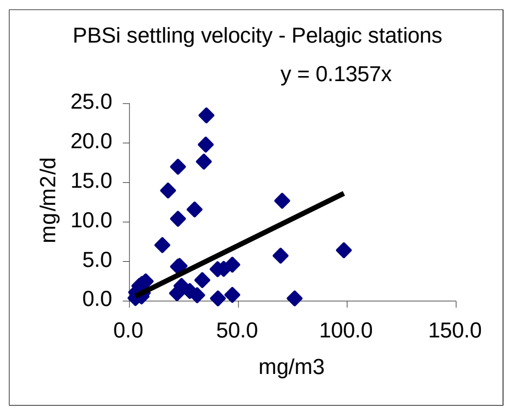
To obtain sedimentation velocity (m/d), regressions between sedimentation rates (mg/m2/d) and the parameters concentration (mg/m3) at the exposure depth were performed.

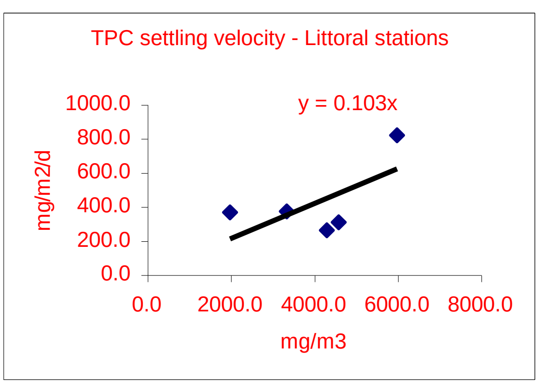
The obtained sedimentation velocity values for TPP at littoral and pelagic stations were 0.117 and 0.031 (m/d) respectively, while those for TPC were 0.103 and 0.086. The results show that sedimentation velocity in littoral statons (bays and gulfs) is much higher than in the pelagic area. This could possibly be due to combination of both the input from the catchment and the processes within the lake.
Further more, the study indicate that sedimentation velocity of PBSi was 0.14, which is higher compared to velocities for TPP and TPC.

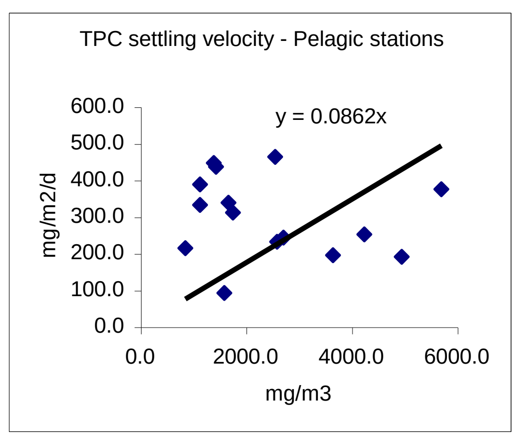












Nutrients distribution (in sediments)

The obtained data show that nutrients (TP and TN) concentration increases with depth, particularly in open waters. However, the study demonstrate that more nutrient levels in sediments are highest at gulfs, river mouths, bays and at some sections of the littoral zone whereby periodical proliferation of water hyacinth, increased oxygen demand and reduced biodiversity can visually be witnessed (Fig. 8a - b)

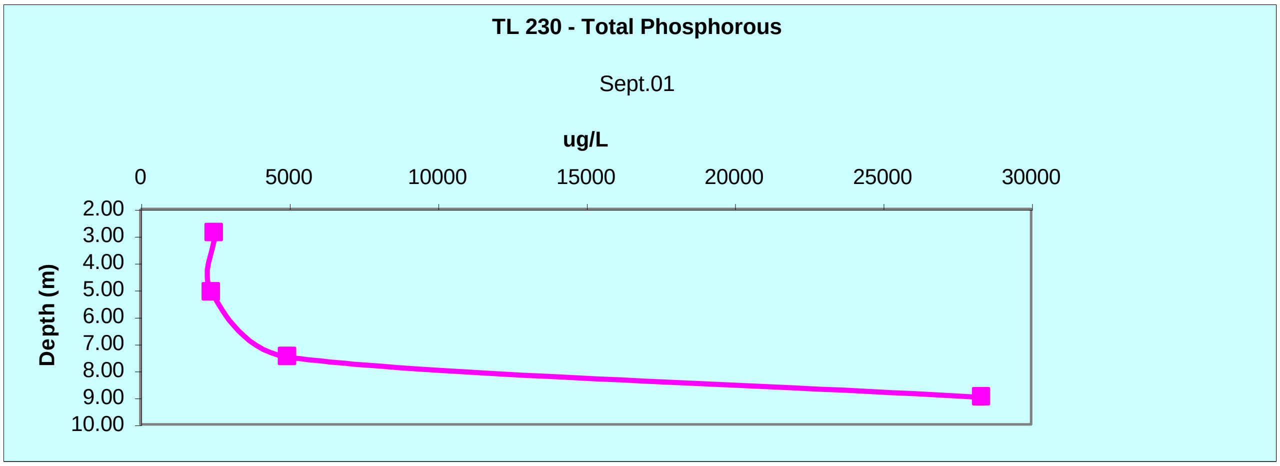


Fig. 8a.

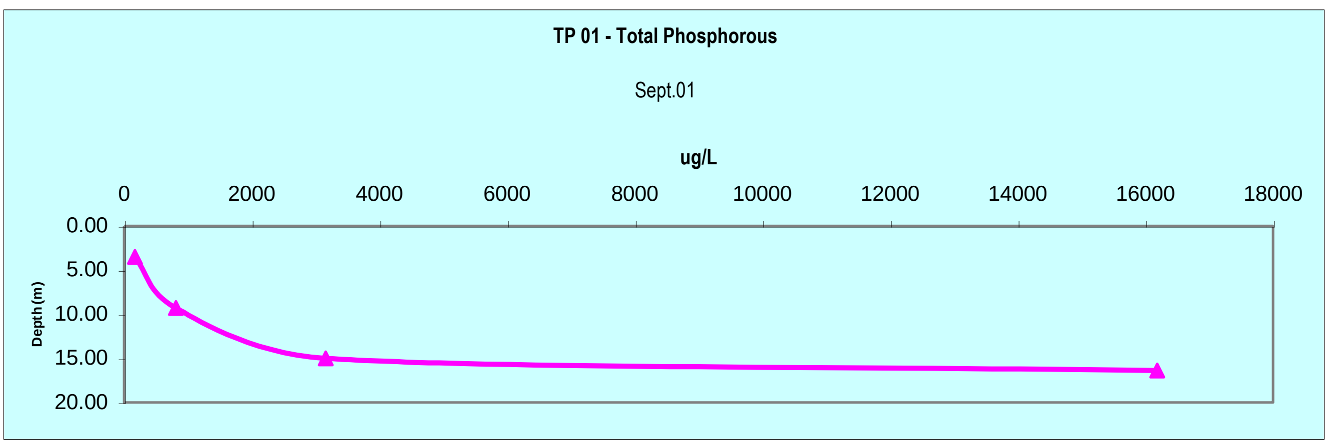


Fig. 8b.

A spatial variation of nutrients along transects.

The study shows that contribution of the sedimentation process to the eutrophication of the lake is more significant in near shore areas than in open waters such as at the gulfs, bays and river mouths due to high sedimentation inputs from the catchments. Poor land use in the catchment, lack of municipal and industrial effluents treatment facilities and poor handling of daily generated solid wastes have triggered transportation of nutrients in the lake via either rivers, surface run off and direct flow of partially or non treated wastes. Furthermore, the study observed that nutrients concentrations were decreasing with distance from inshore to offshore waters (Fg.9a - e).

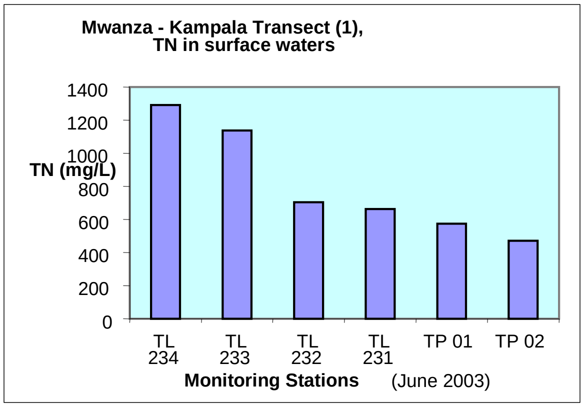


Fig. 9a

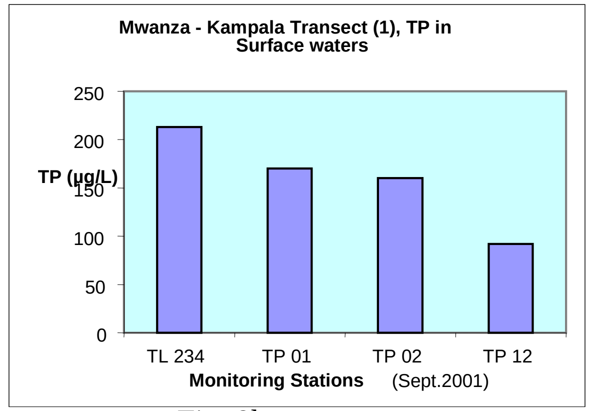


Fig. 9b

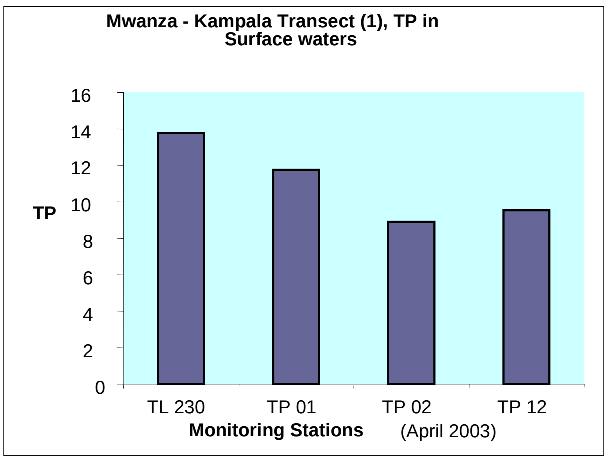


Fig. 9c

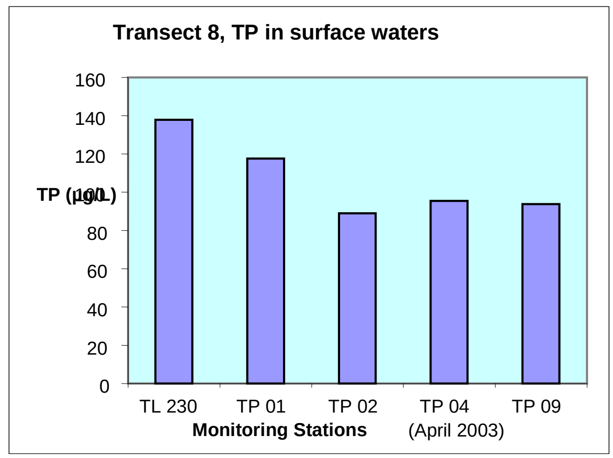


Fig. 9d

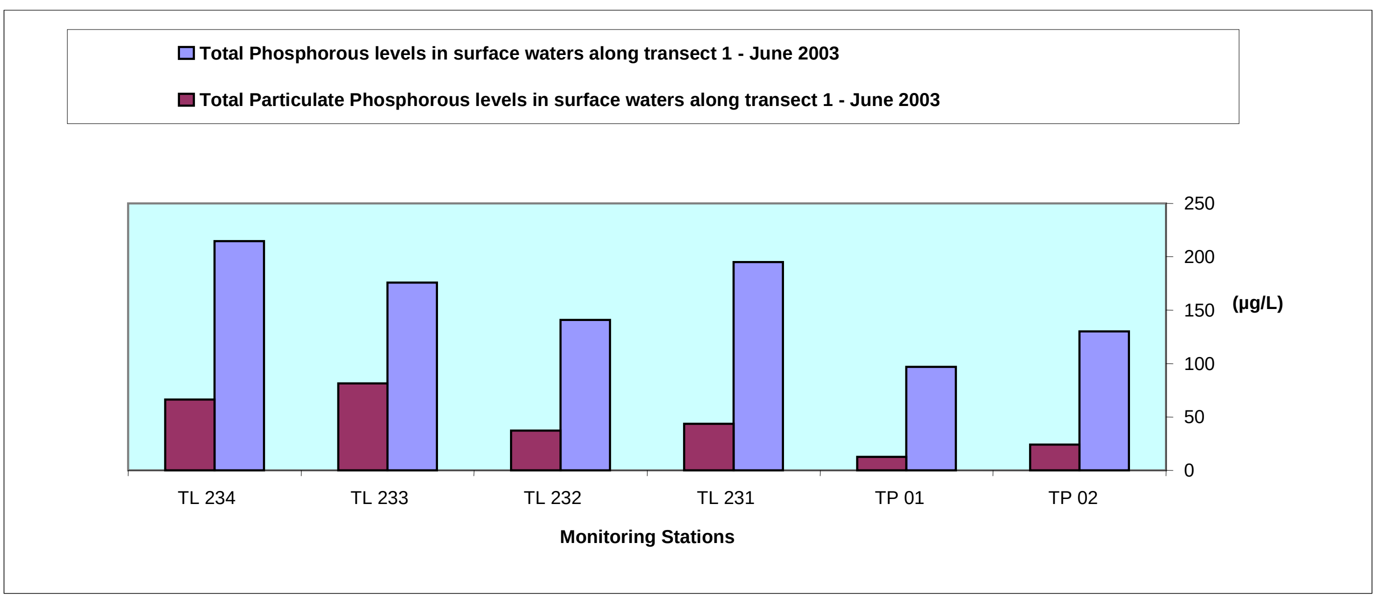


Fig. 9e

Fig. (9a –e): spatial variation of nutrients in sediments

Rivers are among of sediments transport sources to the lake.

River mouths, Gulfs and Bays are the potential areas that receives the highest loads of sediments with rich in nutrients and other pollutants from the catchment including surface runoffs and agricultural areas thereby causing the lake to continue filling up and affecting the quality of water. Many river mouths, gulfs and bays are the important areas for fish breeding and fishing grounds.

According to data collected from Kagera River (measured at Nyakanyasi), results indicate that the suspended sediment loads (annual mean) increased from 400kT/year in 1971 to 600kT/year in 1972 (Chadha, 1972). Currently, it is estimated that the suspended sediment load at the same point is 1400kT/year (Fig 10), which is about 3.5 times that of 1971 (Machiwa at el, 2003).

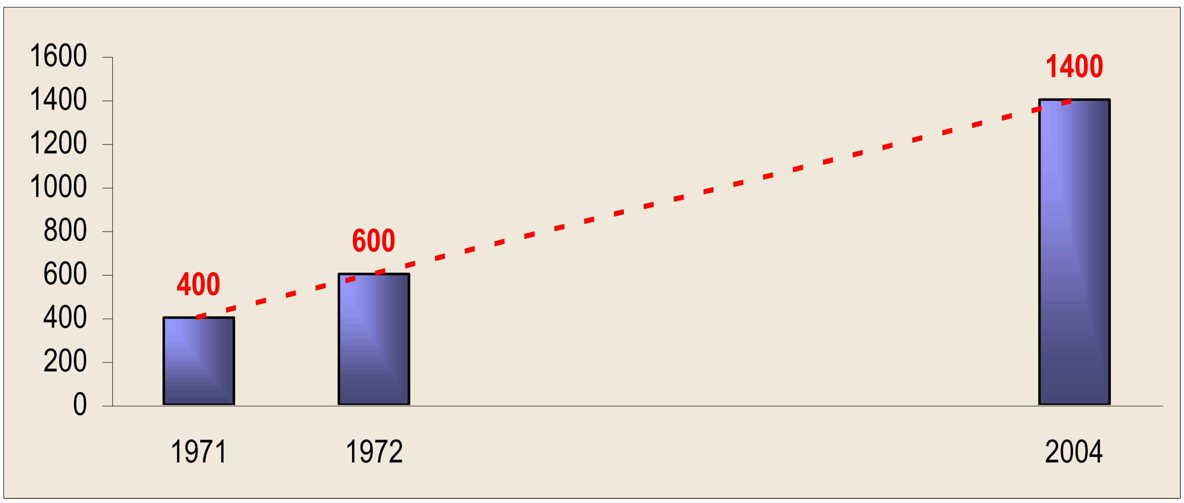


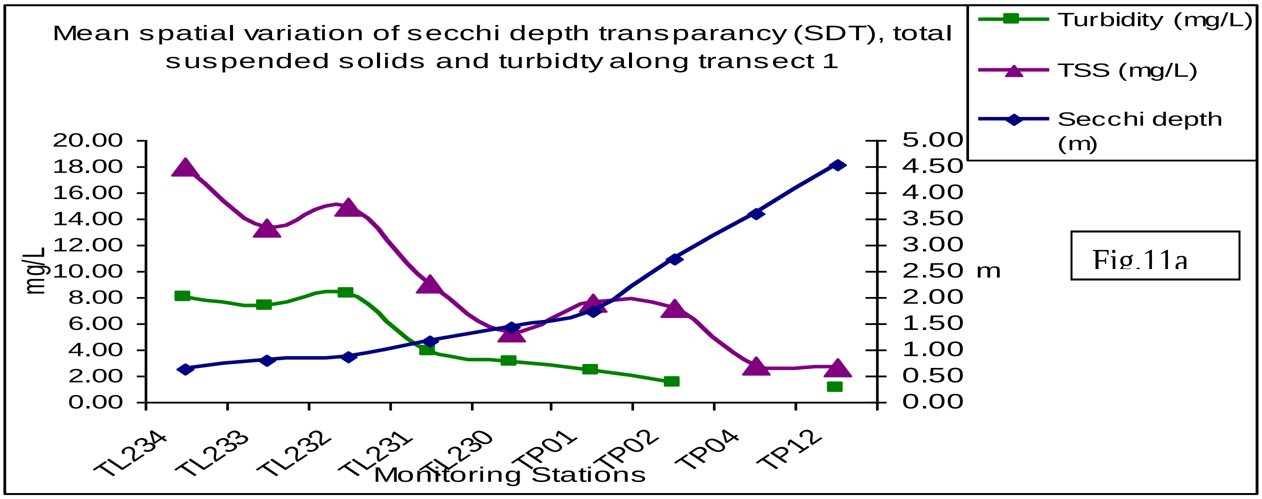
Fig.10: Suspended sediment load trend at Nyakanyasi -Kagera River

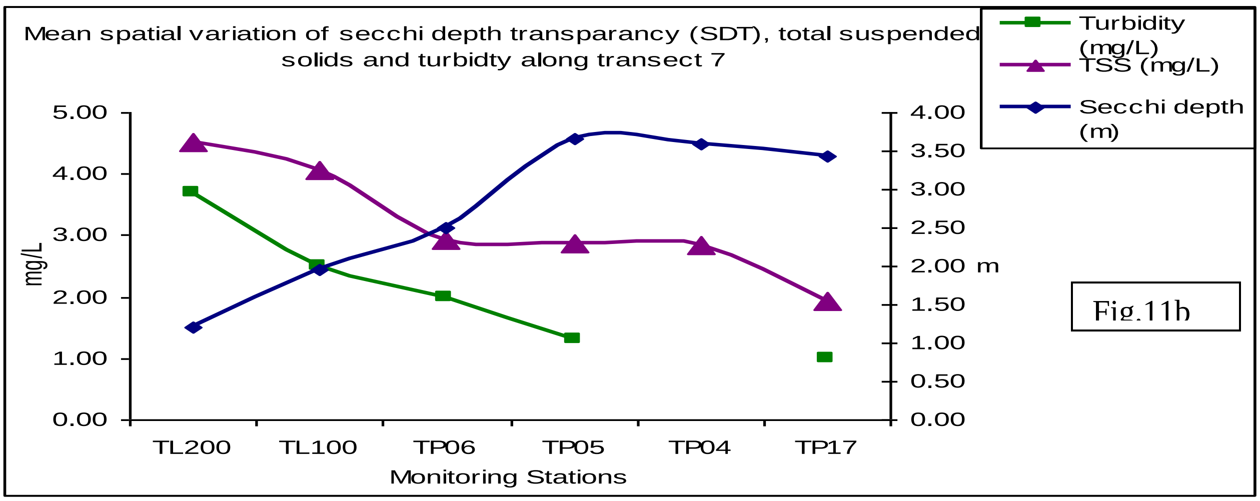
Physical indicators of lake pollution

The natural physical characteristics of the lake has significantly undergone through changes that threats not only aquatics but also the people who mainly depends on the lake for their economy and livelihood as well. The results obtained from this study show that concentration of suspended solids are higher at the littoral stations compared to pelagic stations.

This could have been attributed by human impacts in the lake adjacent areas leading to nutrient inflow in form of sediments.

It is also observed that littoral stations near highly residential areas and urban centres have higher turbidity, suspended solids and discolouration of lake water that accompanied by low water clarity (transparency) than those in areas with low or no settlements (Fig.11a – b). As the results, light penetration is very much limited to few centimetres in shallow areas that are associated with high concentration of suspended particles as the result of luxuriant growth of micro-algae (Machwa at el, 2003).





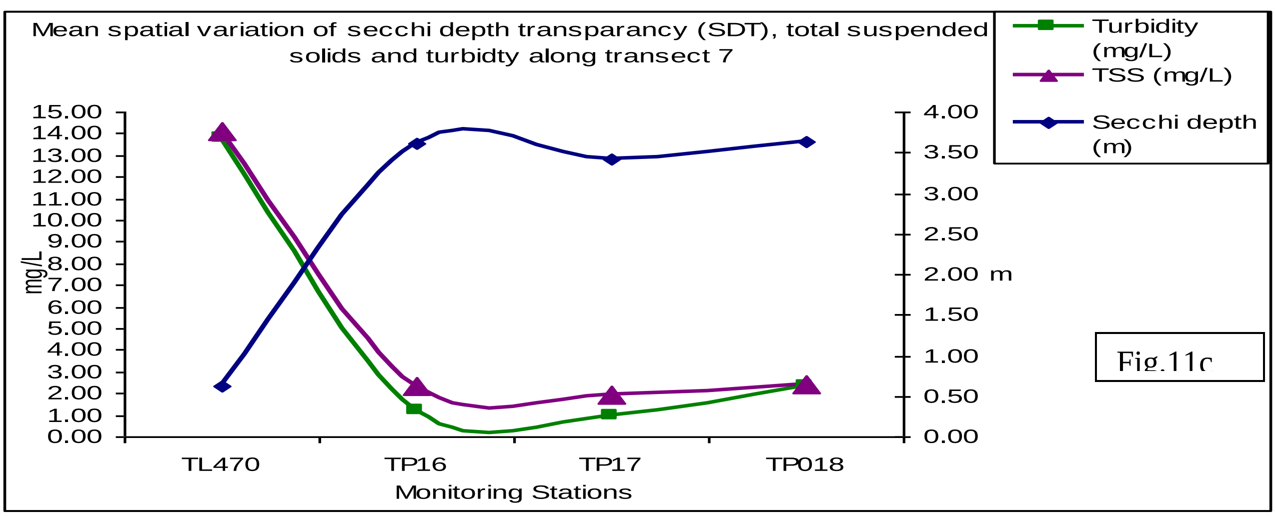


Fig.11: Mean spatial variation of SDT, SS and turbidity.

CONCLUSION

- The results show that sedimentation rates are highest at the littoral stations compared to pelagic stations.
- The stoichiometric composition of the settling material indicates nitrogen limitation and a non-dominance of diatoms. The differences in sinking velocities indicate that the settling material consists dead and living material with a contribution of diatoms.
- It should be noted that sedimentation patterns observed over a relatively short time period (5 years) may not accurately represent patterns over longer time periods. Therefore, the WQM plans to continue the annual monitoring of the Lake sediment range transects to provide estimates of sedimentation rates over longer time periods, as well as provide valuable information on variability in the rates of sedimentation.

RECOMMENDATON

- Tremendous variability of such measurements means vast amounts of data must be collected before average values or trends in them can be meaningfully estimated
- This study calls for short and long terms remedial action plans to rescue the lake from becoming old before its time.
- The results may be used to determine the water quality in the Lake and to set water quality objectives to protect water uses. Also, these results may be used to recommend and evaluate possible remediation activities.
- Reducing the man made sources of nutrients will help reduce the frequency and intensity of algae blooms although will not eliminate them completely.
- Detailed laboratory studies to determine sediment-water fluxes under aerobic and anaerobic conditions is recommended as it will be used to make comparison with field and laboratory results to further refine the rates as are yet to be undertaken as necessary equipment and training were not available during LVEMP's first phase.
- Information from sediment studies may be used for
    - partly reconstruct historical sediment- and water-quality records,
    - determine if sediment and water quality are changing (possibly due to changes in human activity in the basin),
    - provide a warning of potential future water-quality problems,
    - provide a baseline for future assessments to measure the effectiveness of implemented best-management practices in a basin.

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EUTROPHICATION

By: D.K., Rutagemwa, P. Semili, R. Waya, and F. Mwanuzi

ABSTRACT

During the LVEMP 1, the eutrophication study was carried out to establish the effects of nutrient enrichment of the lake (assess its current state); assess the mechanism by which the Lake responds to increased nutrient loadings; and provide the relevant calibration data for the Lake Victoria physical processes and water quality model. This chapter presents the study results for the southern segment of Lake Victoria (Tanzania). The data set obtained for the period September 2000 through March 2005 is much more comprehensive regarding combined spatial and temporal extent than what has been the basis of former "conclusions". Generally, the offshore part of the lake has relatively low chlorophyll-a concentrations and often measurable nutrient concentrations indicating that the primary production offshore may not be limited by nutrients but rather by light as a result of mixing depths. This implies that the ecological turnover offshore may not be significantly affected by inputs of nutrients to the lake. The near shore areas especially the hot spots such as Mwanza and Speke gulfs and Mara and Rubafu bays are highly affected by eutrophication.

Some changes have been observed in the distribution, composition, abundance and biomass of plankton communities, macro-invertebrates and fishes, and the food web structure in response to the negative effects of eutrophication. The phytoplankton was as diverse in inshore as offshore and cynobacteria dominated contributing a large fraction (>50%) of total wet biomass as well as dry biomass of particulate nutrients (C, N and P). The potentially toxic cynobacteria of the genus *Microcystis* and *Anabaena*, and nitrogen fixers dominate the massive algal blooms frequently observed. The zooplankton community consisted mainly crustaceans, rotifera and to a lesser extent larvae of the stages of aquatic insects. The littoral zone was dominated by cyclopoida in terms of numbers and biomass while in the pelagic zone calanoid contributed much to biomass. Rotifera was more diverse in pelagic and littoral zones, but together with the insect larvae, their contribution to biomass was negligible. Vertically, zooplankton communities were concentrated in the bottom layers. Generally, Lake Victoria is progressively eutrophicating, and thus confirming the findings of earlier studies. Based on the Organisation for Economic Co-Operation and Development (OECD) indicative values for trophic status of temperate lakes, the southern portion of the lake Victoria, the largest in the tropical region, falls into highly eutrophic in the shallow sheltered zone to mesotrophic conditions in the deep pelagic zone. However, the chapter also critically evaluates the relevance of the OECD values and proposes strategies for coming up with values relevant for the tropical lakes.

INTRODUCTION

The objective of the activities related to eutrophication i.e. the effects of nutrient enrichment of the lake are: Through data collected in the Lake Water Quality Monitoring Programme to assess the state of eutrophication in the lake; to assess the mechanisms by which the lake responds to increased nutrient loadings; and to provide relevant calibration data to the "water quality model" (nutrient levels, chlorophyll-a, dissolved oxygen etc.)

Eutrophication is an alteration of the production cycle of the lake ecosystem due to enrichment by nutrients (particularly nitrogen and phosphorus). Eutrophication leads to excessive growth of algae or macrophytes affecting seriously the water quality (e.g. low oxygen content, high turbidity, release of toxic gases from the sediments such as hydrogen sulphide). These changes favour the most robust species whilst the more sensitive ones may disappear, and interfere with various uses of water.

The Lake Victoria ecosystem has reportedly undergone substantial changes over the last decades. Increased algal biomass and changes in the species composition from dominance of diatoms to dominance of cyanobacteria have been reported (Hecky 1993, Mugidde 1993, Lehman and Branstrator 1994) along with increased areas with oxygen depletion (Ochumba 1996, Hecky et al. 1998) and extinction of endemic chiclid species (Goldsmith and Witte 1992). However, the temporal and the spatial scales for the changes are still under debate since no lake-wide studies on nutrients, biomass and oxygen have been done on an annual scale.

There are three (3) hypotheses offered for the changes in Lake Victoria (Lehman et al 1998):

- Increased nutrient loading due to population growth and change in agricultural practices.
- Trophic alterations from top-down cascade of predatory interactions by introduction of Nile perch and cichlid species and changes in fishery
- Climate changes towards warmer, more humid and less windy weather reducing mixing depth and frequency of total mixing of the lake

The changes in climate are apparently sufficient to explain the overall change in the lake, but certainly the periodically limitation by nitrogen is influenced by increased nutrient loading from the catchment and most important from wet and dry deposition from the atmosphere. Sediment analyses have verified that increased eutrophication started before the introduction of new fish species (Stager 1998, Lehman *et al* 1998).

The rehabilitation of the Lake Victoria ecosystem and its catchment must start with a regional environmental effort aiming at a description of the temporal and spatial scales of the problems and aiming at identification of the causes of the problems. A framework for such efforts is the Lake Victoria Water QualityModel with its description of relations between climate, nutrient loading and eutrophication processes. Scenarios run as hindcasts or forecasts will be valuable tools for both the understanding of in-lake processes, for the identification of the important causes to the environmental state and for the analyses of management strategies.

Aquatic micro-invertebrates or zooplankton comprise small-bodied organisms (< 1.5 mm body length), which live suspended in the water column and exhibiting only feeble locomotory movements of their own. Water currents, waves, upwellings etc generally distribute them.

There are three main groups of zooplankton in freshwater: Protozoa, Rotifera and Crustacea. Protozoans found in lakes are often ciliates, Flagellates, Amoeba Cercaria and larvae from parasite. The population dynamics and productivity of the protozoa are poorly understood. Although generally a minor part of the zooplankton both numerically and in biomass at times the protozoa can constitute a significant component of the zooplankton productivity (Pace and Orcultt 1981). In Lake Tanganyika for example the biomass of protozoan zooplankton exceed that of the phytoplankton in the euphotic zone while the lake was stably stratified (Heckey and Kling 1981)

Rotifera are both planktonic and benthic. They form a significant component of the zooplankton. These rotifers are the most important soft-bodied invertebrates of the plankton (Pennak 1978; Ruttener-kolisko 1972: Dumont and Green 1980). The main crustacean groups are the cledocera (water flees) and copepoda. The latter is further divided in calanoida and cyclopoida. Zooplankton communities in Lake Victoria composed of mostly crustaceans in which the key groups are copepoda and cladocera.

Non-crustacean zooplankton include rotifers and insect larvae largely chaoborids, adults of which are known as lake flies. The latter is semi-planktonic i.e. live in or near bottom sediments during daytime and more into the water column at night. The adult phase of chaoborus is short lived and the majority of the life cycle is spent as an aquatic larva where it develops through four distinct larvae instars (Irvine 1995). Although larvae of the chaoborus have been shown to feed on phytoplankton (Hare and Carter, 1987; Moore, 1988), it is their predation and possible effect on zooplankton community structure that make them an important component of the food web of many lakes (Pastorok, 1980).

The role of zooplankton in the functioning and production of a aquatic ecosystem is vital (Downing, 1984; Mavuti and Litterick 1991). This role arises from its influence on nutrients dynamics and its trophic position in aquatic food chains. As major primary consumers many zooplanktons are herbivores feeding on phytoplankton, bacteria and detritus (Peters 1984). Others are predacious consuming protozoa and other zooplankton (Irvine and Waya 1992) Zooplankton also function as a food source for higher trophic levels such as fish and they provide an important link in the food chain of natural aquatic system between primary and fish production (Irvine and Waya 1995).

Due to their importance in the ecology of aquatic systems zooplankton are considered a critical factor in successful lake management by bio-manipulation (lampert 1988). It is believed that the survival and the eventual recruitment of various fish species to the fishery largely depend on zooplankton availability, since almost all the fishes include zooplankton in their diet at larvae stage in their life cycle (Fernando 1994).

It has been observed that certain species of zooplankton serve as indicators of water quality in Lake Victoria. The more eutrophic inshore shallow areas support higher abundance and density of rotifers than the deep off-shore waters (Mavuti and Litteric 1991, Owili 1998, Waya and Chande 2004).

The aim of this study is to determine the biomass, composition and distribution of zooplankton in the Tanzanian waters of Lake Victoria. The results are discussed with respect to predation, food and eutrophication status of the Lake.

METHODS

A lake sampling was carried out in the southern part of Lake Victoria for a period of 5 years, from December 2000 to March 2005, using TAFIRI II boat.

Water samples for chlorophyll-a and nutrients (Nitrogen, Phosphorus and Silicon) analysis were collected in duplicate using 2 litre Van Dorn sampler at various depths.The samples were dispensed into 1L brown polyvinyl chloride bottles which had previously been cleaned with phosphorus-free detergent. While in the field, water samples for dissolved nutrients and chlorophyll-a analysis were filtered. For plankton (phytoplankton and zooplankton) analysis, water samples were collected using the same sampler and from the same depths sampled for nutrients. To analyse zooplankton, 2 litres water sample were filtered across 50µm-mesh plankton net. Immediately, the samples were preserved with 1% acid Lugol's iodine solution (for phytoplankton) and buffered 4% formalin (for zooplankton). Photosynthetically active radiation (PAR), pH, conductivity and vertical profile of water temperatures were measured at the time of sample collection using Hydrolab. Water transparency was measured using a Secchi disk.

Laboratory analysis

Determination for total phosphorus (TP), soluble reactive phosphorus (SRP), nitrates (NO_3), nitrite (NO_2) and ammonium-nitrogen (NH_4-N) was done according to American Public Health Association Standards (APHA, 1995).

During the six- year period of eutrophicaton study, the collection of data has been based on monthly and quarterly lake monitoring programmes (see Lake Monitoring Chapter for details) for the Harmonised Lake Victoria Water Quality Monitoring network. It focused on the southern segment of the network comprising of eighteen (18) pelagic (TP) and eleven (11) littoral (TL) stations. The standard variables such as nitrogen and phosphorus fractions (inorganic, particulate, organic dissolved, and total), chlorophyll-a, algae species, zooplankton species, light conditions (measured as Secchi depths or light), and oxygen conditions were investigated. After validation, spatial variability has been examined through calculated statistics such as minimum, maximum, average, median, and upper and lower quartiles by station and presented in tables and by using horizontal contour plots and vertical profile plots. Where the data collection is sufficient, temporal variability has been examined using various time series plots. The quantitative relation between different parameters have been assessed through regression analysis (Chlorophyll-a to transparency, particulate N to particulate P, Chlorophyll-a to N and P etc.) and a global ratio of C:N:P:Si has been estimated to preliminarily assess the regime of nutrient limitation of the primary production.

The laboratories suffered, from lack of adequate equipment and training in low- level nutrient analysis for a long time of the project period and therefore substantial gaps are found in the data series for a number of parameters. Finally, the fact that monitoring and analysis at the limnological level has been new to the laboratories (an on-the-job learning process) it is normal that it has been necessary to discard some of the data during the validation process, thus creating further gaps in the time series. However, the Water Quality Data Base now contains more than 1800 records and around 40988 individual validated values from the lake, and many more in the Profile Data Base. Thus, although conclusions may be considered preliminary, the monitoring is well over its start-up problems and the amount of data concerning the eutrophication of the lake far exceeds what existed previously.

Nutrients have been measured according to the sampling scheme described in Chapter 6 i.e. monthly/quarterly and as profiles. The analysis programme has taken into account the different fractions in which the nutrients appear. Thus the following nutrient parameters have been analysed for:

- TN: total nitrogen.
- TPN: total particulate nitrogen
- DON: dissolved organic nitrogen
- NO_2: nitrite
- NO_3: nitrate
- NH_4: ammonium
- IN: inorganic nitrogen (calculated as the sum of NO_2+NO_3+NH_4 when all three have been measured)
- TP: total phosphorus.
- TPP: total particulate phosphorus
- DOP: dissolved organic phosphorus
- PO_4: orthophosphate
- PBSi: particulate biogenic silicium
- Si: silicium

Plankton

In the laboratory, plankton (phytoplankton and zooplankton) samples were analyzed using compound and inverted microscope. Plankton cells were identified until the species level whenever possible; and standard literature were consulted for identification of species. The numerical abundance (numbers/volume) of phytoplankton and zooplankton obtained using microscope were converted to wet and dry biomass using cell sizes and standard weights from the literature.

Data Analysis.

All the data were processed by use of Excel 2000.

Various methodological and logistic problems have caused gaps in the data sets. However, the validated database now contains around 13,930 nutrient analyses from the lake distributed among the parameters as given in the tables **1.0(a)** to **1.0(f)**.

Table 01: Number of Analyses for Nutrients, Chlorophyll-a, and planktons carried out.

(a)

Year	2000												
Parameter	**TN**	**TPN**	**DON**	**NO_2**	**NO_3**	**NH4**	**IN**	**TP**	**TPP**	**DOP**	**PO4**	**PBS**	**Si**
No. of analyses	-	-	-	65	65	84	65	229	-	-	230	-	14

Year	2000		
Parameter	**Chlorophyll-a**	**Phytoplankton**	**Zooplankton**
No. of analyses	43	50	64

(b)

Year	2001												
Parameter	**TN**	**TPN**	**DON**	**NO_2**	**NO_3**	**NH4**	**IN**	**TP**	**TPP**	**DOP**	**PO4**	**PBS**	**Si**
No. of analyses	-	-	-	480	428	227	156	489	272	281	450	2	343

Year	2001		
Parameter	**Chlorophyll-a**	**Phytoplankton**	**Zooplankton**
No. of analyses	365	397	397

(c)

Year	2002												
Parameter	**TN**	**TPN**	**DON**	**NO_2**	**NO_3**	**NH4**	**IN**	**TP**	**TPP**	**DOP**	**PO4**	**PBS**	**Si**
No. of analyses	-	71	-	303	348	378	317	378	378	377	378	-	378

Year	2002		
Parameter	**Chlorophyll-a**	**Phytoplankton**	**Zooplankton**
No. of analyses	369	407	407

(d)

Year	2003												
Parameter	**TN**	**TPN**	**DON**	**NO_2**	**NO_3**	**NH4**	**IN**	**TP**	**TPP**	**DOP**	**PO4**	**PBS**	**Si**
No. of analyses	145	178	145	367	434	437	375	437	437	437	437	-	437

Year	2003		
Parameter	**Chlorophyll-a**	**Phytoplankton**	**Zooplankton**
No. of analyses	437	364	364

(e)

Year	2004												
Parameter	**TN**	**TPN**	**DON**	**NO_2**	**NO_3**	**NH4**	**IN**	**TP**	**TPP**	**DOP**	**PO4**	**PBS**	**Si**
No. of analyses	166	154	166	166	166	166	154	166	166	166	166	-	166

Year	2004		
Parameter	**Chlorophyll-a**	**Phytoplankton**	**Zooplankton**
No. of analyses	165	112	112

(f)

Year	2005												
Parameter	**TN**	**TPN**	**DON**	**NO_2**	**NO_3**	**NH4**	**IN**	**TP**	**TPP**	**DOP**	**PO4**	**PBS**	**Si**
No. of analyses	15	11	11	62	1	55	-	71	71	71	71	-	71

Year	2005		
Parameter	**Chlorophyll-a**	**Phytoplankton**	**Zooplankton**
No. of analyses	59	90	90

The fact that the particulate and dissolved organic fractions (TPN, DON, TPP, DOP, and PBSi) have been measured less frequently than the inorganic fractions reflects late arrival of some equipments as well as late training in these methods which were new to all three laboratories of Mwanza, Bukoba and Musoma.

RESULTS

Nutrients and Chlorophyll-a

Examples of nutrient and chlorophyll-a data are given in the figures 01,03,06, and 07. They show the ranges of concentrations of Total phosphorous, Chlorophyll-a, Nitrate-Nitrogen, and Soluble Reactive Phosphorous.

Phosphorus

Mean total phosphorus concentrations of whole lake surface water ranged from ….. g/l in ….. to ….g/l each year and the maximum and minimum value were …g/l and ….g/l respectively. The mean soluble reactive phosphorus (SRP) were highest in …… and lowest in …The mean concentrations in pelagic and littoral areas were 90 μg/l and 80 μg/l The concentrations were generally highest in …… and lowest in …… Soluble reactive phosphorus which, is generally thought tobe an indicator of phosphorus forms available for algal uptake (Charlton, 2003), showed values ranging from ….to ….mg/l in littoral zone and …to….mg/l in pelagic zone.

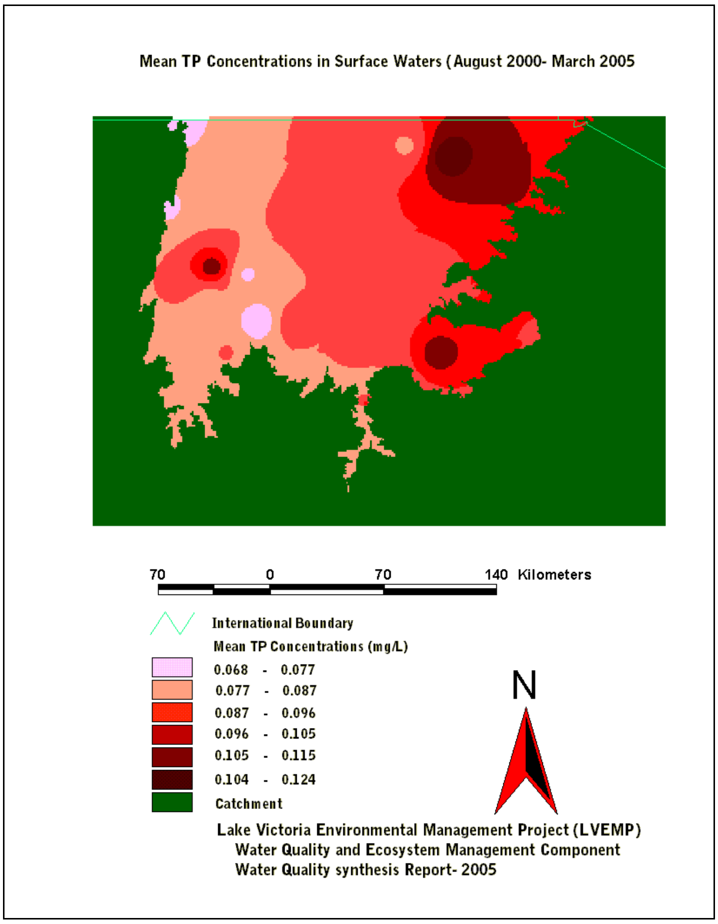

Figure 01: Mean TP concentration of surface waters

When compared to the Redfield Ratio it is seen that the overall N/P ratio in the lake is relatively low indicating potential nitrogen limitation. Table 2.0 shows the ratios of N/P (Total Nitrogen : Total Phosphorus).

Table2.0 : N/P ratios at different depths.

	Depth									
	0m-10m		10m-20m		20m-40m		40m-60m		60m-75m	
		No of Counts		No of Counts		No of Counts		No of Counts		No of Counts
TN	0.958	81	0.475	11	0.572	38	0.617	125	0.787	64
TP	0.094	541	0.098	119	0.111	135	0.123	676	0.101	269
N/P	10.19		4.85		5.15		5.99		7.79	

Chlorophyll-a

Chlorophyll- a as an indicator of algal population, its measure is an economical way to derive some baseline information on the primary production potential of the water. The concentrations in surface water (10 m) ranged between 5 and 6μ/l or below in open water to 10-20 μ/l in near-shore areas. Higher concentrations have been recorded in bays and gulfs. For example, in Mwanza gulf and Rubafu bay levels up to …μg/l and …μg/l respectively were recorded

Transparency

Secchi depths and Extinction coefficient measures provided water transparency/clarity. Figure … represents in an overview the range of measured Secchi depths (transparency)

Chlorophyll-a / Light Relationships

Figure 2.0 presents in an overview the ranges of measured secchi depths (transparency). The contours interpolate the average of all measurements at each station and the bars show minimum and maximum values. It appears that typical values in the middle of the lake range from 3-6 meters (max. 7.5 m) whereas the values at 1.0 or less are common near the shores and in the bays.

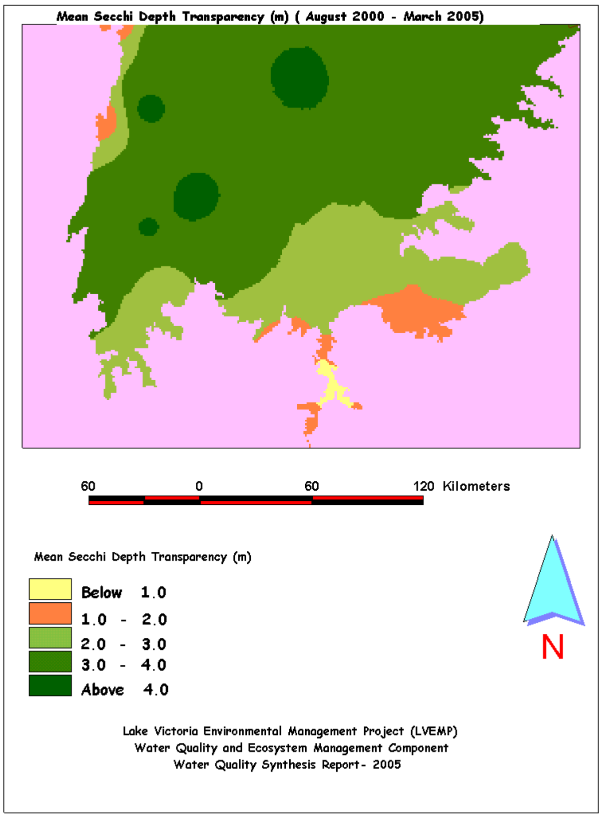

Figure 02: Mean Secchi Depth Tansparency.

The inverse pattern is seen for Chlorphyll-a[1] (see figure….). Here the open parts of the lake show concentrations of 5-6 µg/l or below and the nearshore areas 10-20 µg/l. Locally in bays Chlorophyll-a can raise to very high levels. Thus in Mwanza Gulf levels up to 172 µg/l were found, and the Rubafu bay showed Chlorophyll levels of up to 300 µg/l.

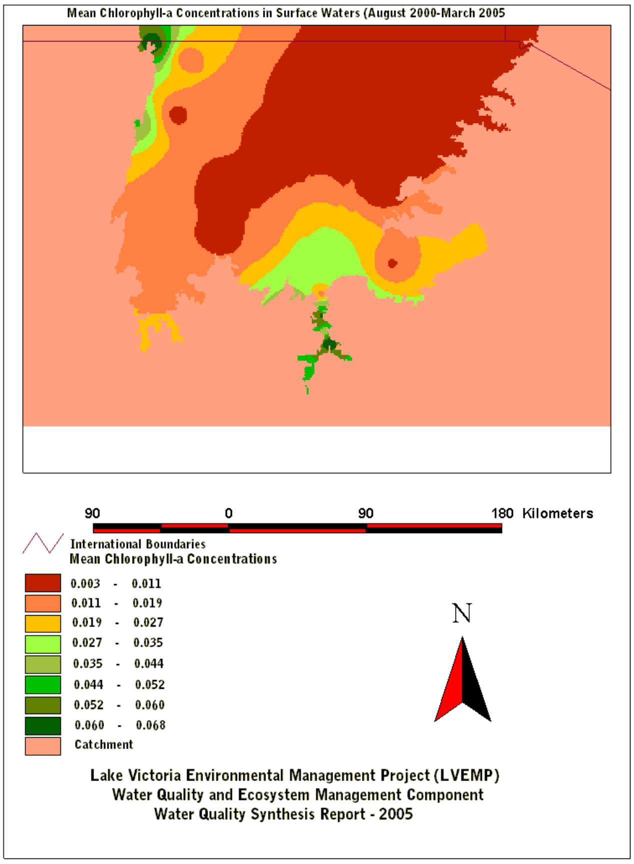

Figure 03: Mean Chlorophyll-a in surface water

Regressions on spatial scales and temporal/spatial scales were performed in order to investigate the consistency in light climate/phytoplankton biomass relationships as a part of data quality assurance and to compare present monitoring results with historical data.. Figures 4 and 5 show regressions the photic zone and the whole lake for the study period.

[1] Chlorophyll-a is a parameter that was applied relatively late and therefore only few measurements contribute to the map.

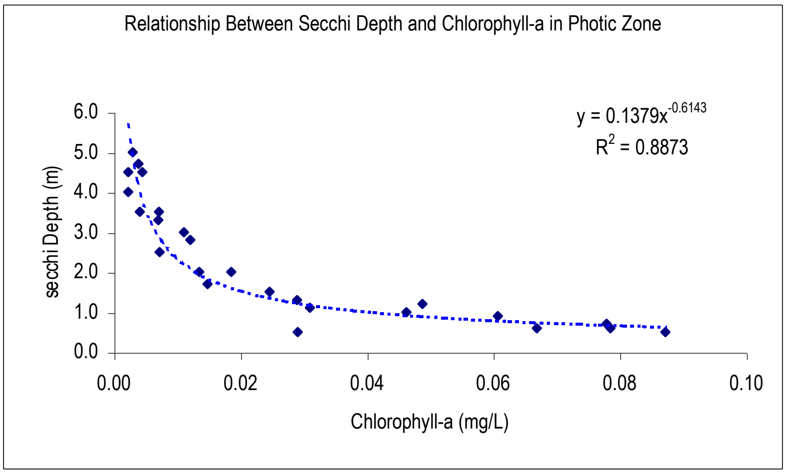

Figure 04 Regression: Secchi depth vs chlorophyll-a for all measurements in lake.

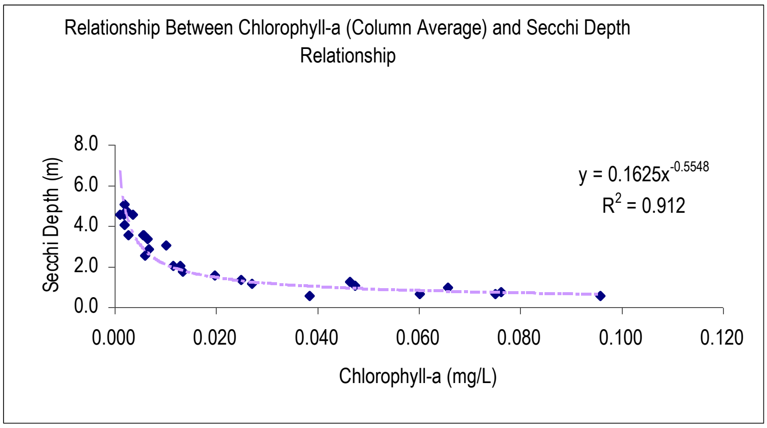

Figure 05 Regression: Secchi depth vs chlorophyll-a for all measurements in lake.

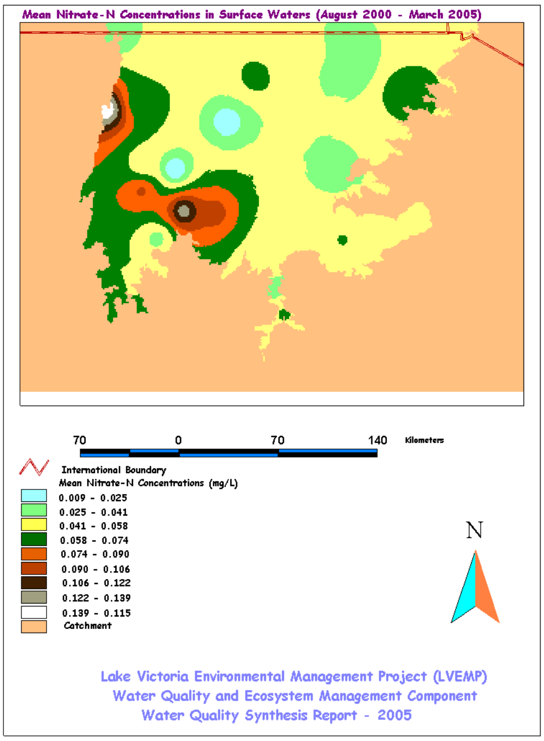

Figure 06: Mean Nitrate-Nitrogen concentration in surface water

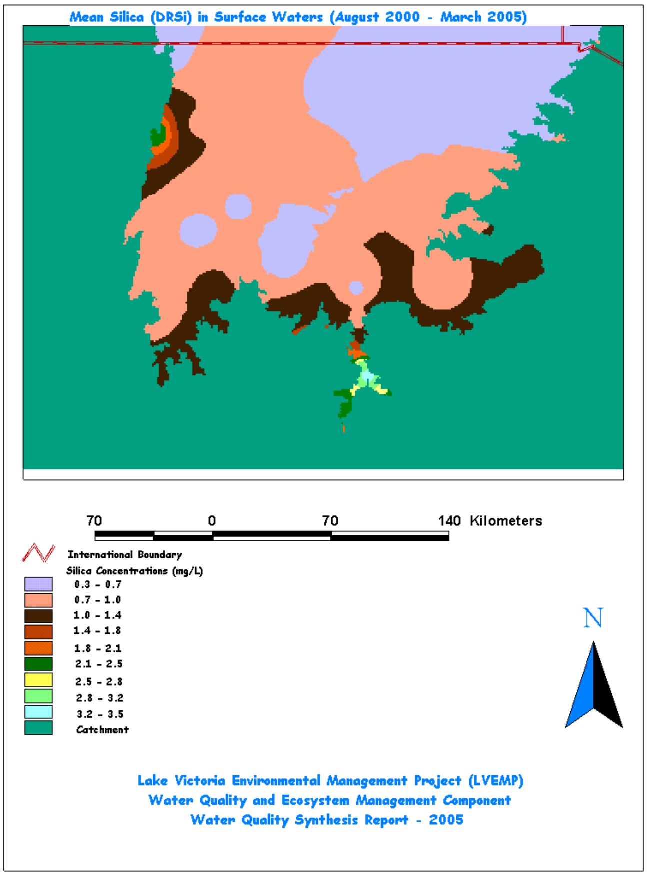

Figure 07: Mean Soluble Reactive Silica in surface water

Oxygen
All three countries have possessed (or been able to borrow) oxygen-profiling equipment during most of the study period. This implies that a relatively good coverage of oxygen measurements has been obtained from the lake and that some tendencies regarding the general oxygen conditions start to appear.

The following figures to) present statistically the magnitude of oxygen deficits at the bottom in the different parts of the lake based on the entire dataset collected.

Oxygen deficits are normally categorised according to effects as follows:

- Dissolved oxygen concentration between 2-4 mg/l: fish and mobile animals flee to better conditions
- Dissolved oxygen concentration between 1-2 mg/l: remaining animals suffers significantly
- Dissolved oxygen concentration below 1 mg/l: remaining animals die

The first figure) shows the estimated (interpolated) area of the lake where at least once during the sampling programme oxygen at the bottom was measured to be below 2 and 1 mg/l respectively (minimum values). The second) shows the areas where 25 % of the measurements have been below 2 and 1 mg/l (lower quartile), and the third) the areas where half of the measurements were below 2 and 1 mg/l respectively.

It should be noted that the amount of data available is still limited, that some stations have only very few measurements and that the assessment value of such maps will improve substantially when one or two full years of measurements exist.

Phytoplankton Species Composition and Biomass

Species composition and particulate nutrients

The community of phytoplankton in the southern part of Lake Victoria is comprised of 5 classes (42 taxa, 218 species) arranged alphabetically (per class) in the list here presented. The five classes are Cyanobacteria (Blue green algae), Diatoms (Bacillariophyceae), Green algae (Chlorophyceae), Cryptomonads (Cryptophyceae) and Dinoflagellates (Dinophyceae).

The phytoplankton community of inshore was as diverse as offshore Lake Victoria. Cyanobacteria were the most common phytoplankton as they appeared nearly continuously in all the samples in both inshore and offshore waters. Consequently cyanobacteria contributed > 50% of the total wet biomass as well as particulate nutrient concentrations from December 2000 to March 2005 . Overall, among the three main groups (Cyanobacteria, Green algae and Diatoms), Cyanobacteria contributes a larger fraction while Green algae contributed the least particulate biomass.

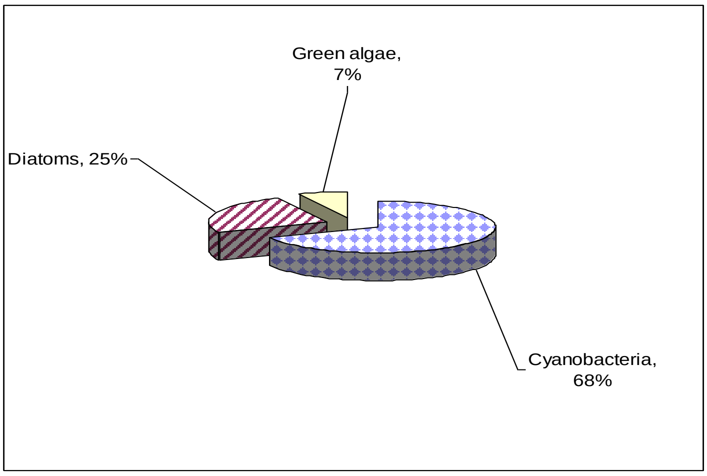

Figure 08: Overall phytoplankton biomass of the three main groups in Tanzanian waters of Lake Victoria, from December 2000-March 2004.

With regards to species diversity, green algae show the greatest diversity of species of any group of the phytoplankton identified during the sampling period (110 species) and the principal species present were *Ankistrodesmus falcutas, Chordatella subsalsa, Cosmarium* spp, *Crucigenia pulchra, Pediastrum simplex, Scenedesmus* spp, *Kirchneriella obesa* and *Oocystis species*. Diatoms represent the second group in terms of species diversity as it recorded 58 species of the identified phytoplankton and the common species present were *Nitzschia acicuralis, Navicula, Cyclotella, Synedra ulna*. *Aulacoseira* (*Melosira*) *were* rarely encountered. *Nitzschia* were more encountered in offshore waters than in near shore waters. While *Aulacoseira* were frequently observed in near-shore stations, specifically those close to the river mouth.

Blue green algae were the third group with respect to species diversity as it was recorded 41 species. The large filamentous cyabobacteria (*Anabaena* and *Planktolyngbya*) and the colonial mucilaginous forms (*Aphanocapsa*, *Microcystis* and *Merismopedia)* were the most common Cyanobacteria during the study period. Dinoflagellates were the fourth group with regard to species diversity as it recorded 3 species. The recorded Dinoflagellates were *Ceratium branchyceros*, *Ceratium* spp and *Glenodinium*. Cryptomonads was the least group with respect to species diversity as it recorded only two species, these were *Cryptomonas* and *Mallomonas* spp.

Spatio-temporal patterns of algal biomass

Phytoplankton wet biomass was in the range of 6.4 X 10^{-4} to 9.6 X 10^{4} µg L-1, average 491.4 µg L-1, in the Tanzanian waters of Lake Victoria. Average total wet biomass was typically 3 times higher the inshore waters than offshore. Similarly, biomasses of particulate nutrient concentrations were higher inshore than offshore.

Zooplankton and invertebrates

Taxonomic composition

Zooplankton community was composed of rotifers and crustaceans comprising cyclopoid and calanoid (diaptomid) copepods and clodocerans (water fleas). Other plank tonic organisms found in the zooplankton community were larvae stages of insects especially chaoboridae. A total number of 22 general and 39 species were observed in the littoral zone. 20 general and 28 species were encountered. Generally rotifera contributed the highest number of species in the littoral and pelagic zones, 23 and 15 species respectively.

Abundance

The abundance of zooplankton during studied period is presented in figure 09. The results show that in the littoral areas the highest densities of zooplankton were recorded in 2002, the mean total abundance reached 7,387 no/l and the lowest was 1,104 no/l. In the pelagic the highest abundance was recorded in 2004 and the lowest in 2001, the abundance was 5041 no/ 1,532 no/l respectively. Throughout the study period cyclopoid copepod contributed highest abundance in the littoral zones. In 2000 cladocera contributed 47% of the mean total zooplankton abundance followed by Rotifera 19 %, Calanoida 7% and cledocera 1 %. Nauplius larvae were numerous contributed 26% of the mean total zooplankton abundance. The trend was the same in 2001 and 2002, but in 2004 Cydopoida was the most abundant group followed by rotifers and calanoid, contributed the same percentage, 3 % each. Generally the mean abundance result shows that cyclopoid is the most dominant group in the littoral zones followed by rotifera, and calanoida. Cladocera are very rare. The nauplius larvae were numerous (Figure 10)

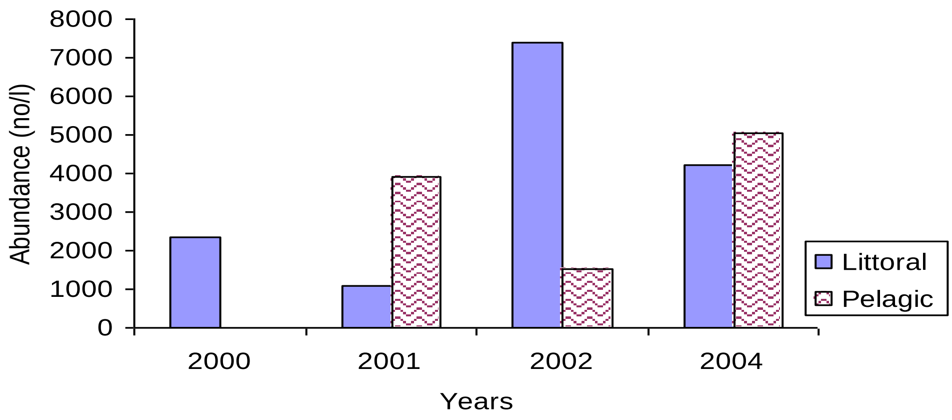

Fig. 09: Abundance of zooplankton in the Littoral and the Pelagic zones of Lake Victoria, 2000 – 2004

In the pelagic the cylopoid also dominated the zooplankton community. It was surprised that in 2001 the rotifera were numerous, the group was next to cyclopoid, contributed 15% of the mean total zooplankton abundance. Overall results show that the dominant group is cyclopoid contributed 29 % followed by calanoida 11 %, Rotifera 10 % and the least cladocera 2 %. Nauplius larvae contributed 48 % (Figure 11)

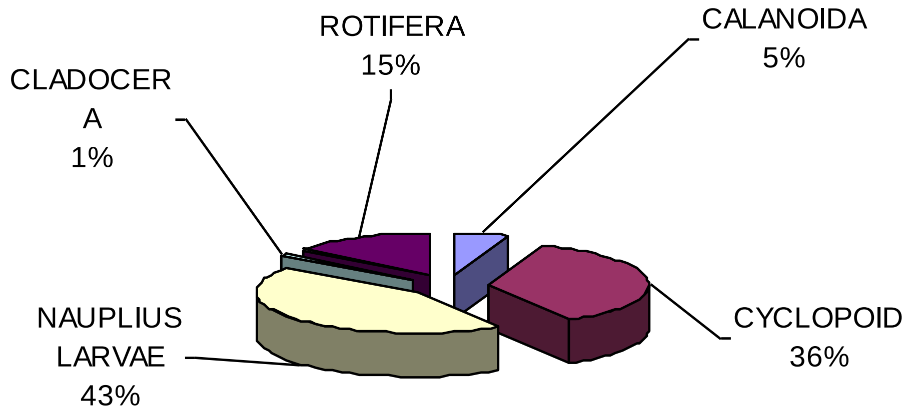

Fig. 10: Over all percent composition of the major groups of zooplankton in the littoral zones of Lake Victoria, 2000 – 2004.

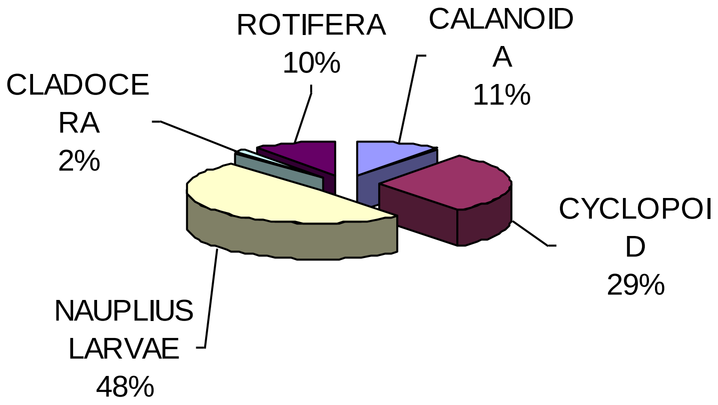

Fig 11: Overall percent composition of the major groups of zooplankton in the pelagic zones of Lake Victoria, 2000 - 2004

Biomass estimates

Mean zooplankton total biomass in both littoral and pelagic zones, during the study period are shown in figure 12. In the littoral zones the highest biomass was observed in March 2004 the mean total biomass was 2896.6 µg/l. The lowest biomass was observed in January 2001, the mean total biomass was 337 µg/l. In the pelagic zones the highest biomass was observed in May 2001 and the lowest in June 2002. The mean total biomass was 5361 µg/l and 183 µg/l respectively.

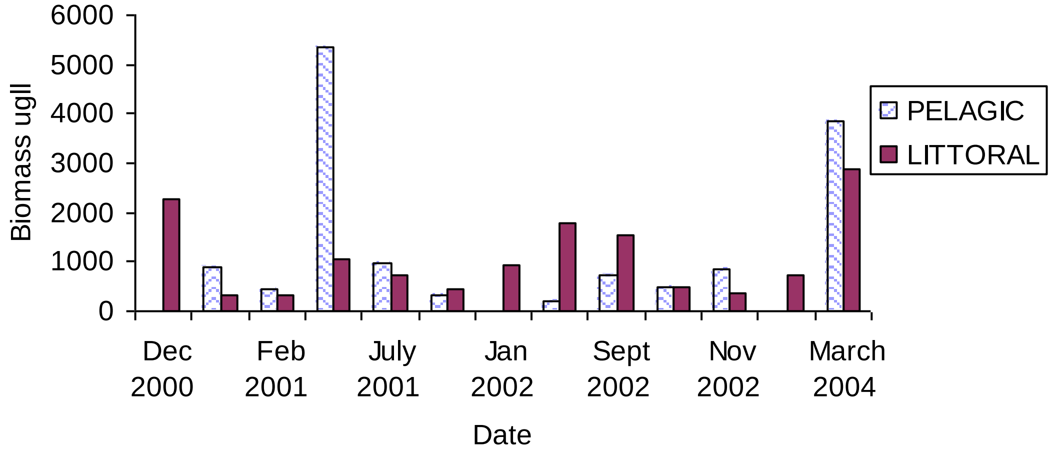

Figure 12: Mean biomass of zooplankton in the littoral and pelagic zones of the Tanzanian waters of Lake Victoria 2000-2002.

In terms of Biomass cyclopoid copepod was the important group contribution highest biomass in the littoral zones throughout. The study period, in 2000, cyclopoid contributed 57 % of the mean total biomass followed by calanoida 35 %, Rotifera 4 % Nauplus larvae 3 % and cladocera 1 %. In 2001 Cyclopoid contributed 63 %, in 2002, 53 % and 2004, 56 %. Calanoid copepod was next to cyclopoid throughout the study period. Contribution of rotifera, nauplius larvae and cladocera always contribute less than 10 % to the mean total abundance. (Figure 13).

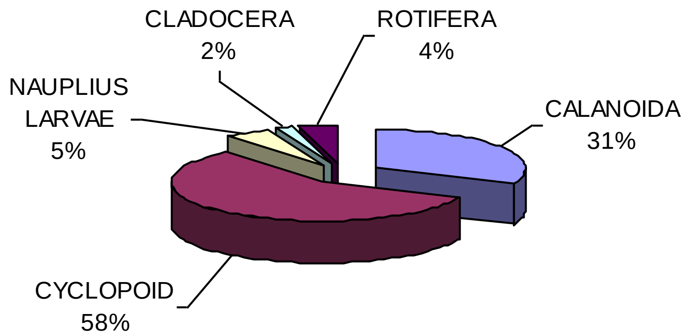

Fig. 13: Over all zooplankton biomass % composition of the main groups in the littoral zones of Lake Victoria, 2000-2004

In the pelagic zones, the calaroid capepod was the important group in terms of Biomass (Fig. 14). In 2001 and 2004, Calanoid contributed the highest biomass, 49 % and 72 % respectively. In 2002 the contribution of calanoid and cloopid was more or less the same. They contributed 44 % and 45 % respectively. Cladocera contributed less biomass in the littoral zones compared to the pelagic zones (Fig 13 & 14). In the littoral zones the contribution of cladocera ranged between 1-3% while in the pelagic the contribution ranged between 3-10%. On the other hand the contribution of rotifera to biomass was higher in the littoral than in the pelagic ranged between 0-10% while in the pelagic the contribution ranged between 0-5%.

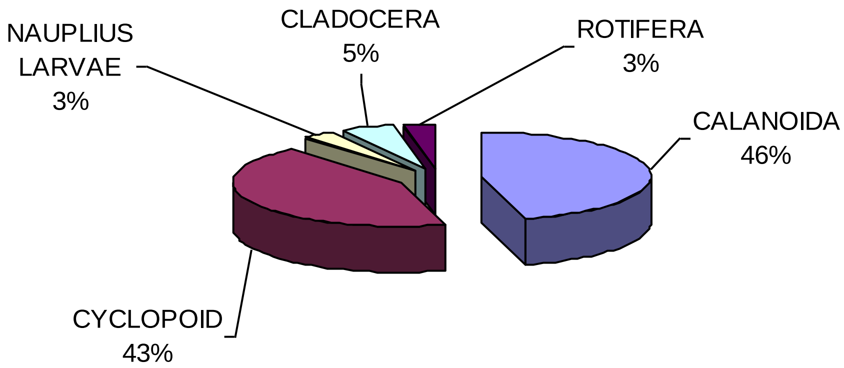

Fig. 14: Overall mean zooplankton biomass of the main groups in the pelagic zones of Lake Victoria, 2001 – 2004

DISCUSSION

Chlorophyll-a / Light Relationships

It was concluded by both Talling (1965,1966) and Lehman et al (1998) that the master variable controlling the eutrophication effects in Lake Victoria is the mixing depth. The relation between photic depth and mixing depth varies with the climate. During cooling of the lake in June-July and to some extent in December- January mixing is increased bringing nutrients to the photic zone. Under these circumstances phytoplankton species compete at low average light favouring the growth of diatoms. In periods with less mixing cyanobacteria, some of which may fix nitrogen, are more competitive (Lehman et al 1998).

Figure….. presents in an overview the ranges of measured secchi depths (transparency). The contours interpolate the average of all measurements at each station and the bars show minimum and maximum values. It appears that typical values in the middle of the lake range from 3-6 meters (max. 7.2 m) whereas the values at 1.0 or less are common near the shores and in the bays.

The inverse pattern is seen for Chlorphyll-a[2] (see figure….). Here the open parts of the lake show concentrations of 5-6 ug/l or below and the nearshore areas 10-20 ug/l. Locally in bays Chlorophyll-a can raise to very high levels. Thus in Mwanza Gulf levels up to 172 ug/l were found. Studies of Murchison Bay in 1997 showed Chlorophyll levels of 300 ug/l.

Regressions on spatial scales and temporal/spatial scales were performed in order to investigate the consistency in light climate/phytoplankton biomass relationships as a part of data quality assurance and to compare present monitoring results with historical data. The regression between extinction coefficient and chlorophyll can be compared to that performed on Tallings 1965 data augmented with modern data by Lehman et al (1998):

$$\text{Light extinction coefficient } (m^{-1}) = 0.036 \text{ (chl } \mu g/l) + 0.15$$

The slope value indicates a high efficiency in chlorophyll and thus light stressed phytoplankton communities. This is also reflected in the high carbon/chlorophyll ratio = 54. The higher value for background extinction in the present study reflects the contribution from the shallow stations. Lake wide regressions on an annual scale are shown in figure……

Oxygen

Good coverage of oxygen measurements has been obtained from the lake and that some tendencies regarding the general oxygen conditions start to appear.

Oxygen deficits are normally categorised according to effects as follows:

- Dissolved oxygen concentration between 2-4 mg/l: fish and mobile animals flee to better conditions
- Dissolved oxygen concentration between 1-2 mg/l: remaining animals suffers significantly
- Dissolved oxygen concentration below 1 mg/l: remaining animals die

The first figure) shows the estimated (interpolated) area of the lake where at least once during the sampling programme oxygen at the bottom was measured to be below 2 and 1 mg/l respectively (minimum values). The second) shows the areas where 25 % of the measurements have been below 2 and 1 mg/l (lower quartile), and the third) the areas where half of the measurements were below 2 and 1 mg/l respectively.

It should be noted that the amount of data available is still limited, that some stations have only very few measurements and that the assessment value of such maps will improve substantially when one or two full years of measurements exist.

[2] Chlorophyll-a is a parameter that was applied relatively late and therefore only few measurements contribute to the map.

For some of the stations the frequency of measurements is sufficient to allow the drawing of time series of the oxygen condition in the water column.

Studies have shown clearly that inshore areas are more affected by eutrophication manifested by high productivity and subsequent impairment of water quality. Water transparency, is high in offshore areas 2-7.5m) but very low in polluted near shore areas (0.5-2m) e.g. Mwanza gulf, (Figure …..).

Generally, the increase in Eutrophication is reflected by the downward trend of water transparency and an upward trend of total phosphorus. Comparison of the annual mean Secchi disc transparency estimated by Akiyama et al in 1974 and the estimation by LVEMP in 2001 at TL 231 in the Mwanza Gulf shows a clear downward trend (Fig…). Similarly, the annual mean total phosphorus for four consecutive years indicates an upward trend for TP 01 (Fig…). This is in agreement with earlier studies (Hecky 1991). In both near shore and offshore areas, blue green algae (including the toxic species *Anabaena* and *microcystis ssp*) have become dominant species (Figure….).

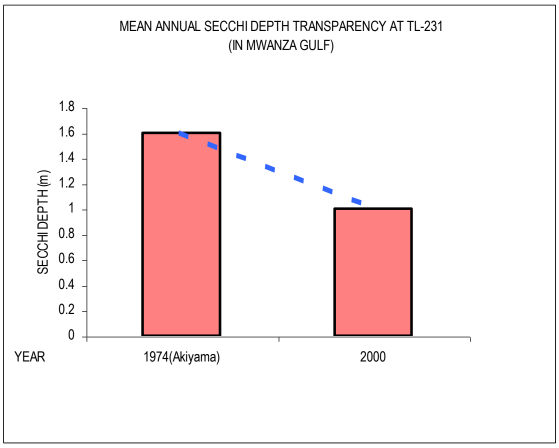

Fig 15 Annual Means Secchi Depth Transparency at TL 231

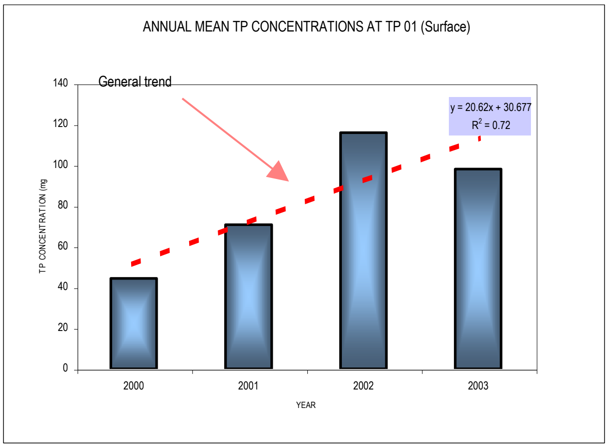

Fig 16Annual Mean TP at TP-01

Oxygen Levels

According to the recent findings, oxygen deficits occur in the offshore parts of the lake but lesser parts are affected and for a shorter period of the year than indicated in earlier studies. Strong oxygen deficits occur in the hot-spot areas (near shore areas including gulfs, bays) independently of the general oxygen regime of the lake. Such events are related to local conditions such as high nutrient input and associated high algae production and low wind mixing. The bottom oxygen levels in the lake for the study period is shown in Fig 15 below. The figure shows the part of the lake bottom, which would be anoxic 50 % of the time.

However, the presence of Hydrogen Suphide at the lake bottom in the offshore (Fig…) in March 2004 indicated severe anoxic conditions. This calls for more intensive water quality monitoring to produce a finer picture of the lake water quality. Unavailability of fish in the area which led to migration of fishermen from Goziba Island (in the centre of the lake) to the islands of Ukerewe, and other southern islands located in relatively shallower areas was associated with hydrogen sulphide laden lake bottom. Hydrogen Suphide is toxic to fish. Thus, the hostile environment caused by the toxic gas in the bottom sediment, and the very low oxygen concentrations in the near bottom waters should have led to migration of fish to relatively “less deep” waters with favourable conditions.

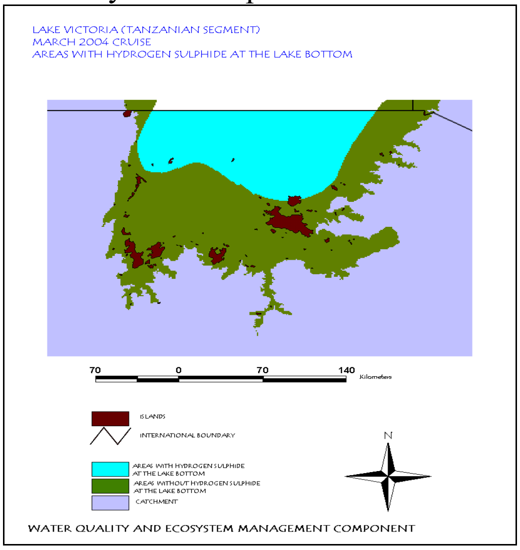

Figure 17…: Areas with Hydrogen Sulphide at the bottom of the lake

Phytoplankton analyses show that there is an increase in algal biomass in near-shore areas, both blue-green and diatoms. Offshore, the algal biomass concentrations are quite low. In both areas blue – green algae (Fig…) has become the dominating species. In the diatoms, there has been a shift from *Melosira* to *Nitchia* dominance. In both near-shore and offshore areas blue green algae including the toxic species has become the dominant species. Generally the offshore part (60 to 70% of the lake area) has relatively low chlorophyll-a concentrations and often-measurable nutrients concentrations indicating that the primary production offshore may not be limited by nutrients but rather by light due to mixing regime. This implies that the ecological turnover in the offshore parts of the lake may not be significantly affected by inputs of nutrients to the lake.

Phytoplankton community

The higher phytoplankton biomass inshore than offshore is because mean light conditions were better inshore. In inshore, reduced mixing depth allows relatively high mean water column irradiances unlike offshore where the deeper mixed layer leads to low light availability. In the modern Lake Victoria, the euphotic depth is often ≤ 10 m offshore and is half as shallow inshore and stratification is necessary to create a good light environment for planktonic algae. But mixing depths are always ≥ 20 m at offshore and compatible with only low algal biomasses as light limits photosynthesis over most of mixing layer. Another explanation for higher biomass in near shore stations is because of intrusion of waters through rivers, surface runoff, inflows of urban and industrial effluents and stronger mixing due to shallow depth. Therefore, shallow areas have higher nutrient concentrations and better light conditions and they support higher primary production than offshore (Lungáyia *et al*, 2001).

The main component group and numerically the largest component of the phytoplankton were Cyanobacteria, with a higher percentage of the phytoplankton mean density and biomass (> 50%) as shown in Figure 2. Diatoms was the second dominant group and represent 16%. While Green algae was the least group and recorded 7%. The current results of blue-green algae dominating other algal types are consistent with observations made from previous studies in Lake Victoria (Verschuren *et al.*, 2002; Kling *et al.,* 2001; Hecky *et al.*, 1994; Mugidde, 1993; Ochumba 1990; Ochumba and Kibaara, 1989). The higher P loads relative to N from the catchment (Hecky 1993, Lipiatou *et al*., 1996) and resultant high concentrations of total P (>2.0μM) has doubtlessly contributed to the dominance of cyanobacteria in Lake Victoria.

In Lake Victoria when thermal stratificationoccurs raises light availability and N-demand, the heterocystous N-fixing cyanobacteria, *Anabaena* dominate other cyanobacteria (Kling *et al.*, 2001; Mugidde, 2001). The high abundance of the *Anabaena* in Lake Victoria may be related to the simultaneous effects of N-deficiency and light availability. *Anabaena* is a "sun" species with high light requirements and has been shown to competitively displace other species under saturating irradiances in N-limited culture experiments (Nobel *et al*., 1998).

The observations that Cyanobacteria, including the toxic species *Anabaena* and *Microcystis* dominating other algal types, provides information for water management in Lake. It is important that environmental factors associated with the continued presence of toxic cyanobacteria be investigated further as algal toxin production has been confirmed in Lake Victoria (Sakadende, 2002; FIRRI, Uganda, unpublished data). Algal toxins effects may already be having adverse consequences on the productivity of the fishery and may be responsible for some of the massive fish kills that frequently occur in Lake Victoria.

Elsewhere, cyanobacteria microcystin toxins have been demonstrated to alter the hatching time of rainbow trout and adversely affect the survival, growth and morphology of zebrafish (Oberemm *et al.*, 1999). Microcystin toxins have been shown to slow down zooplankton growth, and Daphnia. (Thostrup *et al*., 1999). Fish mortality due to algal toxins have been confirmed elsewhere (Zimba *et al*., 2001). Algal toxins not only cause damage to aquatic organisms but also can be accumulated in the bodies of these organisms and consequently, transfer of these toxins to humans upon eating fish and mussels (Mohamed *et al*., 2003).

Blue-green algae in some raw water sources had caused sporadic operational problems, such as blockage of raw water filters or the production of tastes and odors in finished waters, for water suppliers. Airborne microcystin can directly affect people, especially when showering (Kotak *et al*., 1994; Dunn, 1996).

Some species of Cyanobacteria such as the *Anabaena* and *Cylindrospemopsis* which dominated in this study are known to have ability of fixing atmospheric nitrogen and hence can influence the nitrogen budget of Lake Victoria through nitrogen fixation. In deed, Mugidde (2001) reported that biological fixation of nitrogen is the largest single source of N (480 kilo tones per year). This atmospheric source likely account for over 80% of total N loading to the lake.

Zooplankton and invertebrates community

Zooplankton communities are sensitive to changes in water environment quality. In Lake Victoria changes in relative abundance of zooplankton taxa have been reported as the lake has become eutrophic over the past several decades (Mwebaza-Ndawula 1994). Similar observations have been made in lakes Mutanda and Mulehe in western Uganda (Green 1976).

This attribute of zooplankton will be used to monitor environmental changes including eutrophication (Hecky 1993) and pollution (Calamari *et al.* 1995), which have assumed great importance in the Victoria basin in pace with industrialization and increased use of agro-chemicals on farmlands and have implications on fish productivity and sustainability.

The occurrence and characterization of Lake Victoria zooplankton community by Copepoda, Cladocera (waterfleas) and Rotifera has been reported by scientists working in different parts of the lake at different times (Worthington 1931; Rzoska 1957; Akiyama et al. 1977; Mavuti & Litterick 1991; Mwebaza-Ndawula 1994; Waya 2001, Waya and Mwambungu 2004). Similar observation has been observed in the current study, three groups of zoolplankton has been observed but their diversity, abundance, distribution, biomass and community size structure has been changed.

Changes in relative abundance of zooplankton taxa have been reported as the lake has become eutrophic over the past several decades (Mwebaza-Ndawula 1994; Waya and Mwambungu 2004). Similar observations have been made in the current study. The taxonomic composition shows that rotifer contributed the highest number of species in the littoral and pelagic zones of lake Victoria. This observation can be explained by the degradation of water quality i.e. eutrophication (excessive nutrient loading) and pollution (water contamination) the condition which is dangerous to the living aquatic organisms including zooplankton. Rotifers are doing well in the Lake as they have the ability to tolerate eutrophic conditions. For example the rotifer *Brachionus calyciaflorus* is not affected by the presence of Cynobacteria (Starkweather and Kellar 1983).

Higher species diversity in the littoral than in the pelagic zones shows that littoral zones are more eutrophic than the pelagic. The assertion is also supported by the mean values for total phosphorus and the secchi disk. The mean water transparency was low in the littoral than in the pelagic zones (3.31 m and 0.99 m) respectively. The same observations was also reported by Mavuti and littenck 1991; Owili 199; Waya and Chande 2004 and Waya and Mwambungu 2004)

Eutrophic condition is also evidenced by the reduction of diversity of cladocera. One of the impacts of eutrophication to zooplankton community is the changes in relative abundance by elimination of least tolerant species (Green 1971 and Waya and Mwambungu 2004). According to the findings of the work done in March, April and between August and December, 2000, large Daphids were more successful in offshore regions and that the smaller forms tended to dominate near shore regions of large lakes. This was not the case in current study. The cledocera were very rare especially the large cladocerans. This can be explained by the toxicity handling and mucous characteristics of cyarobacteria, mean that they form an inadequate food source, both by being individually protected and by creating an unfavorable environment for efficient grazers (Hubble and Harper 2000). Cyanobacteria also inhibit the feeding process of zooplankton, the effect is more with large cladocerans than copepods, rotifers or small cladocerans like Bosmina (Lampert 1987).

While changes in relative abundance due to eutrophication may not raise biodiversity concerns, it can drastically alter trophic interactions between prey and predator fish organisms with consequences to production dynamics in fisheries. For example, a zooplankton community dominated by small bodied rotifers as usually the case under eutrophic conditions (Mwebaza-Ndawila 1998. Mavuti and Litterick 1991, Waya and Mwambigu 2004; Waya and Charde 2004) is not likely to sustain fisheries production to a higher level as a crustacean-based zooplankton community. This has been noted in the current study. The cladocera and the calanoida, which used to occur in large numbers in the pelagic Lehman 1996, Waya and Mwambigu 2004). There, were few during the study period.

The reduction of this big zooplankton during the study period can be explained by the predation pressure of fish and invertebrates predators. The zooplanktivorus fishes are known to be selective feeders and would go from prey that they can capture at minimum cost. That's why they prefer the large zooplankton calanoid copepod and big cladocerans. Cladocerans are reported to be vulnerable to fish predation than copepods and rotifers due to their large size and slow mobility (Owili 1999). This preference of fish on large zooplankton could partly, explain the low abundance of calanoid copepod and cladocera and high abundance of cyclopodia copepod. This trend contrasts with the historical zooplankton assemblage (Worthington 1931) which was dominated by calanoid copepods (Mwabaza-Ndaivula 1994) and cladocera also use to occur in much higher ralative abundance (ca 30%) compared to the small proportions ca 3-5%) in the morden community (Mwebaza Ndaivula 1994).

Nitrogen-fixation

Nitrogen is the main constituent of the protoplasm of any living cells as it forms major component of proteins and nucleic acids. Nitrogen exists in several forms (oxidation states) such as NO_2^-, R-NH_2, NO_3^-, NH_3, N_2O, and N_2. Of all forms, NH_3 is the biologically assimilated form of nitrogen and the elemental nitrogen (N_2) is the most stable form of nitrogen and it is not readily available for assimilation (Madigan *et al,*. 2000). The abundance of N_2 is relatively very high in the atmosphere, it comprise about 78% by weight of air. In spite of being found in large amount the utilization of N_2 as nitrogen source requires a lot of energy and special enzyme (nitrogenase) to break the nitrogen triple bonds. Only few prokaryotic microorganisms are able to do so and they are called nitrogen fixers or diazotrophs and the process is called biological nitrogen fixation (Trainor, 1978).
A general pattern of increasing dominance of N-fixing types (*Anabaena* and *Cylindrospermopsis*) in inshore waters of Lake Victoria has been observed in this study and confirmed earlier findings (Kling *et al.*, 2001). Currently, biological fixation of nitrogen is the largest single source of N and account for over 80% of total N loading to Lake Victoria, exceeding dry atmospheric and rivers inputs (Mugidde *et al.*, 2003). However, further studies are recommended to confirm these findings.

OECD Indicative Values for Indicators of Eutrophication

The water quality of Lakes has a trophic state depending on the value of a number of parameters. Thus eutrophication or lake water quality assessment and classification can be based on the values of these parameters. Numerous indices have been developed tomeasure the degree of eutrophication of water bodies. Many have been based on phytoplankton species composition, but are not recommended since they are complicated to undertake, difficult to interpret and are affected by local conditions. Suitable alternatives for biological indicators are total particulate organic carbon (POC) and chlorophyll-a, since they represent total biomass (R. Thomas, *et al).*
In the OECD countries, lake water quality is commonly assessed by reference to a scheme proposed by the OECD. The scheme sets limits for the annual average values for total

phosphorus, chlorophyll-a, and water transparency and for maximum and minimum values of chlorophyll-a and water transparency respectively (Table…).

Table 03: Trophic classification scheme for lake waters proposed by the OECD (OECD, 1982)

Lake category	Mean Total phosphorus (mg/m^3)	Chlorophyll-a (mg/m^3)		Transparency (m)	
		Annual mean	Maxima	Annual mean	Minima
Ultra-Oligotrophic	<4	<1.0	<2.5	>12	>6
Oligotrophic	<10	<2.5	<8.0	>6	>3
Mesotrophic	10-35	2.5-8	8-25	6-3	3-1.5
Eutrophic	35-100	8-25	25-75	3-1.5	1.5-0.7
Hypertrophic	>100	>25	>75	<1.5	<0.7

Table 04: Modified version of the OECD scheme based on values of annual maximum chlorophyll concentration. Indicators related to water quality and the probability of pollution.

Classification scheme			Category Description			
Lake Trophic Category		Annual Maximum Chlorophyll mg/m^3	Algal Growth	Degree of Deoxygenation in Hypolimnion	Level of Pollution	Impairment of use of Lake
Oligotrophic	(O)	<8	Low	Low	Very low	Probably none
Mesotrophic	(M)	8-25	Moderate	Moderate	Low	Very little
	Moderately (m-E)	25-35	Substantial	May be high	Significant	May be appreciable
Eutrophic	Strongly (s-E)	35-55	High	High	Strong	Appreciable
	Highly(h-E)	55-75	High	Probably total	High	High
Hypertrophic	(H)	>75	Very high	Probably total	Very high	Very high

CONCLUSIONS

The in-lake monitoring of water quality is now operational, but a proper assessment of the state of eutrophication of the lake requires at least one full year of measurements, which has not been obtained during the project period for various reasons. However, the data set available at the moment is much more comprehensive regarding combined spatial

and temporal extent than what has been the basis of former "conclusions" on the lake and gives some indications regarding future conclusions.
Overall, the data indicates that due to combination of a large surface area and relatively shallow depth, the lake does not react homogenously (LVEMP, 2002). Thus, mixing occurs at different times and to different degrees in different parts of the lake and e.g. oxygen deficits do the same. Generally, the offshore part of the lake (60 – 70% of the lake area) has relatively low chlorophyll-a concentrations and often measurable nutrient concentrations indicating that the primary production offshore may not be limited by nutrients but rather by light due to the mixing regime. -Moreover, the general carbon/nutrient ration is low which also supports this hypothesis. This implies that the ecological turn-over in the offshore parts of the lake may not be significantly affected by inputs of nutrients to the lake (LVEMP, 2002).

Oxygen deficits occur in the offshore parts of the lake, but the data from the study indicates that lesser parts of the lake are affected, and for a shorter time than was expected based on former studies.

On the other hand, the data shows clearly that near shore areas may be highly affected by eutrophication, especially the hot-spot areas such as Mwanza Gulf and Mara and Rubafu bays. In these areas chlorophyll-a concentrations today rise far beyond what has been measured (in the extensively studied northern parts) previously. Thus, the present study has measured a maximum of 170 ug/l of chlorophyll-a in Mwanza Gulf and in Mara and Rubafu bays measured up to …… and …… respectively. For comparison, Talling (1965, 1966) reported maximum values of chlorophyll-a of 70 ug/l in near shore areas of the lake. A low N/P ratio in the near shore waters of the lake indicates that nitrogen may occasionally be limiting here.

It is likewise evident, that strong oxygen deficits occur in the hot-spot areas independently of the general oxygen regime of the lake. Thus, several meters of oxygen free water column has been registered both in Mwanza Gulf. Such events are related to local conditions such as high nutrient input, high algae production and, at the same time low wind mixing.

Phytoplankton community

This study and the published information confirm the increase of algal biomass and dominance of Cyanobacteria which led to negative consequence on water quality including de-oxygenation of the water. Some of Cyanobacteria species (genera) such as the *Anabaena* and *Cylidrospermopsis* have ability to fix atmospheric nitrogen and hence can significantly contribute to the eutrophication of Lake Victoria through nitrogen fixation as recently confirmed Mugidde (2001).

Zooplankton and invertebrates

The zooplankton and invertebrates community in Lake Victoria plays a key ecological role in the nutrition and survival of all fish larvae and juveniles fishes regardless of species. Furthermore, the consumption of zooplankton on phytoplankton is important in the improvement of the water quality. As grazers on algae they keep down the algae population and hence prevent algal blooms i.e. the mass occurrences of cyanobacteria, which are frequently toxic in fresh, brackish and marine waters throughout the world. Such blooms have constituted a health hazard to human and animals.

Zooplankton can provide a lot of information with respect to measure of the health of the environment because of their sensitivity to changes in characteristics of the aquatic ecosystems. certain species of zooplankton especially amongst the cladocerans and rotifers may be used as indicators of organic and chemical pollution in the water (Mavuti *et al.*, 1991), either through direct analysis of the food they take, or by monitoring the changes in species richness or abundances. Therefore zooplankton can act as bio-indicator of environment pollution.

The study show that zooplankton community and invertebrates changes with time as indicated by degree of abundance/biomass of some more valuable fish such as Cladocera and increase of less valuable organisms such as Rotifers. This observation is an indication of highly eutrophic conditions in Lake Victoria.

Recommendations

The basic recommendation is to finalize outstanding data compilation (especially phytoplankton) and to continue with the data collection to obtain at least one full year's data. This monitoring program was meant to evaluate the variability of the various eutrophication indicators within the lake with the intension to propose a reduced future monitoring program. The collected data has shown that the ongoing monitoring program must be considered a minimum for the next years to reveal the spatial and temporal variability of the eutrophication indicators within the lake.

The observations that blue-green algae including the toxic species *Anabaena* and *Microcystis* spp are series concern to policy makers and water and fisheries managers. Algal toxins effects may already be having adverse consequences on the productivity of the fishery and may be responsible for some of the massive fish kills that frequently occur in Lake Victoria. It is important that environmental factors associated with the continued presence of toxic cyanobacteria be investigated further as preliminary findings confirm algal toxin production in Lake Victoria (Sekadende, 2002; FIRRI Uganda, unpublished). Furthermore, performing a lake-wide study on algal toxicology is necessary, as it will equip the water and fisheries managers in the region with crucial information on algal toxin problem of the lake.

It is clear that eutrophication management for optimum fisheries, in a water body like Lake Victoria will at a time be in conflict with eutrophication management for recreational, domestic, agriculture and industrial water supply, and other uses of the water since increased nutrient loads lead not only to increased fish production but also to decreased water quality in terms of most non-fisheries-related uses. Therefore, there is need to investigate the optimum-maximum phosphorus load that will provide the maximum yield of fisheries and but not enough to cause unwanted water quality characteristics such as detrimental amounts of oxygen depletion, fish kills, dominance of toxic blue green algae.

In view of the vulnerability of zooplankton from environmental degradation, research efforts need to focus on regular monitoring of the communities as part of an early warning mechanism for potential decline in fish production in case of further deterioration in the lake's water quality.

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PESTICIDES AND METAL CONTAMINATION

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ABSTRACT

Since the activities associated with metal and pesticide contamination of the environment are increasingly carried out in the Lake Victoria basin, the Lake Victoria Environmental Management Project (LVEMP) has since 2000 through 2005 attempted to identify sources and contaminant "hotspots" through rapid assessment of metal concentration levels in water, biota, sediments, and the atmosphere. A review of literature and a pilot study on micro-pollutants with reference to pesticides in the River Simiyu catchment and Magu bay in the Speke gulf, as well as inventory of agrochemicals used in the Lake basin, were undertaken.

The studies have concluded that generally, at present the mining activity in the Lake basin has had no impact on levels of heavy metals in the Lake System. Also to a great extent, it is now apparent that neither fish nor humans are at risk from increased levels of heavy metals particularly mercury in the lake basin. Mercury concentrations in most fish species are generally lower than the WHO maximum allowable concentration of 500 ng/g ww in edible fish parts. In sediments, the concentration of As is less than 6 $\mu g\ g^{-1}$ dw and Cd is below 1.9 $\mu g\ g^{-1}$ dw. Although not extensively used in the River Simiyu catchment, the organo-chlorine pesticides such as dichloro-diphenol-trichloroethane (DDT) and hexachlorocylcohexane (HCH) were frequently detected in water samples. Agricultural areas of the upper catchment contributed significantly to the sources of contamination during high flows in April 2003. The estimated pesticide average daily load during high flows (100 m^3/s) was 4.3 kg/day. Three organo-chlorine pesticides namely DDT, HCH, and Endosulfan with concentrations ranging between zero and 2 μg/l were detected in surface water samples from Speke gulf. The elevated concentrations appeared during the rain season in April 2003 when river discharge was high. This suggested that the high contaminant loads were associated with increased Simiyu river discharge to the Speke gulf.

Artisanal gold mining utilizing mercury in extracting gold from its ore remains a potential source of mercury pollution, and the contribution of the identified pesticide residues from the Simiyu catchments to Lake Victoria is significant This emphasizes the urgent need for establishing the status of pesticide contamination in other Lake Victoria tributaries, and calls for efficient pesticide and mercury monitoring and research programmes for both pesticide users and artisanal gold miners in effective application of agrochemicals and efficient ways of gold extraction respectively. Although large-scale commercial miners using cyanide in the production the effluent discharge is zero, it is important to ensure that their systems are closely monitored.

INTRODUCTION

The source of toxic contaminants including metals and pesticides to water sources is usually material derived from human activities. In many areas natural rock substrates may also result in high levels of toxic metals but these rarely cause human health problems since natural cycles of weathering, transport, and deposition are slow processes. Thus the occurrence of metals and pesticides residues in the environment is a direct manifestation of loss during manufacture, transport, and use thereof.

Metals

The Lake Victoria basin is well endowed with mineral wealth because of the auriferous deposits. The rocks of the Lake Victoria Gold Fields (LVGF) are chiefly granite-greenstones (Bell and Dodson, 1981). These greenstones and the associated sediments have a high potential for gold and base metal deposits (Condie, 1981; Anhaeusser, 1984). In the southern and eastern parts of Lake Victoria basin, gold mineralisation in association with other metals commonly occurs in the greenstones. Auriferous deposits in LVGF are reported to be hosted in sulphides such as pyrite, chalcopyrite, pyrrhotite, arsenopyrite or even in traces of galena and sphalerite (Kahatano and Mnali, 1997), Therefore gold mining activities may release considerable amounts of Cu, As, Pb and Zn into the environment. Gold ore processing activities include excavation of the soil, crushing the rocks and washing of the powdered rock to concentrate the ore. Metals in the excavated waste rock and tailings are easily leached by runoff. Lake Victoria gold fields comprise a number of gold mines that are located to the south and east of Lake Victoria in Northern Tanzania. Between 1930 and 1950s, gold mining in LVGF was being conducted by registered small and medium scale companies as well as by individuals. Both medium and small-scale miners use mercury in the purification of gold. Because of this long history of mining and mercury usage in gold ore purification there is a high probability of considerable accumulation of metals in Lake Victoria basin. In fact, there are reports showing that mercury is being released in large quantities into the environment in Lake Victoria basin from gold mining operations (Nriagu, 1992; van Straaten 2000a; 2000b). Mercury is lost to the atmosphere, soil, waters and sediment. Several workers (e.g. DHV consultants. 1998; van Straaten, 2000a; 2000b; Campbell, 2001; Ikingura and Akagi, 2002a) have documented pathways, receptors, controls, and fate of mercury the mining activity releases into the environment. On the contrary, studies that have been conducted between 1996 and 2004 (Ikingura and Akagi, 1996; Migiro 1997; DHV consultants 1998; van Straaten 2000a; 2000b; Ikingura and Akagi, 2002a; Campbell *et al*. 2003; Machiwa *et al.*, 2003; Machiwa, 2003a; 2004; Kishe and Machiwa, 2002) do not indicate a pronounced mercury and other heavy metals pollution in Lake Victoria because of gold mining activities in the basin. However, there is clear evidence that mining activities have led to accumulation of metals in the environment immediate to the mines (DHV consultants 1998) and in wetland soils receiving discharges from mining areas (DHV consultants 1998; Machiwa, 2003b). Nevertheless, in this particular case, it is true that pathways, receptors, controls and fate of mercury released into the environment by LVGF mining activities are not well construed. Hence, more studies are required to assess the extent of loss of mercury to water, soil, tailings and atmosphere in the Lake basin Also studies to determine the amount of mercury that actually reaches into Lake Victoria and its fate in the lake are lacking. Indeed, there are unknowns in the mercury budget of the lake, the significant one and that has not received adequate attention is atmospheric input from mining and biomass burning activities. Also input of mercury through groundwater flows from contaminated aquifers is still a gray area.

Pesticides

Pesticides include agrochemicals such as fumigants, fungicides, herbicides, insecticides, and rodenticides and others to mention few. These are used in the production of both crops and livestock (Arnold, 1992). They are used to increase quality and quantity of crop produce. The chemicals can also be used to maintain public health (rodents and mosquitoes etc) animal welfare and definitely improve economy of farmers (Arnold, 1992). However, there is also a negative side of agrochemicals, which includes, destruction of biodiversity and causing poisoning of humans when used inappropriately. Agrochemicals when sprayed to crops (in case of pesticides) will kill pests as well as predators. For Example, killing aphids will kill ladybirds (predators) and surviving aphids can invade the sprayed area and cause more danger to the crop (Knight et *al*, 1989). What ever the reason, safe use and handling of Agrochemicals will always reduce hazards to human health and environment (Arnold, 1992). Many chemical compounds have been used to improve both crop and livestock production and many more others are being recommended for use to day. The eco-toxicological effects of intensive use of persistent organo-hlorine pesticides such as DDT, Toxaphane, heptachlor and 'drins' were noticed in early 1960's and gradually, use of these compounds has been discontinued. Within the insecticide group, Organophosphate compound and pyrethroids had undergone increased use, partially compensating for the declining usage of organo-chlorine pesticides.

The use of pesticides in the lake basin dates back to the colonial era when they were meant to control pests for important cash crops. In the late 1960s and beyond, organo- chlorine compounds such as D.D.T. were greatly used particularly in cotton production and health sanitation in Towns (Musabila, 2000). As cotton and coffee are major cash crop consumers of pesticides, different types of pesticides had been introduced for use in the last few decades. It can be noted from table 01 that from 1990/91 to 1995/96, more than 15 formulations of pesticides were introduced in Mwanza region to control pests in cotton fields. Organo-chlorine pesticides have been used for crop protection (mainly cotton) and protection of livestock against ticks. Extensive use of pesticides in cotton fields occurs mainly between the January and April. These pesticides have found their way to the environment and aquatic organisms. For example, according to Ijani *et al* (1997), analytical results from the tissues of the African fish eagles collected from lake Victoria area, showed that the kidneys were contaminated with *p,p´*-DDE and o,*p´*,-DDE and these organochlorine pesticides, and beta-HCH were also present in the brain and liver tissues.

Table 1: List of Common Pesticides in Mwanza Region during 1990/91-1995/96

Names of pesticide	Years ('000) Liters					
	1990/91	**1991/92**	**1992/93**	**1993/94**	**1994/95**	**1995/96**
Thiodan	131.70	583.68	484.80	477.801	22.80	46.00
U-Kombi 50% U.L.V.	47.70	155.19	-	-	-	-
Ripcord (Cypermethrine)	224.32	202.63	270.00	280.00	60.00	-
Sumicidin 3% U.L.V.	86.36	143.71	179.80	158.80	-	-
Cymbush 3% U.L.V.	15.00	-	102.40	50.00	84.00	-
Politrin 1.8% U.L.V.	-	98.00	57.60	90.00	103.00	10.40
Karate 0.6% U.L.V.	-	89.33	95.00	100.00	39.00	36.20
Melcypermethrine	-	3.00	37.40	5.00	160.00	-
Bulldog	-	-	-	80.00	64.00	10.00
Nuselle	-	-	-	-		37.00
Fasgac	-	12.40	20.00	-	-	-
Decis	-	-	-	24.60	45.00	24.60
Fenom C	-	-	-	25.20	75.00	15.60
Karate 2 ED	-	16.34	10.00	20.000	33.00	--
Cymbush 6 ED	-	19.29	2.52	-	-	-
Total	**505.08**	**1,323.58**	**1,253.52**	**1,311.40**	**891.00**	**179.80**

Source: Tanzania Cotton lint and Marketing Board, 2000

The purpose of this report is to give an overview of the status of heavy metal (with emphasis on mercury) and pesticide pollution in Lake Victoria basin.

METHODS

The methods applied in the collection of data and information on heavy metal and pesticide pollution are as follows:

2.1 Metals

Sampling sites

The studies conducted so far have generally covered the whole Lake Victoria basin (Tanzanian part) with historical and current gold mines. Samples collection has covered a large part of the lake basin particularly areas potentially exposed to metal pollution from mining and non-mining activities.

Sampling and Analysis

(a) Sediment and soil samples

Sediment samples were retrieved from the lake bottom by grab sampling or box coring. The samples were frozen at -20^{o} C until they were analysed. Samples were freeze dried or oven dried and homogenized (Machiwa, 2000). Heavy metals were determined by atomic absorption spectrophotometry after strong acid digestion. In few studies a non -destructive technique (scanning Sequential X-Ray Fluorescence) was been used.

Fish samples

Fish were filleted to remove portions of muscle tissues from both sides of fish using stainless steel blades. Fish tissues were stored at -20^{o} C, metals in wet samples were analysed by using an atomic absorption spectrophotometer or a semi-automatic mercury analyzer after strong acid digestion.

Quality assurance/Quality control

Certified Reference Materials (CRMs), PACS-2 and DORM-2 from National Research Council Canada as well as BCR-143R and BCR–422 from Institute for reference Materials and Measurements (Belgium) were used for QA/QC purposes in some of the studies.

Pesticides

In this chapter, Agro-chemicals specifically refer to pesticides. The methods for Inventory of Agro-chemicals, Agro-chemical Use and Handling, and Pesticide residues in the Simiyu catchment and Speke gulf are as follows:

Inventory of Agro-chemicals in Lake Basin

The study on inventory of Agro-chemicals covered the regions of Shinyanga, Mwanza, Mara and Kagera, and it was meant to contribute towards increased knowledge on the agro-chemicals used in the Lake Victoria Basin, and provide baseline data. The study relied on primary and secondary information from all possible sources. These included literature review, interviews and discussions with key officials and staff from government institutions and NGOs dealing directly or indirectly with agro-chemicals, and private agro-chemical stockists; and site visits and discussion with farmers.

Agro-chemical Use and Handling (Pilot Study)

The study was carried out in Magu District – Mwanza region to examine the status of Agro-chemical use and handling by farmers, and their potential risks to human and ecosystem health. Villages in fourteen (14) wards of Magu district (pilot area) were randomly selected based on their involvement in the production of both field and horticultural crops. Also included in the study was the Buswelu settlement (in the outskirts of Mwanza City) for its intensive production of horticultural crops. Data collection was carried out through interviews and questionnaires for farmers, extension workers, and input stockists.

Pesticide residues in Simiyu catchments and the Speke gulf.

Study area

The studies were carried out in the Simiyu catchment located in the south east of Lake Victoria, and in the Speke gulf where the Simiyu discharges. The Simiyu catchment was considered to be one of the main contributors to the deterioration of Lake Victoria quality, because it is a relatively large catchment (10,800 km2), with many agricultural activities, using agrochemicals (LVEMP, 2000) and generating high yields of sediments (Machiwa, 2002).

(a) Simiyu Catchment

The Simiyu catchment is located in the south-east of Lake Victoria and is drained mainly by the Simiyu river.Short rains fall in November through December, and long rains in March to

May. The river is ephemeral with a maximum discharge of about $210m^3s^{-1}$ during long rains and zero discharge during the dry season in August-September. The main activities in the catchment are cattle rearing and cotton farming and the pesticides commonly used are mainly pyrethroids followed by organophosphorus and organochlorines . The pesticides are usually applied in January through April (Rwetabula, 2004).

(b) Speke gulf

The Simiyu river discharges into the Speke gulf located in the south east of Lake Victoria**.** The gulf has a surface area of about 2400 km2 (Rwetabula, 2004) and amaximum depth of about 40m (Machiwa, 2002). The gulf water circulation and transport are generally turbulent as aresult of the strong winds of June to August. In the river mouth (Magu Bay), the river water inflow is also a major driving force of circulation and transport (LVEMP, 2002).

Sample collection and analysis

Extensive field measurements were carried out in May 2002 by establishing twelve (12) sampling stations in the Simiyu catchment (Figure 01), and eight (8) stations in the Speke Gulf (Figure 02). Water samples were collected *et al* using grab sampler (Van Dorn) in the middle of the river at mid-depth for each sampling station. These were collected in triplicate, for determination of pesticides. Sampling and preservation were carried out according to the standard (Åkerblom, 1995; Greenberg, 1992) procedures, and transported immediately to the laboratories for analysis. Pesticides analysis was done as described by Åkerblom (1995). Varian Star 3400 and Hewlett Packard 5890A gas chromatographs equipped with 63Ni Electron
Capture (EC) and Nitrogen-Phophorous (NP) detectors were used for the analysis.

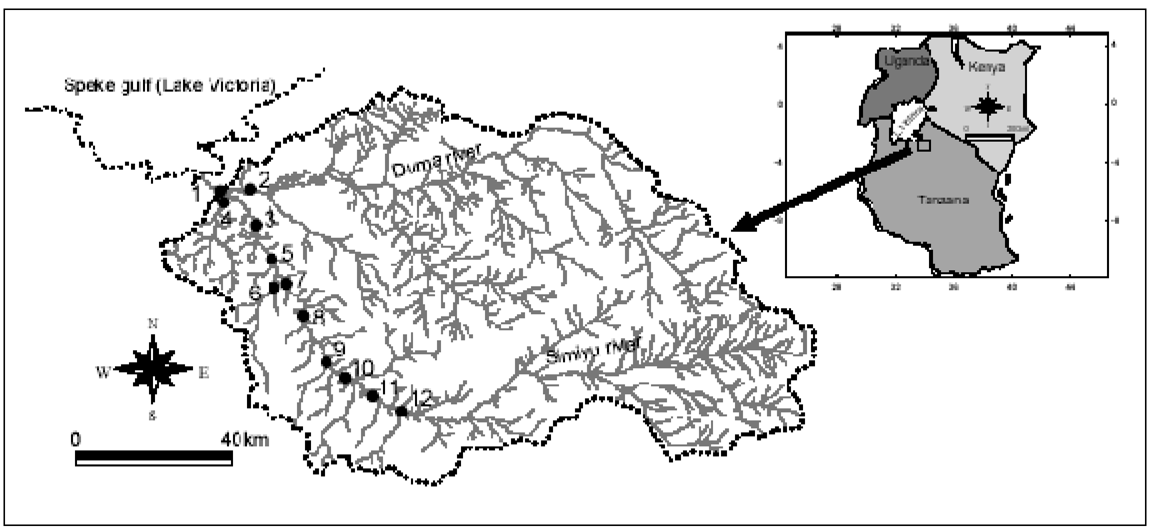

Figure 01: Simiyu river and its catchment area with the twelve sampling stations

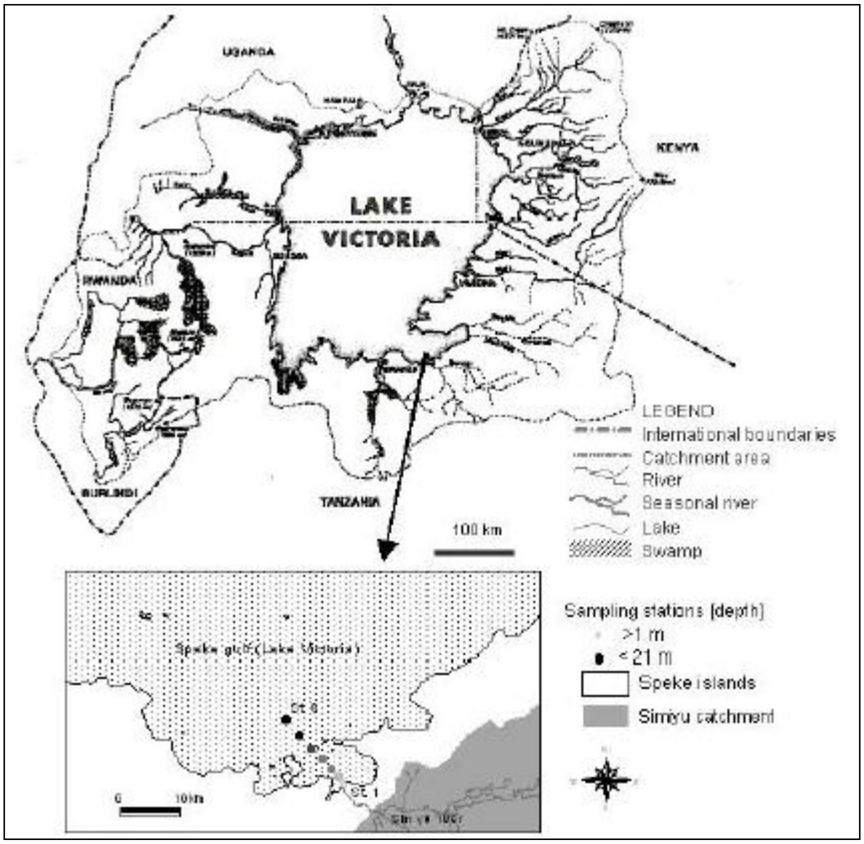

Figure 02: Sampling stations in the Speke Gulf

RESULTS AND DISCUSSION

Metals:

Mercury Concentration in River water and sediment in Lake Victoria basin

According to the Tanzanian water quality standards, mercury in drinking water should not exceed 1 ppb. Only one stream water sample that was collected at Lwamgasa had mercury concentration above 1 ppb.

Total mercury concentration in soil and river sediments in mining areas is generally low except in specific locations where mercury was being used by artisanal miners. Mercury concentration in river sediment was generally low, < 0.01 ppm to about 1 ppm. However, there are few "hotspots" such as Tigiti River where some sediment samples contained 36 ppm, Nyangwe River (13 ppm) and Ikungu beach (13 ppm). In these areas it is likely that the high mercury in the sediment is a result of gold ore processing by artisanal miners.

Heavy metals in Lake Victoria water and sediment

The concentration of arsenic in sediment samples is generally low, below the average value (6 $\mu g\ g^{-1}$ dw) for continental soils (Chester, 1990). Sediment samples from Isanga River mouth, Magu Bay and Suguti inshore area had concentrations of arsenic close to 6 $\mu g\ g^{-1}$ dw. Sediment samples from Mirongo River mouth, Mori Bay and Ikungu had arsenic content below the limit of detection (0.01 $\mu g\ g^{-1}$). The concentration of cadmium ranges from 0.1 to

2.3 μg g^{-1} dw. The average concentration of Cd in continental soils is 0.35 μg g^{-1} dw (Chester, 1990). Lead concentration in sediment samples ranges from 1.2 to 59.1μg g^{-1} dw. The average value for Pb in continental soils is 35 μg g^{-1} dw (Chester, 1990). Zinc concentration in the lake sediments ranges from 35.1 to 189.7 μg g^{-1}. According to Chester (1990) the average concentration of Zn in continental soils is 90 μg g^{-1} dw. Copper concentration in the lake sediments ranges from 5.3 to 48.3 μg g^{-1}. The average concentration of copper in continental soils is 30 μg g^{-1} dw (Chester, 1990).

Total mercury concentration in lake water is generally below 1 ppb. The highest concentration of total mercury was recorded in inshore waters at Ikungu (5.05 ppb). Other areas that had total mercury concentration in lake water close to 1 ppb were Lukumbo (1.02 ppb), Simiyu river mouth (0.9 ppb), Mirongo river mouth (1.46 ppb), Suguti (1.10 ppb) and Shirati Bay (0.82 ppb). Mercury concentration in lake sediments from inshore areas is generally less than 0.01 μg g^{-1} dw except at few locations (Ikungu, Magu Bay and Mori Bay) where the concentration is approximately 1 μg g^{-1} dw in some samples.

Heavy metals in wetland soils and crops in Lake Victoria basin

Total mercury was alarming in a sample of tubers growing adjacent to the sluice area of Samina (Machiwa 2003b). A sample of yam had 1.9 ppm, but none of the sugarcane juice samples contained total Hg > 0.01 ppb. For rice grain samples, there was no significant difference in total mercury concentration in samples collected from farms in wetlands of rivers draining areas with and without gold ore processing activities. The range of total Hg in rice samples was from 0.05 to 0.38 μg g^{-1} dw.

Concentrations of heavy metals in fish

Arsenic

The study that was conducted by Machiwa (2003a) showed that arsenic concentration in all the analysed fish species was below the limit of detection (0.01 ng g^{-1} ww).

Cadmium

Nile perch samples that were collected, weighed between 0.008 kg and 88.3 kg and total length ranged from 9.8 cm to 182.5 cm. Cadmium was generally low in the flesh of Nile perch, ranging between <0.001μg g^{-1} ww and 0.05 μg g^{-1} ww. In samples from inshore waters, cadmium concentration in *Lates niloticus* edible parts was highest (0.005 μgg^{-1} ww) in fish that were fished adjacent the Mirongo River mouth and lowest in *L. niloticus* from Mori and Shirati Bays. There was no significant difference in Cadmium content of *L. niloticus* from fishing areas of the lake that are within and away from catchments with gold mining activities in both Mwanza ($P = 0.085$) and Mara ($P = 0.086$) Regions. However, the concentrations of Cadmium in the < 15 kg Nile perch were significantly different ($t = 2.594$, $P = 0.018$) between samples from Mwanza (0.013±0.006 μg g^{-1} ww) and Musoma (0.006±0.001μg g^{-1} ww). There was no significant relationship ($r = - 0.1337$, $P = 0.151$) between concentrations of Cadmium in muscle tissues and weight of fish.

Highest Cadmium concentration (3.49±0.23 μg g^{-1} ww) in *Oreochromis niloticus* was recorded in fish from the southern tip of Mwanza Gulf, close to the Isanga River mouth. Specimens of *O. niloticus* from Shirati Bay had the lowest Cd content of 0.14 μg g^{-1} ww. Nevertheless, Cd content of *O. niloticus* from fishing areas within and outside catchments that have gold mining activities was not significantly different both in Mwanza ($P = 0.908$) and Mara ($P = 0.884$) Regions.

For the minor fish species that are rarely caught by fishers, the highest concentration of cadmium (3.65±1.13 ng/g ww) was found in *Clarias gariepinus* from adjacent to Isanga River mouth and lowest (1.72±0.41 ng g^{-1} ww) in specimens from Mara Bay. The haplochromines were collected from only few locations and the specimens had relatively higher Cadmium concentration (> 3 ng g^{-1} ww) than most of the sampled minor fish species. Samples of other fish species such as *Schilbe intermedius*, *Synodontis victoriae*, *Brycinus* spp and *Labeo victorianus* from Magu Bay had almost same concentrations of cadmium (ca. 2 ng g^{-1} ww).

Lead

The concentration of lead in *L. niloticus* muscle tissues was low. In most of the fishing areas it was below or just above the detection limit (0.01 μg g^{-1} ww), ranging between <0.01 μg g^{-1} ww and 0.19 μg g^{-1} ww. The highest Pb concentration (0.13±0.04 μg g^{-1} ww) was found in *L. niloticus* specimens from the lake adjacent to Mirongo River mouth.

The concentration of lead in *O. niloticus* muscle samples was below the limit of detection (0.01 μg g^{-1}), only few specimens had concentration close to 0.1 μg g^{-1} ww. For the minor fish species that are rarely caught by fishers Lead concentration was generally low (from < 0.01 to 0.1 μg g^{-1} ww), in most of the minor fish species. The highest concentration (3.62 μg g^{-1} ww) of lead was found in the Haplochromines fished in Mara Bay.

Zinc

The concentration of zinc in the flesh of Nile perch ranged between <0.01 μgg^{-1} ww and 18.94 μgg^{-1} ww. Like Cd, the concentration of Zn in the < 15 kg Nile perch was statistically higher (t = 4.647, P = <0.0001) in Mwanza (6.53±0.63 μg g^{-1} ww) than in Musoma (3.49±0.24 μg g^{-1} ww) samples. There was no significant relationship (r = - 0.0145, P = 0.877) between concentrations of Zn in muscle tissues and weight of fish. The difference between Zn concentration in *L. niloticus* from lake areas that are within and outside catchments with gold mining activities both in Mwanza (P = 0.158) and Mara (P = 0.104) Regions was not significant.

The highest zinc concentration (14.1±8.1 μg g^{-1} ww) in *O. niloticus* muscles was recorded in samples fished in Mwanza Gulf, adjacent to Mirongo River mouth in the city of Mwanza. *O. niloticus* from Suguti fishing area had the lowest Zn content (2.6±0.5 μg g^{-1} ww) in their muscles. There was no significant difference (P = 0.629) in Zn content of *O. niloticus* from fishing areas within and away from catchments having gold mining activities in Mara Region. In Mwanza Region *O. niloticus* from fishing areas outside catchments with gold mining activities had significantly high Zn content (P = 0.030). However, if *O. niloticus* from Mirongo River mouth were excluded, the difference in Zn content of *O. niloticus* from fishing areas within catchments with gold mining activities and those without was not significant (P = 0.268).

For the minor fish species that are rarely caught by fishers The mean concentration of zinc in *C. gariepinus* ranged between 11.4 and 5.0 μg g^{-1} ww, the highest concentration (22.3 μg g^{-1} ww) was found in specimens from Magu Bay. Zinc was also high in Haplochromines from Mori Bay (17.2 μg g^{-1} ww) and Mara Bay (14.3 μg g^{-1} ww). *Labeo victorianus* and *Brycinus* spp. that were fished in Magu Bay also had concentrations of same magnitude as the Haplochromines.

Copper

The concentration of copper in the muscle tissues of Nile perch was low, ranging between 0.01 μgg^{-1} ww and 0.97 μgg^{-1} ww., the higher Cu concentrations (> 0.7 $\mu g\ g^{-1}$ ww) were obtained in *L. niloticus* that were fished close to the Mirongo River mouth and Luchelele area (about 15 km from Mwanza city centre). The concentrations of Cu were not significantly different in *L. niloticus* from areas closer and away from gold mining activities in Mwanza (P = 0.196) and Mara (P = 0.173) Regions

Samples of *O. niloticus* from adjacent the Mirongo River mouth and Nyikonga had copper concentration of 0.5 $\mu g\ g^{-1}$ ww, samples from other fishing areas had concentrations of about 0.2 $\mu g\ g^{-1}$ ww in their muscles. Generally livers of both *L. niloticus* and *O. niloticus* contained higher concentration of the analysed heavy metals compared to the muscles. For the minor fish species that are rarely caught by fishers Copper concentration was highest in *S. victoriae* that was fished in Mori Bay (0.8±0.2 $\mu g\ g^{-1}$ ww) and *C. gariepinus* (0.7±0.1 $\mu g\ g^{-1}$ ww) of Mwanza Gulf, adjacent to the Mirongo River mouth. The concentration of Cu was consistently low (< 0.5 $\mu g\ g^{-1}$ ww) in most of the minor fish species from the majority of fishing areas.

Mercury

Nile perch samples collected weighed between 0.008 kg and 88.3 kg and total length ranged from 9.8 cm to 182.5 cm. The fish samples had total mercury concentration ranging between < 0.01 ng g^{-1} ww and 684.2 ng g^{-1} ww. The larger specimens (most likely longer lived) generally had higher total mercury concentration compared to the smaller samples. Kruskal-Wallis statistic showed a significant difference in the concentrations of total mercury among the weight groups (H´ = 48.022, P < 0.0001). The relationship between total length and weight of Nile perch fitted a power function. The concentration of total mercury in Nile perch weighing less than 10 kg was below the WHO recommended limit (200 ngg^{-1} ww) for at risk groups (frequent fish eaters, pregnant women and children). For fish > 10 kg none had total Hg concentration in muscle tissues exceeding 1000 ng g^{-1} ww. The ratio between females and males in the sample was 1:1.07. The concentration of total mercury in Nile perch muscle tissues related linearly (r = 0.627, P = <0.0001) with fish weight (Fig. 1). The mean concentration of total mercury in *L. niloticus* from Shirati Bay (which is remote from gold mining areas) was not significantly different (P >0.05) from values for *L. niloticus* samples from other sampling sites including those that were closer to mining areas. There was no significant difference (P > 0.05) between Total mercury concentration in *L. niloticus* from L. Victoria in Mwanza and Mara sampling locations. However, highest total mercury concentration was obtained in *L. niloticus* collected from Nungwe Bay, followed by samples from areas close to Isanga and Mirongo River mouths. In Mara Region, *L. niloticus* from Mara Bay adjacent to the mouth of Mara River had the highest total mercury concentration and samples from Shirati Bay had the lowest concentration.

Oreochromis niloticus and the minor fish species such as *Labeo victorianus* all had low mercury concentration, below 500 ngg^{-1} ww, the limit established by FAO/WHO (1999). The FAO/WHO methylmercury guideline level for non-predatory fish is 0.5 μg/g ww and for piscivorous fish such as *L. niloticus* is 1.0 μg/g ww

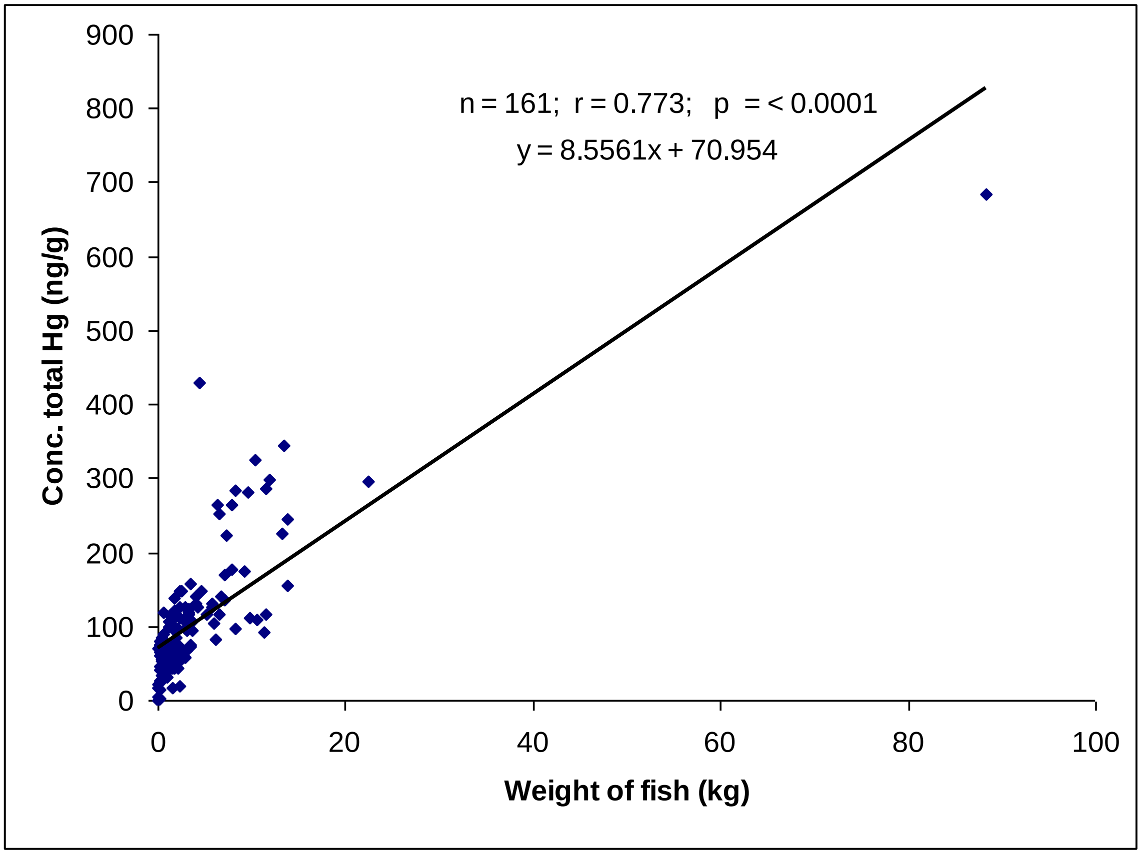

Figure 03: Relationship between the concentration of total mercury and body weight of Nile perch (Machiwa *et al*. 2003; Machiwa, 2004)

Heavy metals in rivers and wetlands in Lake Victoria basin

It has been reported by DHV consultants (1998) that heavy metal content (including Hg) in the immediate surrounding of the Bulyanhulu artisanal gold processing area and in sediments in the upper reaches of Bulyanhulu river were high as a result of Hg usage. Bulyanhulu stream sediments from certain locations had values as high as 5.35 ppm compared to background concentration of 0.01 - 0.02 ppm. However, overwhelming reduction of Hg content in the stream sediments occurred after flowing through the Igonzela swamp (from 3.37 ppm to 0.17 ppm at 3 km from the source, down to 0.01 ppm after draining through swamp). This observation overemphasizes the great need to preserve swampy areas around the lake.

DHV consultants (1998) observed that mercury levels in fish and water from Isanga River system were generally low. In the case of fish, mercury in fish from Isanga River was highest in specimens collected further upstream closest to the point source (Mahinga swamp) and lowest furthest from the point source (at the mouth of Isanga River) in southern part of Lake Victoria. According to DHV consultants (1998), fish tissues from specimens collected at the southern tip of Lake Victoria (Smith Sound) had very low Hg content (< 40 ppb). The study showed that cichlids that occupy a lower trophic level had generally lower Hg concentration in their livers and muscle compared to lungfish. In all cases, liver sample contained higher Hg concentration than muscle of the same fish.

Heavy metals levels in Lake Victoria water and sediments

Arsenic has rarely been determined in sediments of Lake Victoria despite its association with auriferous ores such as arsenopyrite (Kahatano and Mnali, 1997). The only available data

(Makundi 2001) show elevated levels (up to 498±13 ppm) of As in Lake Victoria sediments adjacent to Mwanza city. The results from Machiwa (2003a) indicate low concentration values for As in the lake sediments (< 0.01 – 6 ppm), suggesting the need to include quality assurance/control measures in the analytical protocol.
The results from recent studies indicate low concentrations of cadmium in the lake sediments both at locations that are within and outside catchments with gold mining activities (Makundi, 2001; Machiwa, 2003a; Kishe and Machiwa, 2001). Although Cd concentrations in some areas in the lake are above continental soil average, this reflects the high background level of Cd in the lake basin soils.

Lead concentration in lake sediment was highest in areas that are closer to the city of Mwanza than anywhere else. In lake sediment samples collected close to Mwanza city, Kishe and Machiwa (2001) obtained lead concentration of 54.6±11.1 $\mu g\ g^{-1}$ dw, similar to 58.1±17.6 $\mu g\ g^{-1}$ dw the results obtained by Machiwa (2003a). The higher Pb concentration in lake sediment closer to the city indicates influence of fossil fuel burning and municipal runoff.

Copper and zinc have their highest concentration in sediments adjacent to Mirongo River mouth. Copper concentrations are slightly above the average for continental soils and Zn concentrations were double the continental soil average. Copper and Zn are metals that are strongly connected with technological development, hence the elevated levels adjacent to Mirongo River mouth suggests municipal sources, such as industrial effluent and runoff. Copper and Zn pollution of the lake via Mirongo River appears to be an emerging threat. The available data suggest that gold mining is not a significant source of Zn and Cu in the lake. The current heavy metal levels in the Tanzanian part of Lake Victoria is of equal magnitude as that reported in other parts of the lake, for instance, Mothersill (1976) in the Ugandan portion, and Onyari (1985) in the Kenyan portion. The study by Machiwa (2003a) concluded that generally the concentrations of metals in lake sediments close and away from gold mining activities are not statistically different.

Contamination of Lake Victoria fish with heavy metals
So far, there is still paucity of information on heavy metals concentrations in fish from Tanzanian waters of Lake Victoria. Previous reports on heavy metals (apart from Hg) in fish of Lake Victoria includes Mohammed (2000) and Kishe (2001). These reports gave concentration values that are a bit high compared to results of Machiwa (2003a) especially for copper, lead and zinc. Only Machiwa (2003a) included CRMs in the analytical protocol, to a greater extent improving the reliability of the results.
Generally, the concentrations of Cd, Pb, Zn and Cu were low in all fish species. The more or less equal concentrations of Pb, Cu and Zn in fish from fishing areas located close and away from areas of mining suggest that levels of these metals in fish are not influenced by mining activities.

Tuzen (2003) has reported very low heavy metal content in non-carnivorous marine fish from the middle Black Sea. The concentration of Cd ranged between 0.03 and 0.14 $\mu g\ g^{-1}$ ww, Pb ranged between 0.06 and 0.26 $\mu g\ g^{-1}$ ww, Cu ranged between 0.4 and 0.9 $\mu g\ g^{-1}$ ww and Zn ranged between 2.9 and 6.9 $\mu g\ g^{-1}$ ww. With the exception of Cd that was high in the marine fish, the concentrations of lead, copper and zinc are of equal magnitude as that of Lake Victoria fish. The current studies therefore, indicate that gold mining activity in the lake basin has little influence on current concentrations of heavy metals (As, Cd, Cu, Pb and Zn) in fish. The metal concentrations are equally low in Lake Victoria fish from areas close and away from gold mining activities.

Typical background levels of total Hg in freshwater fishes from non-polluted areas range from 100 ngg^{-1} to 200 ngg^{-1} ww (WHO, 1976), although Hg concentration in large carnivorous species can be as high as 800 ngg^{-1} ww. A recent study by Machiwa (2004) and Kishe and Machiwa (2002) show that Nile perch of LV has low mercury content, generally within the permissible limit (WHO, 1976; 1989; 1990; FAO/WHO, 1999) of 500 ngg^{-1} ww (or 1000 ngg^{-1} ww for the piscivorous fish). Indeed, Nile perch that weigh less than 10 kg have less than 200 ng total Hg g^{-1} ww and are safe for regular consumption by the at risk groups such as children and pregnant women (WHO, 1990). Campbell et al. (2003a) also reported that Nile perch usually have total Hg below the WHO limit except when they approach a weight of 10 kg. The recently introduced "slot size" regulation in Tanzania ensures that only Nile perch of total length between 50 and 80 cm (>2 kg and <8 kg) reach local and international markets, making Nile perch absolutely safe for human consumption. Actually the recent results augment previous findings by other workers who observed low levels of total Hg in fish from Lake Victoria (Ikingura and Akagi, 1996; Harada et al., 1999), from rivers (DHV consultants, 1998) and from hydroelectric dams (Ikingura and Akagi, 2002b). The studies acknowledge good linear relationship between total Hg concentration and size of Nile perch, similar to the observation by Farkas et al (2003) in a freshwater fish *Abramis brama* and de Pinho *et al*. (2002) in marine fish. as well as by Szefer et al. (2003). The researchers confirm that feeding habit influences metal concentration in fish. The accumulation of mercury in fish flesh is a result of biological concentration through the food chain. Piscivorous species have highest total Hg and methyl mercury compared to species that feed mainly on small invertebrates. In the case of the proportion of $MeHg^{+}$ to total Hg, piscivorous fish generally contain a higher proportion (~ 90%) of $MeHg^{+}$ compared to their non-fish eating counterparts (~ 75%), even within the same family (de Pinho *et al*. 2002). Nevertheless, it has been observed that biomagnification of mercury by the top predator in Lake Victoria is not severe because of what Campbell et al. (2003b) summarized as: Short food chain length in Lake Victoria that minimizes biomagnification steps between trophic levels; Rapid and consistent fish growth ensuring higher tissue production that acts as a diluent to the body burden of mercury; The available mercury is partitioned between the large amount of organic matter (living, dissolved and particulate) present in Lake Victoria, ensuring just meager share to each component; The not yet well-construed biogeochemisty of mercury in Lake Victoria may be favoring the existence mercurial compounds that are not readily available for biotic uptake.

Ikingura and Akagi (1996) found rather lower concentrations of total Hg in *L niloticus* from Nungwe Bay, the range was 6.9 – 11.7 ngg^{-1} ww, the authors did give morphometric data of their samples. Machiwa (2003) observed that the concentration range of total Hg in *L niloticus* from Nungwe Bay was 95.1-395.9 ngg^{-1} ww. This apparent increase of total Hg in Nile perch from Nungwe Bay calls for the need of periodic monitoring, so as to ascertain the levels and to allow sufficient time to take appropriate measures. The study by Machiwa *et al.* (2003) showed that mercury concentration in fish from areas suspected to be affected by mining activity and areas that are remote from mining activity was not significantly different ($P > 0.05$). The observation probably confirm the suspected regional/global atmospheric deposition as a possible route for mercury to Lake Victoria.

Following the survey in Nungwe bay, Ikingura and Akagi (1996) concluded that there was no increased exposure to mercury (THg and $MeHg^+$) from LVGF by the local fish eating community at Nungwe Bay. DHV consultants (1998) also observed that Hg was a problem to people who use it directly. Fishers and their families even close to mining areas are not at a high health risk. The survey results concluded that it was unlikely that the local communities who consume small fish caught in Lake Victoria in the vicinity of mining areas and in contaminated rivers draining from gold mining areas are over exposed to mercury. Also other studies (Harada *et al*., 1999; Appleton *et al*., 2004; Taylor *et al*., In press) have indicated low human exposure to mercury pollution in Lake Victoria basin, with the exception of those who are in direct contact with it.

Pesticides:

Inventory of Agro-chemicals in the Lake Victoria Basin and a Pilot Study on Agro-chemical Use and Handling.

A summary of the quantities of pesticides used in the Lake Victoria basin during the period 1986/87 through 1999/2000 is given in table 02. However, it was observed that with liberalization of trade it had become increasingly difficult to obtain the quantities of pesticides applied in the basin. The chemicals were obtained from different sources within and outside the country and records of the quantities were not readily available. Actually, the stockists failed to give actual figures of agro-inputs. Pesticides mostly consumed were organo-chlorines (thiodan, thionex and bravo), and pyrethroids (ripcord, karate and bulldog).

Table 02: Summary of Agrochemicals distribution and use in Lake Victoria Basin (1986/87-1999/2000).

Region	**Pesticide**		**Fertilizer**
	Litres	**Kgs**	**Tons**
Shinyanga	8,587,264	21,548	6,16**8**
Mwanza	6,391,995	55,346	2,520
Kagera	95,570	45,926	6,566
Mara	3,741,831	1,525,850	2,913
Total	**18,816,660**	**1,648,671**	**18,166**

Source: LVEMP- Inventories of Agrochemicals in the Lake Victoria Basin.

. The major consumers of agro-chemicals were major cash crops namely cotton and coffee and the pesticides recommended for use in the Lake Basin are given in table 03 below.

Table 03: List Of Pesticides Recommended For Use In The Lake Basin

Name of pesticide		Formulation	Appl. rate g a.I/h	Date recommended	Pests controlled
Common	Trade				
Endosulfan	Thiodan	25% ULV*	625	October, 1972	ABW SBW, Aphids (moderate control),
Endosulfan	Thonex	25% ULV*	625	October, 1974	Jassids, Lygus and Helopeltis
Permethrin	Ambush	5% ULV*	125	29th Oct.1981	ABW, (SBW), Aphids, Jassids, (Lygus)
Permethrin	Ambush	25% EC**	75	29th Oct.1981	(Helopeltis), (Dysdercus), (Calidea)
Cypermethrin	Ripcord	1.8% ULV*	45	Oct-88	
Cypermethrin	Polytrin	1.8% ULV*	45	Oct-89	
Cypermethrin	Cypaz	1.8% ULV***	45	Oct-86	ABW, SBW, Aphids, Jassids, Lygus
Cypermethrin	Melcypermethrin	1.8% ULV***	45	Oct-90	(Dysdercus), (Calidea-moderate control)
Cypermethrin	Sherp	1.8% ULV***	45	Oct-89	Stainers, Helopeltic-moderate control
Cypermethrin	Pyrexcel	1.8% ULV***	45	Oct-89	
Cypermethrin	Nurelle	1.8% ULV**	45	Oct-88	
Cypermethrin	Cymbush	1.8% ULV**	45	Oct-89	
Cypermethrin	Cymbush	10% EC**	45	Oct-88	
Fenvalerate	Sumicidin	3% ULV*	75	14th Nov.1984	ABW, SBW, Aphids, Jassids, Lygus
Fenvalerate	Sumicidin	20% EC**	75	14th Nov.1984	(Dysdercus), (Calidea)
Flucithrinate	Cybolt	1.7%ULV*	42.5	30th Oct.1986	(Pink bollworm), American bollworm,
Flucithrinate	Cybolt	10% EC**	42.5	29th Oct.1988	Aphids, Lygus, Jassids, Calidea, Dysdercus
Lambada Cyhalothrin A	Karate	0.6% ULV*	15	27th Oct.1987	Cotton strainers,
Lambada Cyhalothrin A	Karate	5% EC**	20	29th Oct.1988	Pink bollworm, American bollworm,
Lambada Cyhalothrin A	Karate	2% ED*	7	27th Oct.1989	Aphids, Lygus, Jassids, Calidea, Dysdercus
Esfenvalerate	Sumi-Alpha	0.5%ULV***	12.5	29th Oct.1988	Spiny bollworm, American bollworm,
Esfenvalerate	Sumi-Alpha	2.5% EC**	20	27th Oct.1988	Aphids, Lygus, Jassids
Alphacypermethrine	Fastac	0.8% ULV**	20	27th Oct.1989	Sp.&A.bollworms, Jassids, Lygus, Stainers
Deltamethrine	Decis	0.3% ULV**	7.5	29th Oct.1989	Cotton stainers, (Whilte flies) Spiny,
Deltamethrine	Decis	0.5% ULV**	12.5	29th Oct.1981	(Pink and American bollworms
Deltamethrine	Decis	2.5% EC**	12.5	13th Oct.1983	Aphids and Lygus
Fluvalinate	Maurile	2% EC**	100	27th Oct.1989	(Spiny) & American bollworms, Calidea
Fluvalinate	Sandoz	2% EC**	100	27th Oct.1989	Aphids and Lygus
Biphenthrin	Talstar	2% ULV***	50	25th Oct.1991	Spiny & American bollworms, Calidea
Betacyfluthrin	Bulldog	0.5% ULV***	12.5	25th Oct.1991	Aphids and Lygus
Cypermethrin + Prophephos	Fenom C	1%+16% ULV***	25+400	25th Oct.1991	Spiny & American bollworms, Calidea Aphids, Jassids, Calidea, Lygus, Red spiders
Deltamethrin + Dimethoate	Decis D	0.6%+12% ULV***	7.5+300	25th Oct.1991	(Spiny) & American bolloworms, (Calidea) Aphids, Lygus,, Jassids, Calidea, (Dysdercus)
Flucithrinate	Cybolt	1.66% MEULV***	33.25	25th Oct.1991	Spiny & Ammerican bolloworms, (Calidea) Aphids, Lygus,, Jassids, Calidea, Dysdercus

Source:ARI-Ukiriguru Lake Zone, 2000

NB: 1. When the pest is enclosed it implies that according to the manufacturer the pest is controlled by

2. The formulations which are all ULV are to be applied at a rate of 2.5 litres per Hactre at a swath width of 4.5 metres 5x90 centimeters ridges, or 3x150 centimeters ridges,

3. The formulations wihci are all EC are to be applied at a rate of 1201 (chemical Solution + water) per hactre.

4. *Recommended for Eastern and Western area of the lake zone

5. 5. **Recommended for Eastern part of the lake zone only.

6. ***Recommended for Western part of the lake zone only

Currently horticultural crops along the lakeshores dominate the usage of Industrial agrochemicals in the basin due to ther ready market. It was further observed that farmers apply chemicals either at lower doses or higher doses, practices that have detrimental effects to human and Lake Victoria ecosystem health. Suppliers/Stockists were found to be unaware of the safe use and handling of agrochemicals. As a result of these findings, training of both farmers and input stockists on safe use and handling of agrochemicals was conducted**.** Seminars have been held in collaboration with National agricultural Institutions involving stockists, farmers and extension workers from Mwanza, Misungwi, Geita and Sengerema districts in Mwanza Region. A total of 2,572 stakeholders have been trained on various agrochemical management techniques. This includes integrated pesticide management (IPM), Integrated Plant Nutrition Management (IPNM), Organic farming, and proper agronomic practices. The results are encouraging, for example by using IPM techniques, the scouting method on cotton, sprayings were reduced from 6 times to 3 times per growing spray regime. This has led to reduced cost of production to farmers and reduced health and environmental risks.

Crops that accounted for greatest consumption and use of pesticides in the plot study area are cotton and horticultural crops. The study revealed that the pesticides applied are mainly carbonates, pyrethroids, the toxic organophosphorus and few organochlorines. The principal pesticides used in the study area in the 1999/2000 farming season are indicated in table 04. From the table it can be read that the farmers in the lake basin use large amounts of pesticides, as more than 400 litres and 130 kilograms of different pesticides were used by a small sample of 100 farmers. Since some of the farmers could not recall the amounts they had applied in their farms, the amount reported in the table should be less than the actual amount used. The use and handlng of pesticides vary greatly among farmers and in most cases there is mishandling and misuse of pesticides. The problem of misuse is a result of the farmers' inadequate knowledge with regard to use and handling of the chemicals which, again is a result of inadequate agricultural extension workers, and inadequate knowledge of the few extension workers available.

No proper disposal methods for used pesticides containers and as a result some are incinerated, or disposed of into pit latrines, but some are used for storage purpose e.g. for storage of kerosene, cooking oil and milk and drinking water.

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Table 04: Principal Pesticides Used in the Study Area (Kilograms/ Litres)

Trade Name	Common Name	Group	Type	Amount
Ripcord	Cypermethrin	Prethroid	Insecticide	120 lts
Thiodan/Thionex	Endosulphan	Organochlorine	Insecticide	160 lts
Fenom C/Selecron	Profenofos + Cypermathrin	Organophosphorus + Pyrethroid	Insecticide	80 lts
Sumicidin	Fenvalerate	Pyrethroid	Insecticide	8 lts
Bulldog	Betacyfluthnin 0.5% ULVA	Pyrethroid	Insecticide	24 lts
Karate	Lamada cyhalothrin	Pyrethroid	Insecticide	0.5 lts
Diazinon	Diazinon EC, WP,G	Organophosphorus	Insecticide	2.2 lts
Sumithion/Novathion	Fenitrothion	Organophosphorus	Insecticide	3.2 lts
Demethoate/Rogor	Aimethoate 40% EC	Organophosphorus	Insecticide	0.2 lts
Sevin or Sapa carbaryl	Carbaryl	Carbamate	Insecticide	0.5 lts
Blue copper (Cocide)	Copper hydroxide	Inorganic	Fungicide	40 kg
Dithane M-45	Mancozeb	Carbamate	Fungicide	25 kg
Cobox/BASF	Copper oxychloride	Inorganic	Fungicide	17 kg
Antracol	Propineb 70%	Carbamate	Fungicide	17 kg
Bravo	Chlorothalonil	Organochlorine	Fungicide	12 kg
Topsin/Cycosin	Thiophanate Methyl 70% WP or 40% ULVA	Carbamate	Fungicide	13 kg
Ridomil	Metalaxyl + Mancozeb 75 or 56%	-	Fungicide	2 kg

Pesticide residues in the Simiyu river.

The total concentrations of pesticides residues detected in the Simiyu river in both May 2002 and April 2003 are shown in Fig. 2. Two organochlorine pesticides, namely DDT (p,p'-DDT, o,p'-DDT, p,p'-DDE and p,p-DDD) and HCH (α,β,γ and δ- isomers), and one organophosphorous, Fenitrothion, were identified in the samples collected in May 2002. Three organochlorins, DDT (p,p-DDT and p,p-DDE), HCH (α, β and γ-isomers) and Endosulfan (α, β-isomers and sulphate) were detected in the samples collected in April 2003. DDT concentrations in the May 2002 and April 2003, ranged 0.01-0.85and 0.25- 1.18 μg/l respectively. p,p-DDT was the only chemical detected with peak concentrations of 0.85μg/l and 1.18μg/l. Also both p,p'-DDT and p,p-DDE were frequently detected in most of sampling stations suggesting recent use of DDT in the in Simiyu catchment. The concentrations of HCH in the May 2002 and April 2003, ranged 0.03 –12.26 and 0.08- 2.15μ g/l. The α–HCH and γ-HCH were the most frequently detected pesticides in both May 2002 and April 2003 indicating the use of technical HCH in the area. A peak concentration of 12.26 μg/l for δ-HCH was detected in May 2002. This extremely high concentration could be associated with Technical HCH spills.

Endosulfan (α, β-isomers and sulphate) was not detected in the May 2002 samples, however, it is among the organochlorine pesticides which have been commonly used in the cotton farming. It appeared in the samples collected in April 2003, with concentrations ranging between 0.04 and 1.33 μg/l. It was α-Endosulfan that gave a peak concentration of 1.33 μg/l. α and β-Endosulfan were most frequently detected and thus suggesting its recent application in the area. The absence of Endosulfan residues in the May 2002 samples can be related to its rapid degradation in both soil and water. Fenitrothion at concentrations ranging between 0.45 and 4.01 μg/was only detected in the samples collected in May 2002.The fact that Fenitrothio was not detected in samples from most of the sampling sites, indicates that it is not used extensively in the Simiyu catchment. However, organophosphorous pesticides degrade more rapidly than organochlorine pesticides. The distribution of DDT, HCH and Endosulfan as shown in Figure 04 indicates that all chemicals originate from the areas surrounding the upstream sampling stations.

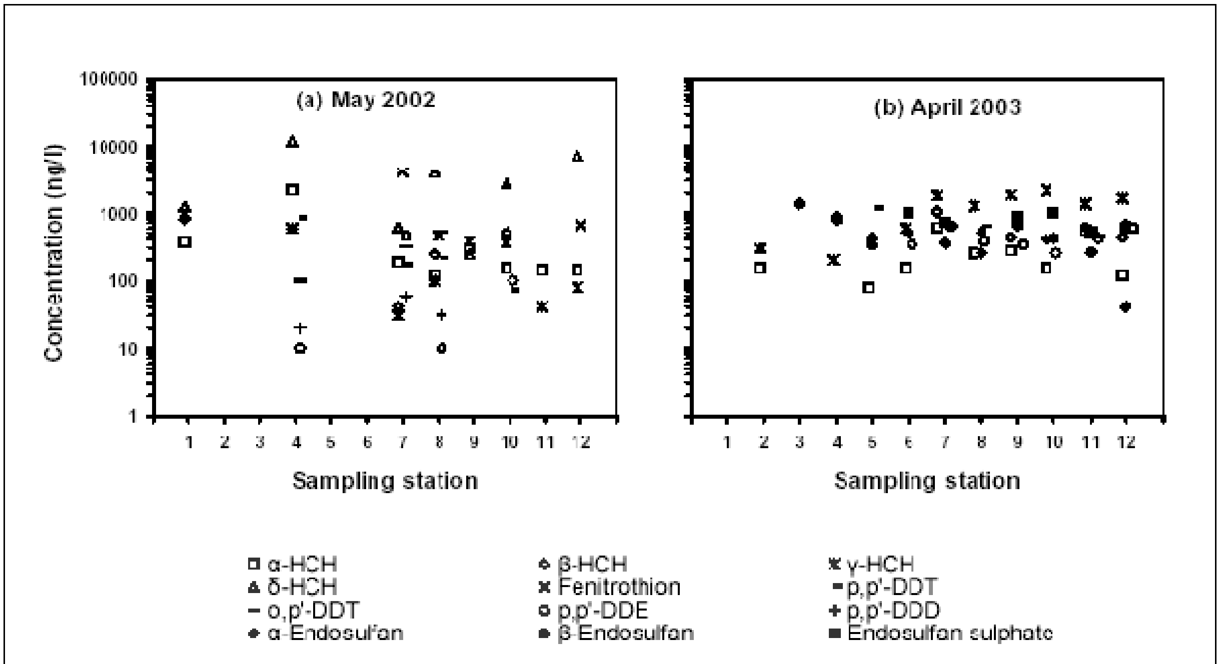

Figure 04: Total pesticide Concentrations in the Simiyu River in May 2002 (a) and April 2003 (b)

Pesticide residues in the Speke Gulf.

Two organochlorines, DDT (o,p'-DDT, p,p'-DDE, and p,p-DDD) and HCH (β,γ and δ somers) were detected in the water samples taken in May 2002, and three organochlorines, DDT (p,p'-DDT, p,p'-DDE, and p,p-DDD), HCH (α, β and γ isomers) and Endosulfan (α and β isomers, and sulphate) were detected in the water samples collected in April 2003.Concentrations of DDT in May 2002 samples ranged between 0.01 and 0.32 μg/l and between 0.17 and 0.50 μg/l in April 2003. p,p'-DDE showed peak concentrations of 0.32 μg/l and 0.50 μg/l in May 2002 and April 2003 respectvely. The most frequently detected pesticide were o,p'- DDT in May 2002 and p,p'-DDE in April 2003. Most of DDT species were detected in the samples collected from stations located far from the river mouth in May 2002, while in April 2003 such a trend was not observed. Concentrations were markedly higher in April 2003. This is probably due to high discharge by the Simiyu river. Higher DDT concentrations detected in the samples collected far from the river mouth probably due to resuspension of the bottom sediments/the mixing in the Speke gulf.Peak concentrations of p,p'-DDE suggest the past use of technical DDT in the Simiyu catchment or the wetlands /littoral zone of the Speke gulf (Rwetabula et al.,2004).

Total HCH concentrations observed in May 2002, range from 0.01 to 0.90 μg/L and from 0.04 to 1.66 μg/l in April 2003.γ-HCH peak concentrations of 0.90 μg/l and 1.66 μg/l were detected in May 2002 and April 2003 respectively. It was also, the most frequently detected pesticide in both measuring campaigns. This is probably due to its physical and chemical properties of being more persistent especially in aerobic conditions and less volatile in water than other HCH-isomers (Howard and Boethling, 1991). Generally, HCH isomers with relatively higher concentrations were detected in April 2003. In May 2002, as DDT, some HCH isomers with high concentrations were detected in samples from stations further away from the Simiyu river mouth. Average ratios of γ-HCH to total HCH concentrations especially for April 2003 were less than 99%, indicating the use of Technical HCH rather than Lindane, of which the gamma isomer is predominant, comprising at least 99% of the mixture (Nowell, 1999; Sanga, 1999). Endosulfan isomers and its metabolites were not detected in the samples collected in May 2002, however it is a pesticide used in the cotton farming arround lake Victoria (LVEMP, 2000; Rwetabula et al., 2004). Endosulfan was detected in April 2003 with total concentrations ranging from 0.17 to 1.83 μg/l. A peak concentration of 1.83μg/l was detected for β- Endosulfan at the farthest station from the river mouth. A metabolite Endosulfan sulphate was among the most frequently detected Endosulfan species, suggesting the near past use of Technical Endosulfan. As for HCH, higher concentrations of Endosulfan were observed at stations located far away from the Simiyu river mouth. Generally, most pesticides were observed in April 2003, this corresponds to higher pesticide concentrations in the Simiyu river as reported by Rwetabula *et al* (2004). Although, organophosphorous and pyrethroid are the most frequently used in the agriculture, none of these were detected in the samples collected in the Speke gulf. This is probably due to their physical and chemical properties, as being less persistent, volatile and less hydrophobic (Nowell, 1999)

CONCLUSIONS AND RECOMMENDATIONS

Food crops (especially tubers and rice) grown quite close to gold washing areas inevitably contain elevated mercury content. This observation emphasizes the need of cultivation of food crops away from mining areas in accordance with the previously recommendation of DHV consultants (1998). Crops that are grown close to water courses even a kilometre away from gold washing areas generally contain mercury within background levels. Rice grown in wetlands remote from gold ore processing areas contain normal Hg concentration even in catchments of streams that drain gold mining areas.

Mercury contamination of soil and is localized, highest concentrations are closer to point sources generally in the vicinity of amalgamation sites in nearby swampy areas. Soil types in gold mining areas play a significant role in immobilization of mercury dispersal through riverine, surface runoff and groundwater transport. Therefore, to a larger extent fluvial transport is ineffectual for mercury mobilisation to the lake. This is due to the soils in LVGF which have excellent heavy metal adsorbing properties because of high clay, iron oxyhydroxides and organic matter content. However, it is important to investigate the adsorption and buffering capacities of various soil minerals and organic matter so as to know the life time and loads of heavy metals that can be retained by these soils.
Swampy areas at present are natural barriers for heavy metals dispersion. They trap heavy metals derived from mining activities thus preventing them to enter into Lake Victoria (DHV consultants BV, 1998). The recent approach to locate gold mining and processing camps away

from river and stream courses, ensures that the dispersion of heavy metals into adjacent areas is limited to the immediate vicinity of the processing site.

Recent results (Machiwa *et al*. 2003) indicate that municipal waste discharge (Mirongo river) and biomass burning (Simiyu river) are possible sources of mercury in Lake Victoria. Therefore, rivers draining urban areas as well as those draining catchments with pronounced biomass burning are potential point sources of Hg. Nevertheless, Regional atmospheric dispersion of mercury should be given high attention (Ikingura and Akagi, 2002a). Sooner or later the use of glass retorts will enhance recycling of mercury and thus reduce atmospheric emissions (Tesha et al. 2001).

The low Hg content in fish and environmental samples from Lake Victoria indicate that the mercury pollution threat is not yet alarming, however, in order to prevent damage in the earliest possible stages constant monitoring of the state of contamination is recommended. This is to allow prevention measures to be taken at the earliest possible time (JPHA, 2001). Equally important is the knowledge of the biogeochemistry of mercury in Lake Victoria; this is another gray area that should be immediately addressed.

Protection of crops and livestock from insects, diseases, weeds and other pests without compromising the human and the Lake Victoria ecosystem health is an immense challenge. It requires the combined and sustained efforts of all stakeholders ranging from the government to communities at village level. The studies have revealed that the farmers use agro-chemicals including pesticides without proper guidance and this increases potential for adverse effects. Agricultural extension services are poor with a high ratio of farmers to extension staff and in some cases are ill trained. Input stockists are not trained and the entry (into the country) of agro-chemicals and pesticides in particular are not strictly controlled as the relevant legislation is not enforced. This calls for development of strategic intervention measures to arrest the situation. The obsolete pesticides still waiting for the proper disposal methods should be closely monitored to avoid their entry into the environment and avoid their harmful effects to human health. Other measures should nclude promotion of integrated pest and soil management practices relevant to local circumstances possible through enhanced training and community participation; promoting awareness and understanding of the technical issues and regulation regarding handling and use of pesticides; and collaborate with other Lake Victoria riparian countries to control the mishandling and misuse of pesticides as this might turn out to be a regional issue.

The results of pilot study in the Simiyu catchment and the Speke Gulf demonstrate that although not extensively used in the catchment, organo-chlorine pesticides such as DDT and HCH were frequently detected in the water samples. This is in agreement with their physical-chemical properties of being persistent, insoluble in water, and more hydrophobic than organophosphates and pyrethroids.

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Areas on the upstream of the Simiyu contribute significantly to the sources of contaminants, the concentrations of which are associated with river flow patterns. Higher concentrations appeared during high flows in April 2003 indicating that gross amount of contaminants are collected by runoff from agricultural fields. Results obtained for pesticides concentrations are not far from of what was observed before by LVEMP-BCWS (2000), Machiwa (2002a) and Henry (2003) in the Lake Victoria and its estuaries. Since origins of some of the contaminants

may be internal rather than from external sources, further investigations in the Speke gulf are needed to study the behavior of contaminant dynamics during both rainy and dry seasons.
Generally, heavy metal and pesticide contamination is a potential threat. Artisanal gold mining utilizing mercury in extracting gold from its ore remains a potential source of mercury pollution, and the contribution of the identified pesticide residues from the Simiyu catchments to Lake Victoria is significant This emphasizes the urgent need for establishing the status of pesticide contamination in other Lake Victoria tributaries, and calls for efficient pesticide and mercury monitoring and research programmes for both pesticide users and artisanal gold miners in effective application of agrochemicals and efficient ways of gold extraction respectively. Although the effluent discharge is zero in large-scale commercial mines using cyanide in the production, it is important to ensure that their systems are closely monitored.

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WATER QUALITY AND HEALTH CONDITIONS IN LAKE VICTORIA REGION (TANZANIA)

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Abstract

One of the two long-term development objectives of the Lake Victoria Environmental Management Programme (LVEMP) is to maximize the sustainable benefits to the riparian communities from using resources within the basin to generate food, employment and income, supply safe water, and sustain a disease free environment. Thus, during LVEMP I, an attempt was made to establish the water quality-health relationship in the Lake Victoria basin through water quality assessment, and collection of data and information on waterborne contamination and water vectored diseases. From 2001 to 2004, water quality monitoring along the near shore areas of the urban centers of Mwanza, Bukoba and Musoma, and rapid assessment of water quality and sanitary conditions along the shoreline settlements were carried out. Information on the common water related diseases associated with poor water quality were also collected through literature search and interviewing personnel working with dispensaries, hospitals, and health centres, as well as district and regional health headquarters. The near shore areas along the urban centers of Mwanza, Bukoba and Musoma exhibited elevated faecal coliform counts, thus indicating high faecal pollution. The study has also shown that the sanitary conditions of the shoreline settlements were poor and hence presented a local public health issue. In addition, water quality and inadequate sanitary facilities data indicated positive correlation with waterborne diseases. The common waterborne diseases associated with the observed conditions include cholera, typhoid, dysentery, diarrhoea, intestinal worms, and amoebiasis. Bilharzia is endemic in the southern and the eastern parts of the lake, where the local customs and nature of the shoreline favour its prevalence. The prevalence of Malaria and HIV/AIDS diseases as well as the status of algal toxins and its associated problems in Lake Victoria are also discussed. Furthermore, recommendations aiming to address the water quality-health related issues and areas for further research are presented.

Key words: HIV/AIDS, shoreline settlement, water related diseases.

INTRODUCTION

The relationship between water resources and health is complex. The most well recognized relationship is the transmission of infectious and toxic agents through consumption of water. Drinking water has therefore played a prominent role in concerns for water and human health. Diseases arising from the consumption of contaminated water are generally referred to as "waterborne". Globally, the waterborne diseases associated with poor water quality and of greatest importance are those caused by bacteria, viruses and parasites (protozoa, intestinal worms, etc. Most of the pathogens involved are derived from human faeces and the resulting diseases are generally referred to as "faecal-oral" diseases; however they can also be spread by means other than contaminated water, such as by contaminated food. Waterborne diseases also include some caused by toxic chemicals, although many of these may only cause health effects some time after exposure has occurred and therefore are difficult to associate directly with the cause.

The second major area of interaction between water and human health concerns its role in personal and domestic hygiene, through which it contributes to the control of disease. Because hygiene is a key measure in the control of faecal – oral disease, such diseases are also "water hygiene" diseases. Also it referred to as water-washed diseases. Other water hygiene diseases include skin and eye infections, such as tinea, scabies, pediculosis and trachoma. All of these diseases occur less frequently when adequate quantities of water are available for personal and domestic hygiene. It is important to note that the role of water in control of water hygiene diseases depends on availability and use, and water quality is therefore a second consideration in this context.

Water-based diseases (also called water contact diseases) are the third group of water related diseases and occur through skin contact. The most important example world-wide is schistosomiasis (bilharzias). In infected persons, eggs of *Schistosoma* spp. are excreted in faeces or urine. The schistosomes require a snail intermediate host and go on to infect persons in contact with water by penetrating intact skin. The disease is of primary importance in areas where collection of water requires wading or direct contact with contaminated surface waters such as lakes or rivers. The water contact diseases also include those diseases arising from non–infectious agents in the water, which may give rise, for example, to allergies and to skin irritation or to dermatitis**.** Recent studies done world wide confirmed that some species of cyanobacteria (blue-green algae) produce toxins which can cause severe dermatitis and eye irritation in people coming into contact with the algae through swimming or showering **.**

The fourth water related diseases is water-vectored diseases: this is disease caused by insect vectors, especially mosquitoes that breed in water; include dengue, filariasis, malaria, onchocerciasis, trypanosomiasis and yellow fever.

Inadequate supply and quality of fresh water, inadequately managed, is arguably Africa's greatest developmental challenge. Over 300 million Africans lack access to clean water and 500 million lack adequate sanitation. Two million deaths occur annually from contaminated water and sub-standard sanitation and 50 percent of the population suffers from water-related disease (Daley, 2003).

On the Tanzanian side of Lake Victoria, several urban centres as well as village settlements are situated along the lakeshores. The major urban centres are Musoma to the east, Bukoba to the west, and Mwanza to the south. In Mwanza municipality only 7% population is connected to the municipal sewers (current population is estimated at 447, 000). In Bukoba (66, 600 population) and Musoma (118, 000 population) urban centres there is no sewerage system at all. The most common sanitation systems in the major towns are pit latrine, bucket toilet or septic tank depending on the economic conditions of the households. Urban high income buildings such as restaurants, hotels, offices and rental accommodation have flush toilets connected to municipal sewers where available. Effluents from septic tanks are also discharged into the municipal sewers or on the ground. Open defecation is common in rural areas along the shores of Lake Victoria.

Knowledge on water quality in relation to health problems experienced by the public could aid in the restoration of the water quality and hence reduction of danger of infectious diseases resulting from exposure to contaminated waters.

METHODS

Sampling sites

The study was carried out along the near shore areas of the urban centers of Mwanza, Bukoba and Musoma. Water samples were collected from .... fixed sampling stations along the Lake Victoria shore areas in Mwanza, Musoma and Bukoba urban centers **(Figure 1).** Rapid assessment of water quality and sanitary conditions along the shoreline settlements were also carried out. Information on the common water related diseases associated with poor water quality were also collected from dispensaries, hospitals, and health centers, as well as district and regional health headquarters within Lake Victoria region (Tanzania part).

Sample and data collection

Water samples

Weekly and quarterly sampling of lake waters was made from various fixed sampling stations at a distance of about 100m from the shore, during the period from January 2001 to December 2004. Samples for bacteriological analysis, were collected aseptically in sterile 250-ml wide mouth glass bottles. After collection, samples were kept in a cool box containing ice-bags and transported to the laboratory, where they were analysed within 3-6 hours of collection.

Toxic algal samples and algal toxins

Algal samples collected from Lake Victoria during monthly and quarterly cruises were used to examine the presence of suspected toxic algal species. Algal toxins ....

Sanitary conditions in shoreline settlements

To understand the sanitary conditions in the shoreline settlements, questionnaires were administered to the village government officers, fishermen, farmers, ...

Water related diseases

Data on the common diseases associated with poor water quality and inadequate or no-existent sanitary facilities were collected through literature search and interviewing personnel working with dispensaries, hospitals, and health centers, as well as district and regional health headquarters. A focus group discussion approach was also used to get views of the people living along the shores of Lake Victoria on how the decline in water quality has affected their health.

HIV/AIDS

Although HIV/AIDS is not a water related disease but its prevalence in Lake Victoria region needs special attention. Thus, data on the prevalence of HIV/AIDS disease were collected using similar data collection tools mentioned above.

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Sample Analysis

Faecal coliform counts

The detection and enumeration of faecal coliforms were done using Membrane Filtration (MF) and M-FC Agar as solid medium (APHA, 1995). With sterile pipette 10-50 ml of water samples were filtered across sterile membrane filters (0.45um). The filters were then placed in the sterile petridishes containing 15ml of solidified medium. Samples from heavily polluted stations especially during wet season were serially diluted before filtration and calculations were made accordingly. The plates were inverted and incubated at 44.5ºC for 24 hours. Blue colonies on M-FC Agar were counted as presumptive faecal coliform using a magnification of X15. Positive colonies were confirmed by EC medium which incubated at 44.5ºC for 24 hours (APHA, 1995).

Toxic algal species

Algal cells were identified until the species level whenever possible, and were counted by the Utermöhl (1958) method using inverted microscope. Calculations of the number of individuals (abundance) were done as shown by APHA (1995). Identification of toxic and non toxic species were done following identification keys and other early publications in the Tropical Lakes. Measurements of cell sizes of each taxon were done and used to calculate bio-volumes which in turn used to estimate wet biomass (Nauwerck, 1963).

Algal toxins

Data searched from the literature (Sakadende et al, 2005, Uganda ....)

Data analysis

Disease related to poor water quality

Data on the diseases associated to the use of contaminated water entered into Excel and processed. The diseases were intestinal diarrhea (cholera, typhoid fever and dysentery), intestinal worms, bilharzias and skin infections

Sanitary conditions

Data gathered through questionnaires and interviews were analysed by SSP.

RESULTS

Faecal coliforms

Faecal coliform concentrations are reported in units of the number of bacterial colonies forming unit per 100ml of water sample (CFU/100mL) (Figures 1 – 4). The concentration of faecal coliforms ranged between 0 to 3 x 10^5 (CFU/100ml). The maximum value was measured in May, 2002 in Mirongo station, Mwanza Urban.

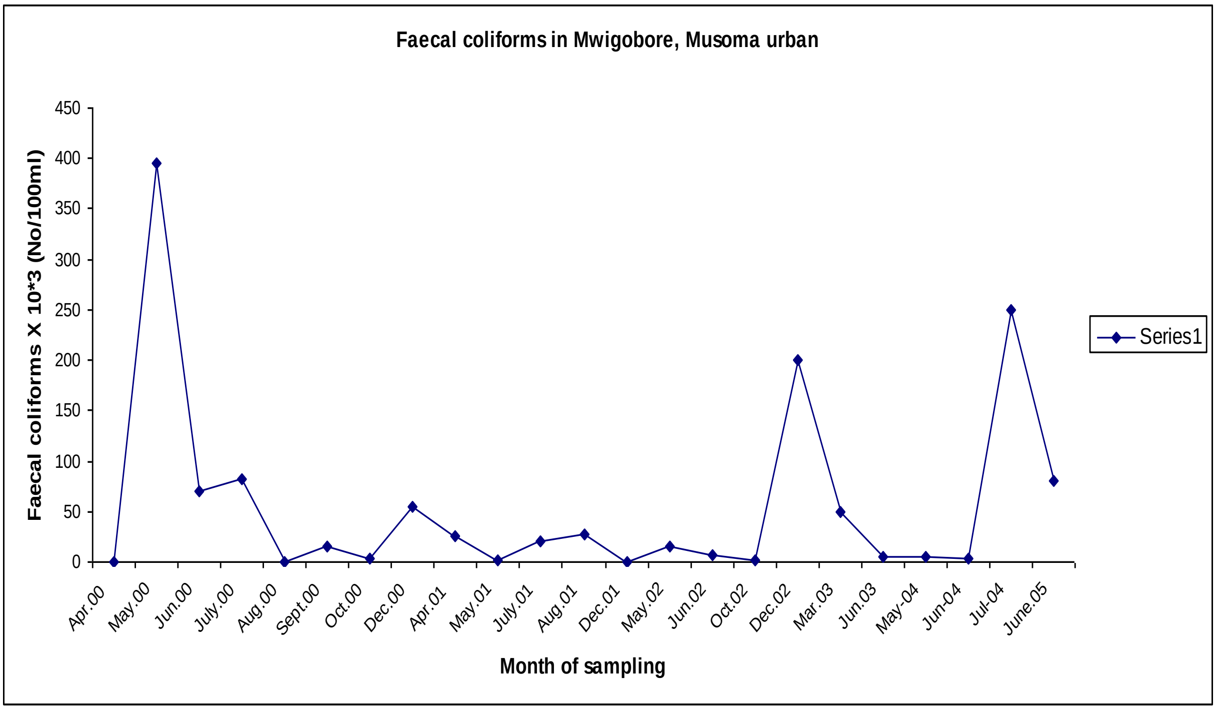


Figure 1. Monthly mean of faecal coliforms recorded in Mwigobero, Musoma Urban.

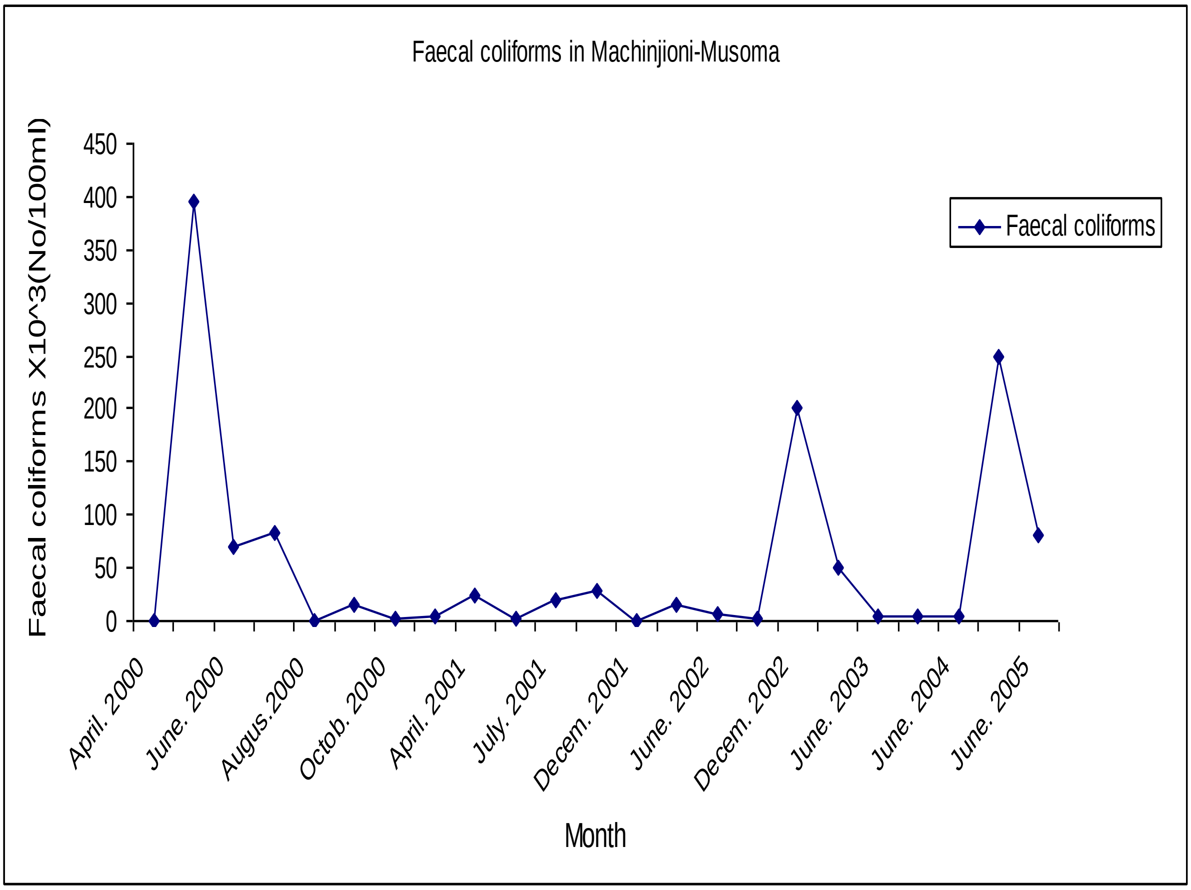


Figure 2. Monthly mean of faecal coliforms recorded in Machinjioni, Musoma Urban.

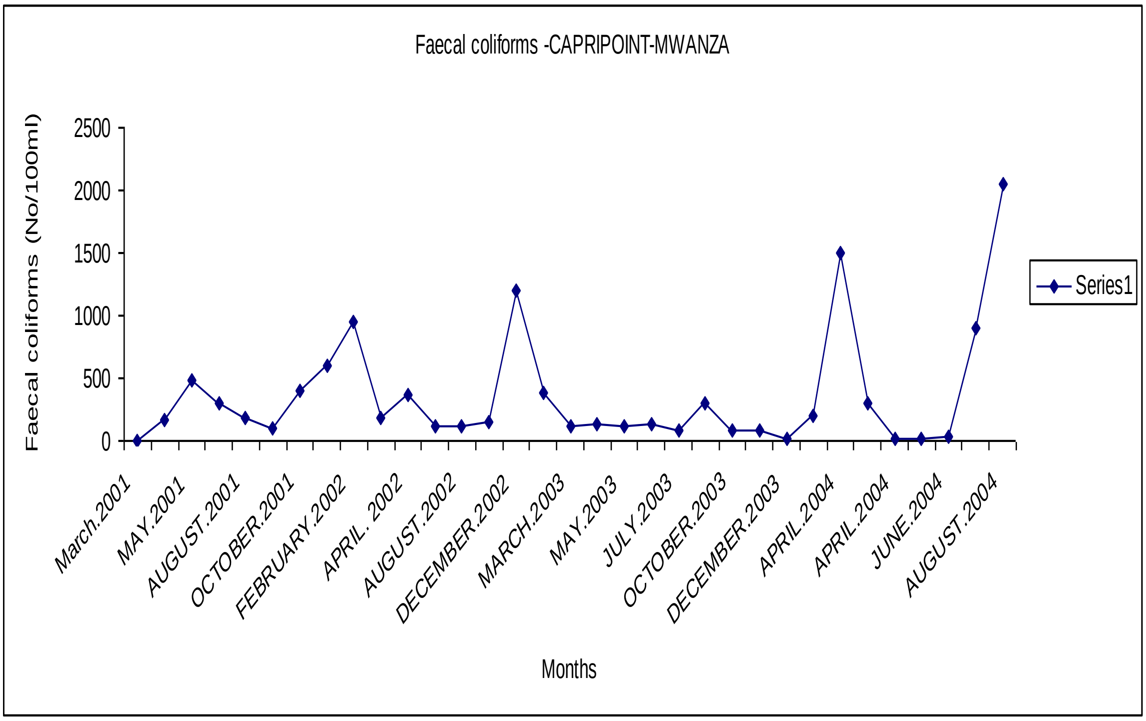


Figure 3. Monthly mean of faecal coliforms recorded in Capripoint, Mwanza Urban.

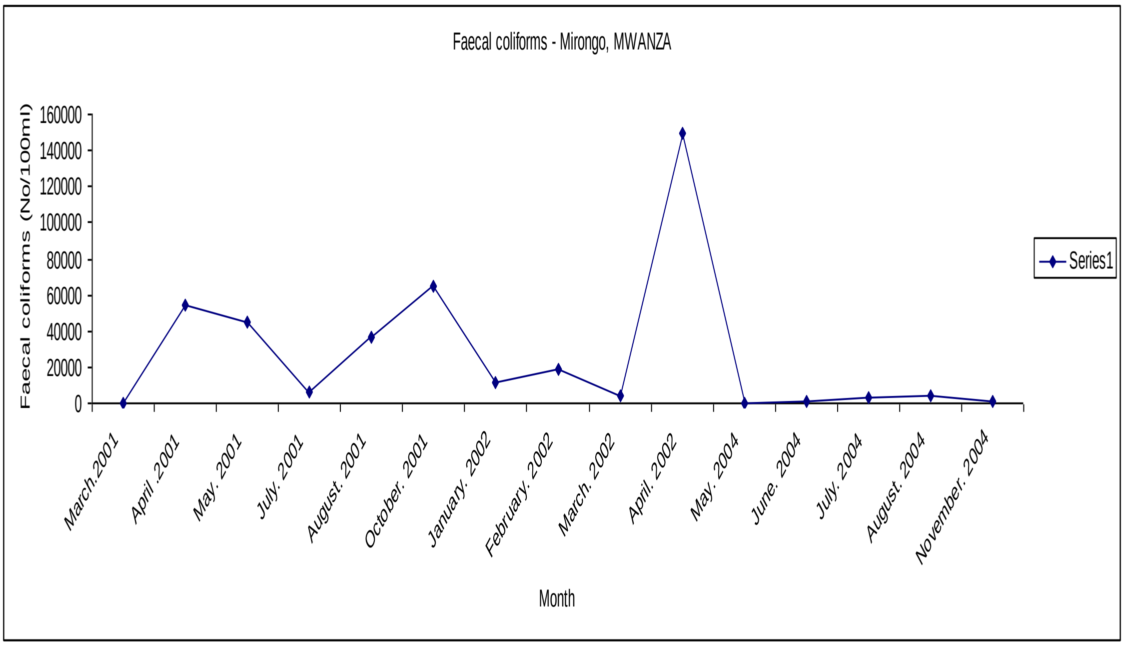


Figure 4. Monthly mean of faecal coliforms recorded in Mirongo, Mwanza.

Water related diseases

The present study shows that intestinal diarrhea (cholera, typhoid fever and dysentery), intestinal worms, bilharzias and skin infections are common in Lake Victoria shore areas, urban centres and in rural areas (figures 5 and 6). Most of these diseases are caused by microbial-contaminated water supplies that are linked to deficient or non-existent sanitation and sewage disposal facilities.

People's perception on how the decline in water quality has affected their health

Ten focus group discussions were held in Mwanza and Musoma in 2002 and 2004. About 95% of the attendees admitted that decline in water quality has affected their health. Attendees from Ukerewe Island in Mwanza region said that they are no longer use water from the lake for drinking. They opt for well water. Students from Ngaza Girls Secondary School located in the outskirt of Mwanza City complained itching and eye infection whenever they take shower using tape water from the water. Mwanza Urban Water Supply Authority supply drinking water to the public places including Ngaza Girls Secondary School. However, the Authority has no complete water treatment facilities. Dominance of toxic species of blue green algae is a common phenomenon in Lake Victoria to date. Theses species are known for skin infection including itching.

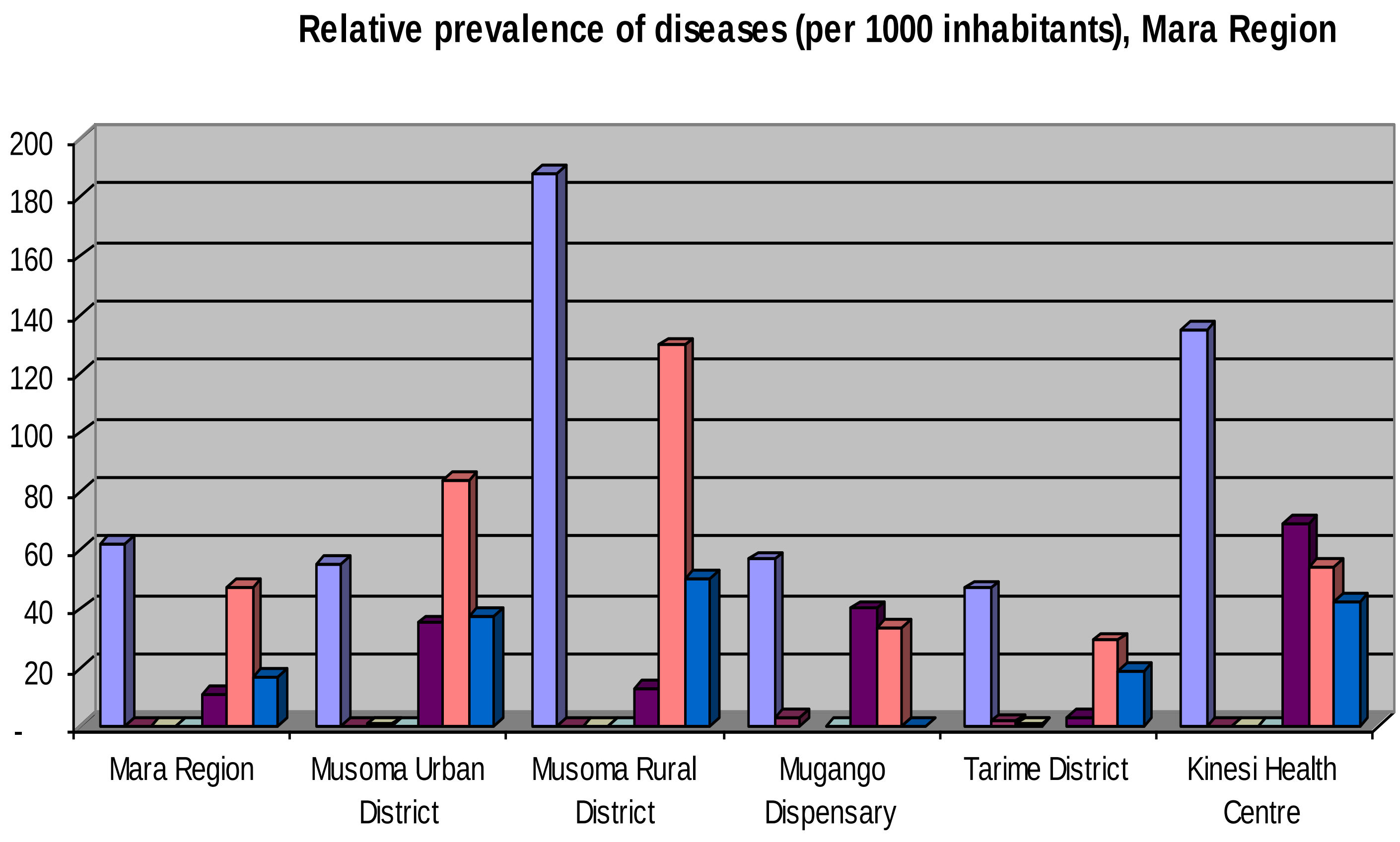
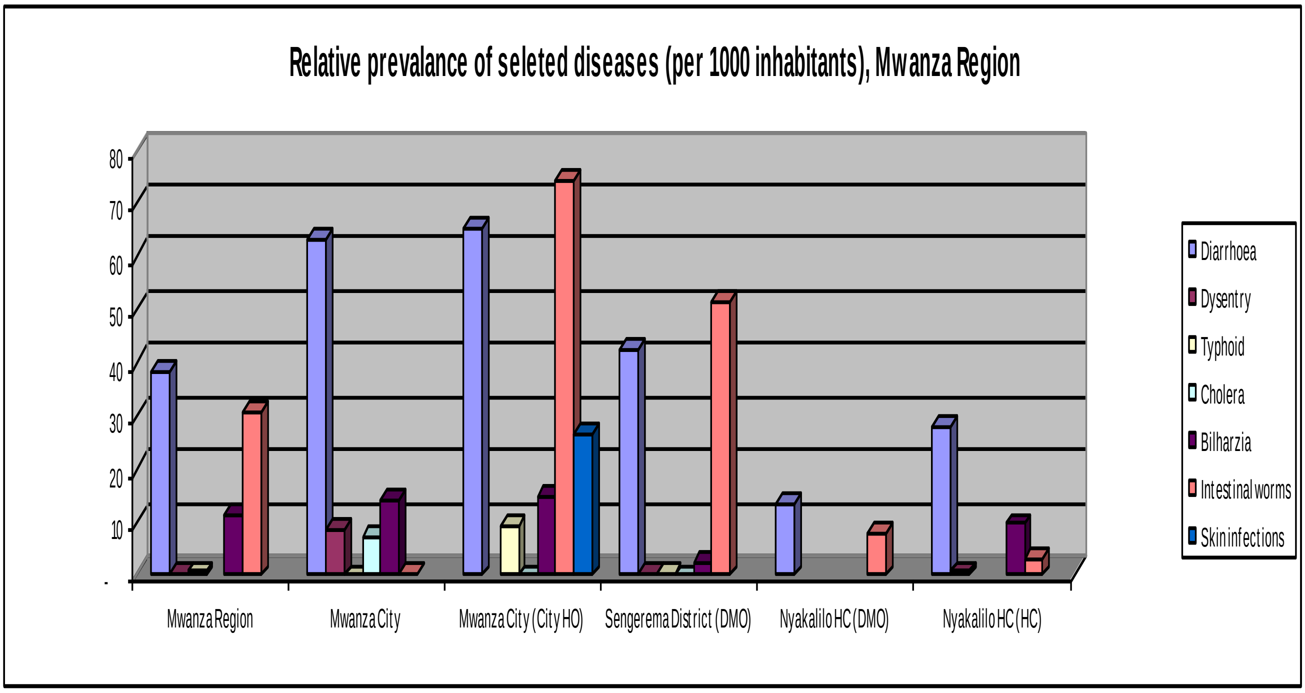


Figure 5: Relative prevalence of selected diseases (per 1000 inhabitants), Mara region (adopted from Tore Report-2004).



Toxic producing algal species recorded in Lake Victoria

In the tropics, main four genera of Cyanobacteria associated to the production of algal toxins are *Anabaena, Microcystis, Cylindrospermopsis* and *Aphanizomenon.* In Lake Victoria, species of genera *Anabaena* and *Microcystis aeruginosa are reported* to dominate the algal samples (LVEMP, 2005; Mugidde, 2003; Verschuren *et al.,* 2002; Kling *et al*., 2001).

Algal toxins produced in Lake Victoria

Phytoplankton of the group Cyanobacteria produce a variety of toxins, subsequently called cyanotoxins, that are classified functionally into Hepatotoxins, Neurotoxins, Endotoxins and Non-specific toxins. Hepatotoxins attack the liver and other internal organs of the poisoned victim. Some have also been identified as cancer promoting substances.Neurotoxins attack neurons and act as neuromuscular blocking agents, leading to respiratory arrest. Endotoxins (lipopolysaccharides) are contact irritants, and can cause severe dermatitis and conjunctivitis in people coming into contact with the algae through swimming or showering. They may also cause stomach cramps, nausea, fever and headaches if consumed. Their presence in airborne droplets can cause asthma. Some are also thought to be possible tumour promoters, although this has yet to be shown. Non-specific toxins: These are relatively slow acting general toxins which progressively damage most organs, including the liver.

Sakadende *et al.* (2005) who worked in the south part of Lake Victoria, Mwanza gulf, in 2 July 2002, reported production of algal toxins, type microcystin-RR. The concentration of the toxins was 992 mg MC-LR equivalent/L.

Sanitary conditions in the shoreline settlements/ Shoreline settlements/sanitary conditions in the shoreline settlements

Nature of the settlement
The types of settlement visited by researchers were **randomly** selected and the results indicated that most of them were fishing villages. With Mwanza having 98.8% (81), Kagera 96.6% (112) and Mara 94.4% (85). Piers in Mwanza were 1.2% (1), Kagera 2.6% and Mara 1.1% (1). Very few fishing villages had developed to the resort standard (Fig. 1). These were, Mwanza 4.4% (4), Kagera 0.9% (1), and Mara 0% (depending on sample).

The type of the buildings (structures) varied from one place to another. This was categorized as permanent, semi-permanent and others for the settlement, which was very difficult to belong to any of the above e.g., thatched huts (Fig. 2). From the findings, most of the structures were thatched homes/huts 51.4% (146), followed by semi-permanent 40.8% (116) and permanent 7.4% (21). Thatched huts were found more in Mara 74.4% (67) followed by Kagera 56.8% (63) and finally Mwanza 19.3% (16). Semi-permanent were high in Mwanza 71.1% (59), followed by Kagera 34.2% (38) and Mara 21.1% (19). The permanent homes were more identified in Kagera 9% (8) and Mwanza 9.6% (8) and the least was Mara 4.4% (4). The test for this variation was very significant ($X^2 = 0.000$) at 95% CI.

Generally, houses built by the rural people in the Lake Victoria coastlines are either of temporary nature or semi-permanent. The later type is mainly mud – houses. Poles and grass sheet are the principal building materials in most of the landing beaches. But these building materials have to be brought from far away. This probably explains why most households in the landing beaches have temporary houses in the real sense of the word save for a few houses, which are for residents who have decided to settle in the beaches.

The thatched huts are built by grass and locally known as "*vi-duku*" (plural) and sometimes are nicknamed "*full suits*". They are common in almost all-landing beaches especially in *dagaa* beaches than Nile perch and Tilapia.
They are usually erected for crewmembers and by fishers who are more or less nomads, migrating from one beach to the other in search of better catches and high wage payment.

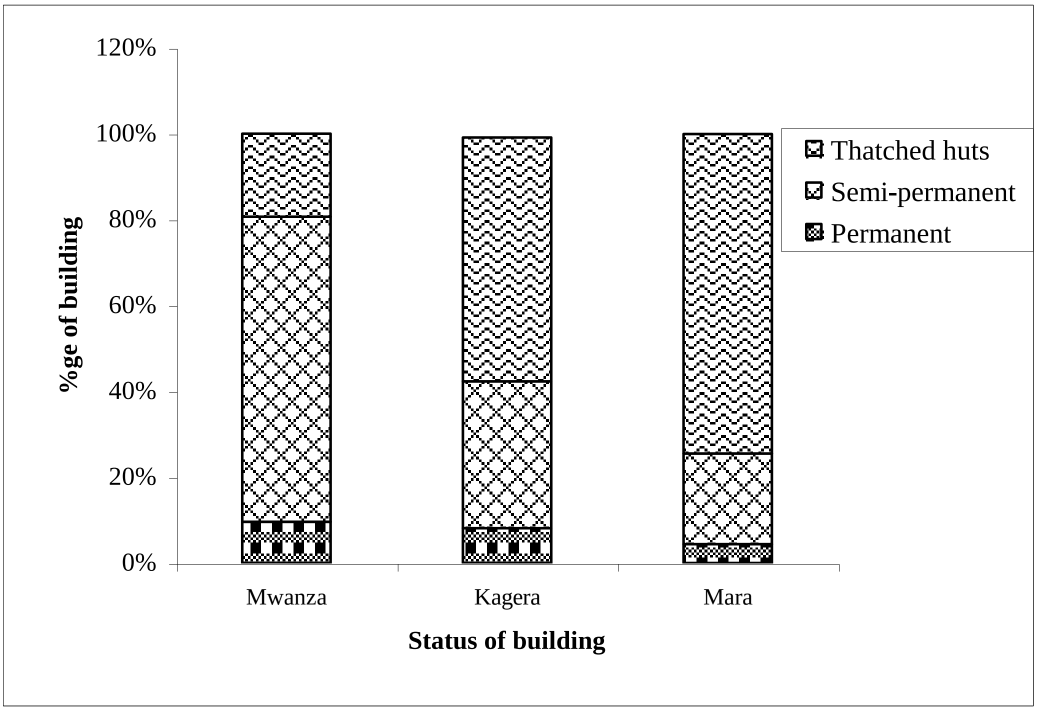


Fig. (2). Status of building structure in surveyed area

Cost of life in surveyed area.

Respondents perception towards their cost of living were mainly moderate 68.7%, (195), low 26.4% (75) and very few in high costs 4.9% (14) category. In all regions majority ranked moderate as their first judgement. The test (X^2=0.005) was significant at 95% CI. Cost of living was mainly focused in food availability and pricing. This relates to their views on the dietary conditions whereby majority perceived to be moderate.

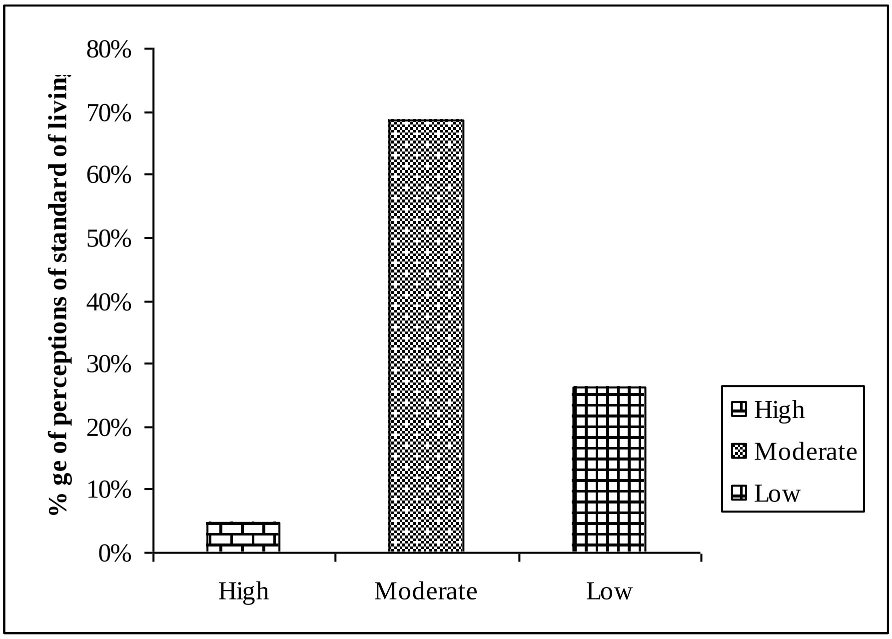


Fig. (3). Respondent's perceptions of standard of living in surveyed sites.

Socio-economic activities and informal sectors in the surveyed areas and its environmental impact to fishing communities.

There were so many economic activities carried out in different settlements. Most of them were connected to fisheries. The respondents indicated that they could not rely on one economic activity in a year. They did more than one activity because of the vulnerability of various resource bases. Nevertheless, not all of them could invest in fishing because of high investment cost and gear theft. These are some of the reasons, which made them to perform more than one activity.

The highest frequencies were found in fishing (22.3%) and selling fresh fish (22%), followed by small business (17.1%), boat repair (12.1%), net mending (12%) and finally sun drying fish (4%) and fish smoking (3.9%). Fishing was done concurrently with other fishing related activities (Fig. 7). Small businesses were bars, hotels, shops, second hand-cloth selling, firewood, fruit selling, sugar cane, tearooms maize/cassava flour and cereals.

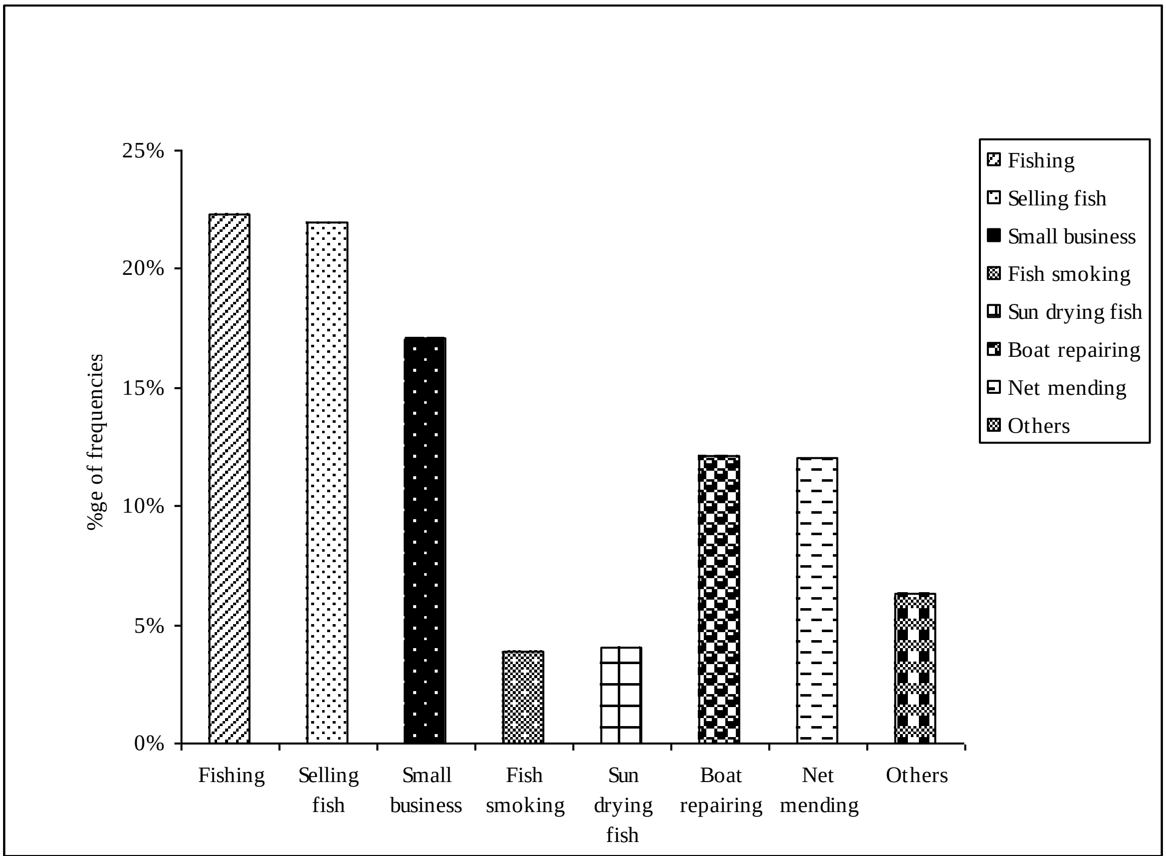


Fig. (7). Main economic activities performed in surveyed sites

Although farming and livestock rearing are important household activities, it was not reported as one of the daily subsistence income generating activities. Livestock was always mentioned as guarantee assert for loans and way of serving their money. Medard *et al.,* (2000:159) also noted this. Fishing and other related activities were the basis for daily survival of communities along the coastline of Lake Victoria. Nevertheless, both cash and food crops are grown though in varying quantities. Cash crops include cotton, coffee, banana, fruits (oranges and tangerines-Ukerewe) and timber and groundnuts. Food crops include paddy, maize, beans, sweet potatoes and cassava. Some are considered both as food as well as cash crops. Farming is largely carried out by a hand-hoe and to a lesser extent ox-ploughs.

Livestock rearing is one of the activities of the communities. Overgrazing in some parts of the fishing communities makes the grazing areas prone to soil erosion and the formation of deep gullies during the rain seasons. Cow dung and urine also flow directly to the lake waters. These are environmental hazards, which villagers are aware of and they would like to have a solution.

In addition, given the prolonged dry spell in Mwanza and Mara five years ago, more and more wetlands have been tempered with and disappeared. As a result of this, pastrolist have to move from one wetland area to the other in search of fresh animal pastures. Environmentally all the soil is eroded to the lake and causing another threat to water resources and human.

Indiscriminate burning of grass on fire has contributed immensely to disappearance of wetlands. It is again common among livestock keepers who claim that grass burning produces some fresh pastures. They forget that in the process of burning the ecosystem, the rain cycle, and the soil fertility are all destroyed. Consequently the rains start late and in scarcity and the wetlands get drier and drier and its normal function to the ecosystem is terminated.

Sanitation status, waste generated and diseases

The source of drinking water varied from place to place depending on the available ecological environmental factors. The common source of water in all regions was lake waters. Mara 41.6% (82) was leading, followed by Mwanza 31.4% (62). The second source was streams, water wells and spring water of which Kagera had 66.6% (70), Mwanza 23.8% (25) and finally Mara had less response 9.5% (10). Tape water from the water supply department was the third source. Kagera had 81.1% (54), Mara 15.1% (10) and Mwanza had few responses to it 3.0% (2). Rain harvesting techniques was identified in Mara with one response only. This indicates that lake is the main dependable water body and thus making the lifeline of the communities possible.

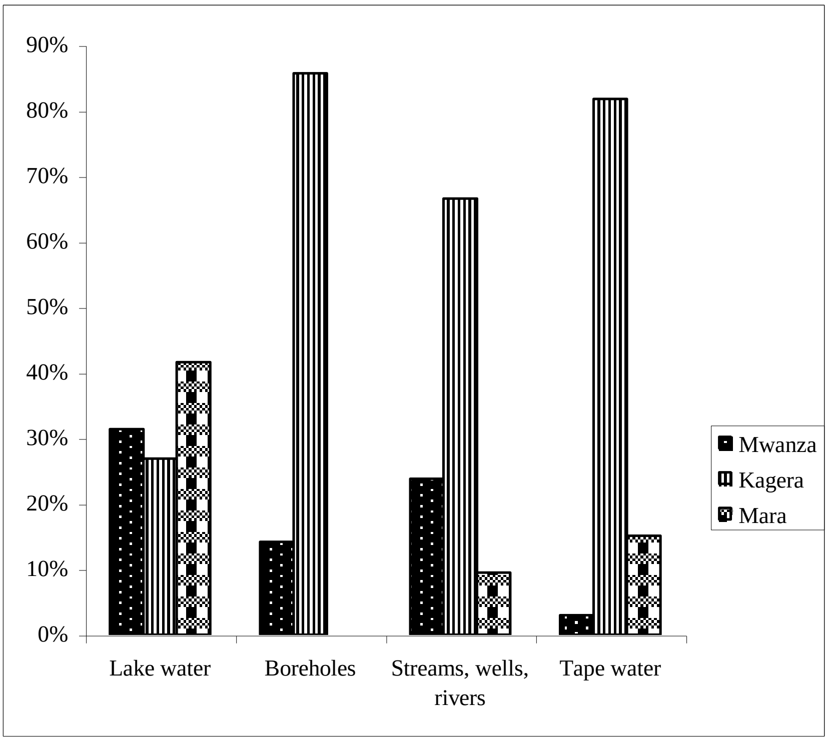


Fig. (9) Responses on sources of drinking water

When the respondents were asked if they had a tradition of boiling water for drinking purposes, majority of respondents said 'no' 40% (114), others said 'sometimes' 35.1% (100) and few said 'yes' 24.9% (71). The (X^2 =0.000) test was very significant at 95%CI. (Fig. 10). This gives a clear explanation that people are drinking in raw form all types of waste, which goes directly to the lake.

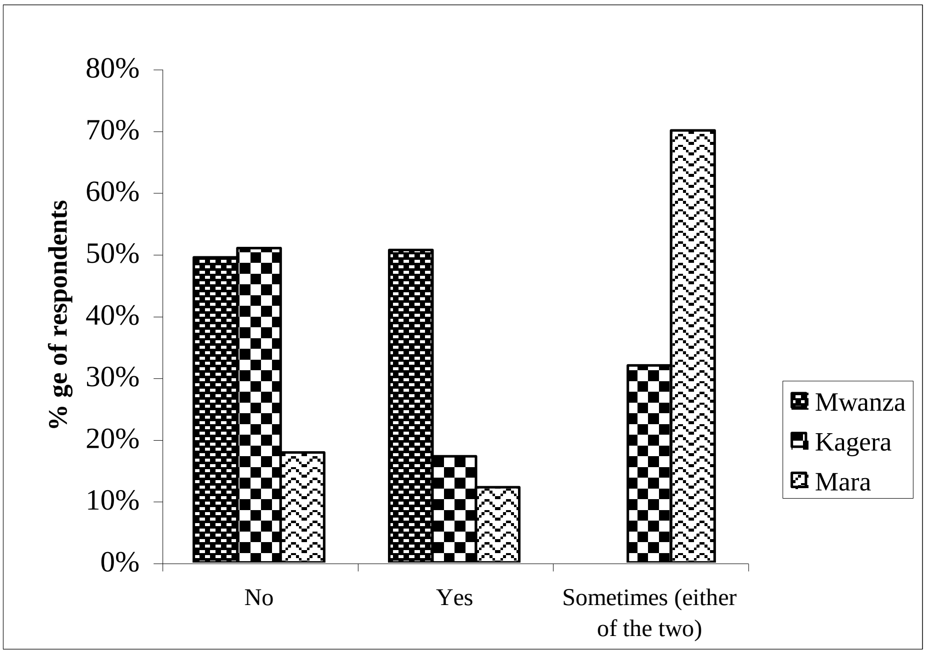


Fig. (10). Respondents whether they disinfect their water or not.

Respondents where also asked where did they wash fish and other utensils. Generally only one common place, the lake was the place where people washed their fish and household utensils. In Mwanza 30.4% (141) of responses, Kagera 32.6% (151), and Mara 36.9% (171) indicated this alternative. Very low responses were indicated on other alternatives. Water supply means had a total of 9 responses, 6 boreholes in Mwanza and others such as wells, rainwater and streams had 17 responses. The difference was significant and the test was (X^2=0.000) at 95% CI. This again contributes to the pollution of Lake waters and it shows how the communities use and rely from lake for various purposes.

Another noted behaviour for those who had permanent homes was how they handled their household utensils. Drying racks and a small pit hole for wastewater from the place where they cleaned their dishes were very common. In such communities, local health extension officers inspected monthly (without notice) and a fine ranging from Tshs. 1,000.00-5,000.00 was instituted if someone did not follow such a bylaw. Medard, *et. al*., (2001:14) also observed it during the lake wide nutritional study.

Nature of waste

Participants where asked to mentioned the nature of waste generated in their settlement. The leading waste were human excreta 42.68% (234), followed by solid wastes 33.38% (183), surface run-off 21% (114) and others 3.06% (17). High incidences of all types of waste were generated in Kagera followed by Mwanza and lastly Mara with more composition of biodegradable and less non-biodegradable.

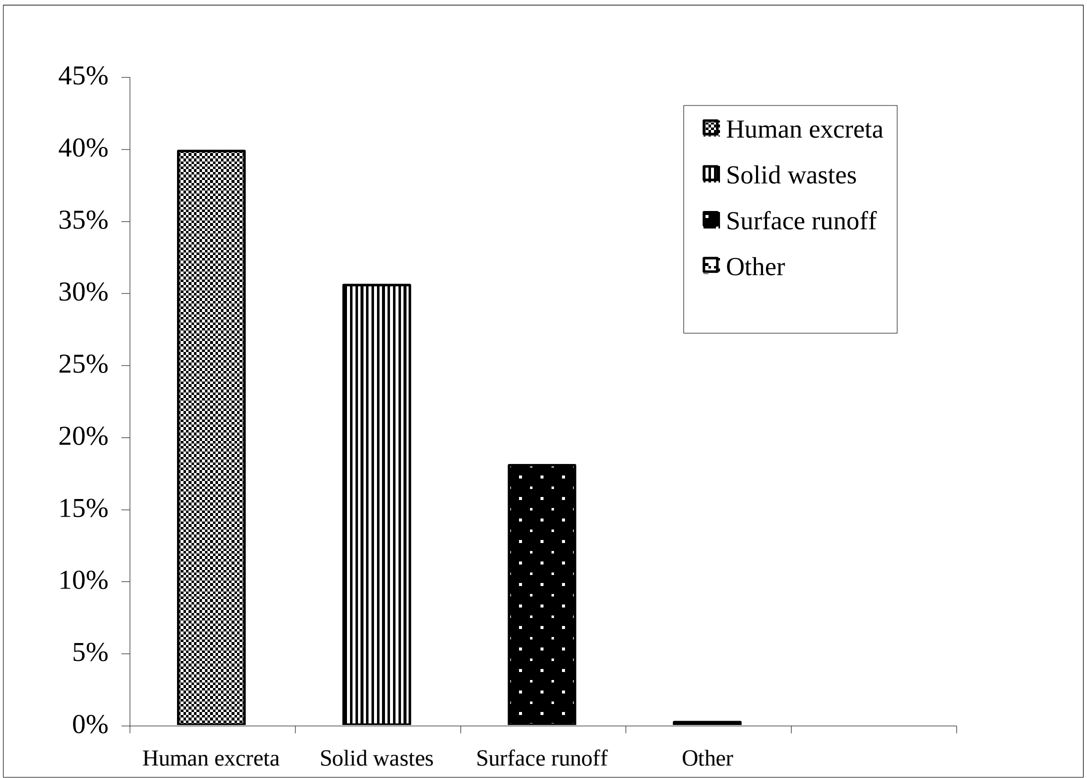


Fig. (11). Participant's responses to nature of waste generated

One important and peculiar observation in almost all the fishing beaches is that there are no toilets. That's why human excreta 42.68% were high. Traditionally, it is a taboo for the father or mother not to use the same place (toilet) for a call of nature with her/his children or even with the daughter or son in-law. This is a taboo for practically all tribes around Lake Victoria[1]. Household's structure toilets, but they are nicknamed as '*choo cha daktari'* meaning doctor's toilet, which is shown when health inspectors go around inspecting the situation of health and sanitation in household. So the households go for a call of nature anywhere, along the beaches, in the lake, and at any other convenient place. Consequent to this, the water is polluted by raw faeces, human and animal urine, household remains and the like. This water, which is literally unsafe for human consumption, is used for all household purposes, namely; cooking, washing, drinking and bathing. In view of this, water borne diseases are rampant in the beaches (Fig.14 and 15). The most affected are the children. Generally life in the beaches is difficult and the environment is unsanitary.

The results from Fig (14) were further confirmed when it was indicated that, the common place for call of nature used were open defecation, pit latrines and inlake. While Mara was leading with open defecation 43.9% (83), and pit latrines 34.8% (77), in Kagera it was pit latrines 38%(84) and open defecation 26.4% (50). Mwanza had high occurrences in using lake 34.6% and almost equal weights on open defecation 29.6% (56) and pit latrine 27.1% (60) (Fig. 12). The test was very significant (X^2=0.001). Very low responses were for septic tanks and others.
From the study, the worse situation in Mwanza Gulf beaches for open defecation (29.6%) and in lake (34.6%) is obvious. Both solid and liquid wastes flow from homes into streams such as Mirongo and Kashishi and finally into the Lake untreated. Squatters are sprouting all over the surrounding hills where services of water, sewage, and power are either non-existent or inadequate. A study by International Council Local Environmental Initiative (ICLEI, 1996) revealed that improvised toilets using drums, and used tyres are made, the contents of which are released at any time and more so during the rain season (emptying them). The raw liquid wastes then flow down the hill, into streams to the Lake.

For example, samples taken at Capri point in 1995, which is a major water-intake from Mwanza, town indicates a concentration of faecal coliform of up to 820/100ml. This indicates that an average person drinking 8 glasses of water in a day takes in at least 1,000 faecal coliform daily. The level of faecal coliform in drinking water is supposed to be zero, and what the current levels suggests in the case of Mwanza is that households in Mwanza use water which is unsafe for human health (ICLEI, 1996).

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[1] Most of the tribes around the L. region such as Sukumas, Jitas, Jaluos, Kerewes and Kara.

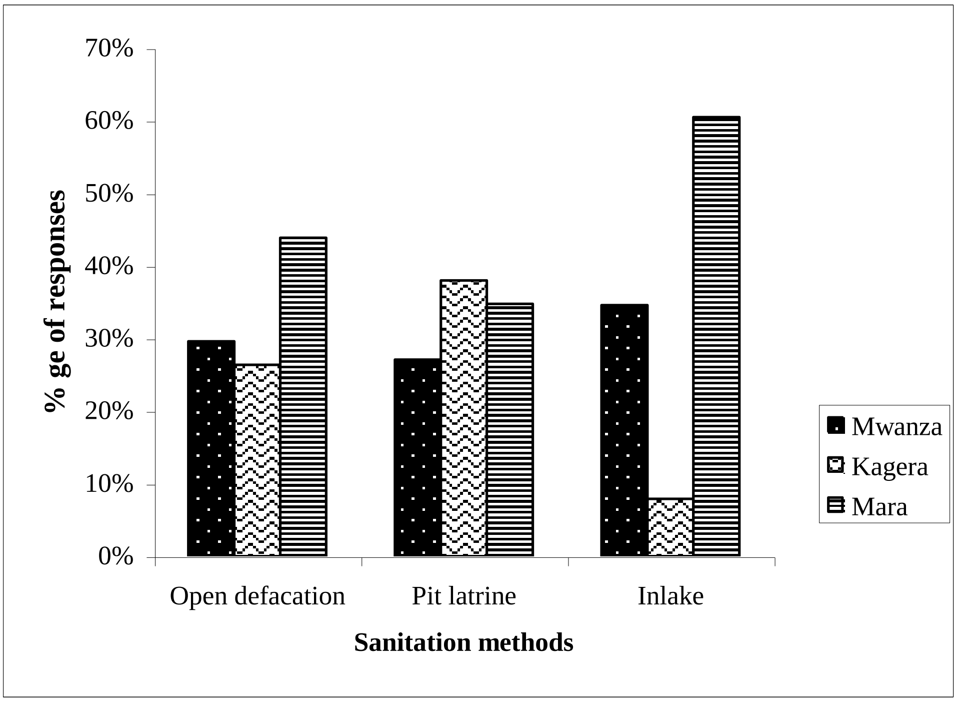


Fig. (12). Common places for call of nature in practice

It was also reported that, 2500m^3 of liquid waste flows into the Lake daily, of which 400 m^3 from Bugando Hospital.

Urban beach communities in Mwanza also feel the problem of industrial pollution. Textiles, leather, oil meals and plants like TANESCO and garages their impact to the lake is generally noticeable. Additionally vessels in various ports in the lake also emit fuel, which are hazard to fauna and flora in the lake.

Waste disposal and management

The methods of waste disposal were small pit-holes 33.3% (172), dumping at shore 28.7% (148), landfill 17.6% (91), incineration 16.5% (85) and others 3.6% (19) (Fig. 13). Incineration method was much more in Mwanza while dumping in the lake and small pit holes were in Mara and landfill in Mwanza.

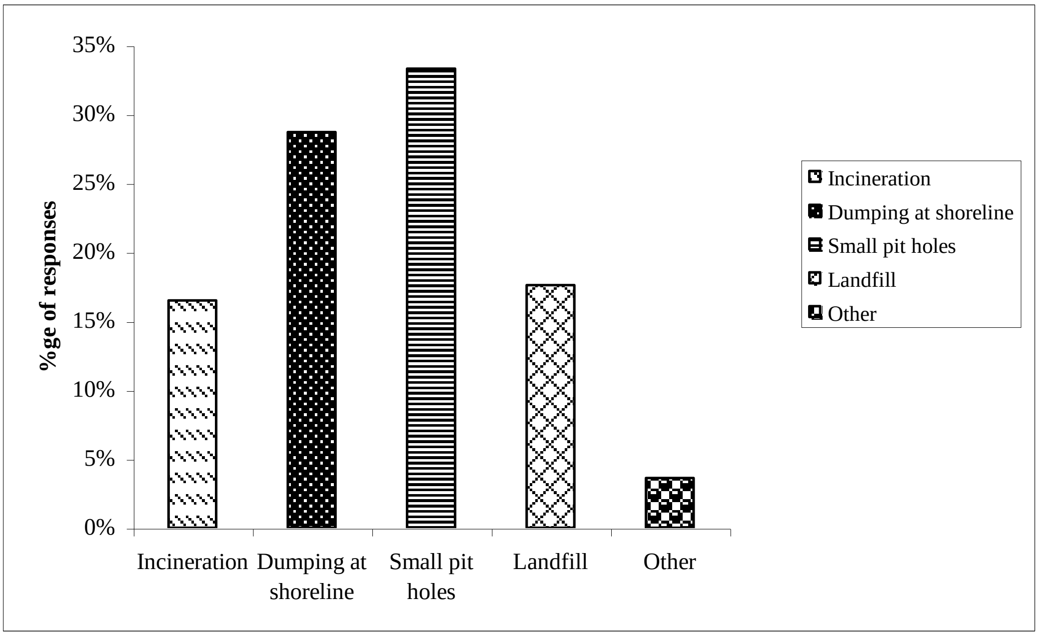


Fig. (13). Method of waste disposal in all settlements.

From the study, it is well established that the sheer volume of wastes generated from the fishing communities is enormous. The major waste management technologies at present are: small pit-holes, dumping at shoreline (open dumps), landfill, and incineration. Small pit holes and dumping at shoreline (open dumping) are the oldest and most common way of disposing waste.

Pit holes: This is common method all over the surveyed sites. Communities normally dig holes (small holes) periodically (weekly or monthly) near the compound. The holes are also used for wastewater for those who wash their dishes at home. With this method, the land becomes so stiff and weak around their compound because they do not compact it but they simply cover it with soil.

Open dumps: In many cases, open dumps in surveyed sites were located wherever land was available (along the shorelines and near their homes) without regard to safety, health hazards and aesthetic degradation. In some instances, the refuse was ignited and allowed to burn. In others the refuse was periodically levelled.
For those who dump along the shoreline, they are directly polluting the lake and allowing the waste to dissolve, sink or float while in lake.
Generally, open dumps tend to create a nuisance by being unsightly, breeding pests, creating a health hazard, polluting the air and sometimes polluting ground, surface water and the lake waters.

Sanitary landfill: This is also very common whereby an excavation or trench into which all domestic solid wastes are placed so that they do not create a public nuisance and hazards to public health. The wastes are normally covered with a layer of compacted soil once it is full. This covering of the waste with compacted soils makes the sanitary landfill 'sanitary' because the compacted layer effectively denies continued access to waste by insects, rodents and other animals. It also isolates the refuse from the air, thus minimizing the amount of surface water entering into, and gas escaping from the wastes. It reduces waste through compacting and biodegradation. It is not appropriate for non-biodegradable materials like polythene, so it is best to only use for organic waste.

Incineration: Incineration of waste as stated above was mainly practiced in Mwanza. Incineration is reported to reduce the volume of the waste by as much as 90 percent and its weight by 80 percent, (Clark *et al.*, 1992) so, incineration substantially reduces the overall amount of waste that must be land filled. In some countries the energy generated is used for industrial purposes. However, recyclables material should be protected from incineration, the ash and smoke released pollutes soils and the atmosphere.

Water borne diseases prevalence

About 80.4% respondents agreed that the surveyed areas were prone to water borne related diseases while 19.6% (56) they disagreed. The disagreement was higher in Kagera than Mwanza and Mara. The test was very significant (X^2=0.000) at 95% CI (Fig. 14).

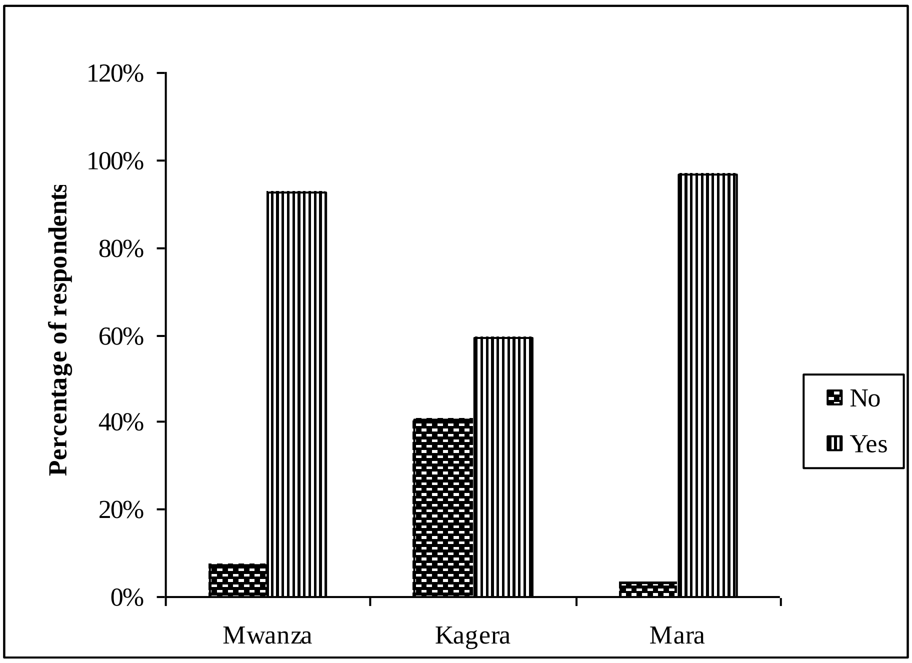


Fig. (14). Respondent's perception on water borne diseases

Of those who said 'yes', they were given chances to rank the first two common diseases. The respondent's orders of frequencies were dysentery followed by typhoid, amoeba, cholera, malaria, bilharzias, and lastly worms.

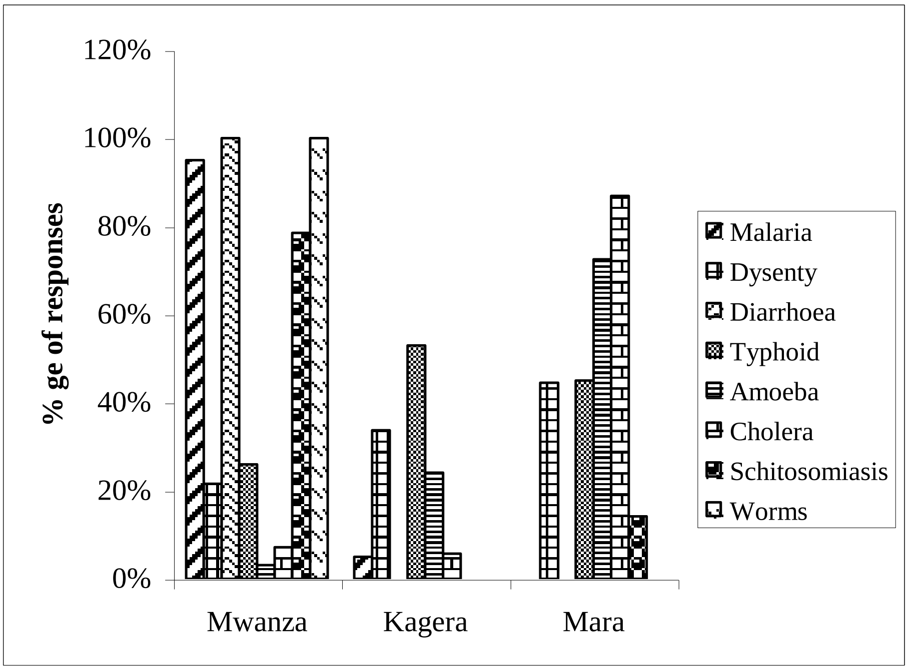


Fig. (15). Responses of diseases prevalence in surveyed areas

The most prevalent disease was dysentery which had high responses in Mara 44.5% (66) followed by Kagera 33.7% (50) and lastly Mwanza 21.6% (32). The second disease was typhoid. Mwanza had 53% (42), followed by Mara 45% (64) and lastly Mwanza 26% (36). The third disease was amoeba. The highest responses were in Mara 72.5% (66), followed by Kagera 24.1% (22) and lastly Mwanza 3.1% (3). The fourth disease was malaria, which had 19 responses in Mwanza and none in Kagera and Mara. The fifth disease was schitosomiasis, which had high incidences in Mwanza 78.5% (11), none in Kagera and 14.2% in Mara. Worms had very low incidences and it was noted in Mwanza with 7 responses.

In some parts, water hyacinth[2] was also mentioned to bring with various types of diseases such as bilharzias, dysentery, and amoebic dysentery and also leaches. According to the local belief, the main cause of bilharzias was drinking dirty water and bathing in dirty water. The weed is said to move with and harbors snails, deadly snakes and crocodiles. This was one of the explanations to some beaches as to why they had prevalent water related diseases.

Participants were asked if water related diseases were endemic. About 74.9% (215) agreed while 25.1% (72) disagreed. Of those who agreed, 64 where from Mwanza, 67 from Kagera and 84 from Mara region. Generally the most endemic diseases were malaria (55.8%) and bilharzias (44.2%).

There are a number of reasons for this incidence of various diseases in fishing villages. The presence of Nile perch, along the shorelines has precipitated an economic boom, and the concomitant development of commercial fishing activities has led to an influx of business people, petty traders, itinerants, hawkers, fishers, smugglers as well as providers

[2] During the study in 1999 some beaches were severely encroached with water hyacinth.

of all kinds of services. Apart from the simple fact that increasing numbers of people making use of the same limited health care facilities will tend to give the impression of a higher incidence of diseases. Population expansion in the absence of any significant improvement of village infrastructure (sanitation, medical services) has probably led to a real increase in the incidence of many communicable diseases.

Poor sanitation, dirty water and influx of immigrants are seen as major causes of diseases, and people tend to relate these to each other in a causal chain: Villagers also see immigrants (Table, 2) as bringing diseases directly into their community. Population increase leads to pressure on clean drinking water, more people using the lake for domestic as well as business purposes (fishing). Defecating in the fields, lake, and any convenient place, leads to dirty water and increasing numbers of flies, which in turn cause an increase in diseases. Ndutulu *et al.,* (1996:10) also noted that the conditions in fishing communities were poor and there were more diseases than in the past because there are more people and therefore more shit. Therefore, apart from lack of proper sanitation and services, it was the influx of immigrants into the fishing villages in recent years that people see the major cause of increased diseases.

Water related diseases

Define..

Waterborne diseases

Caused by the ingestion of water contaminated by human or animal faeces or urine containing pathogenic bacteria or viruses; include cholera, typhoid, amoebic and bacillary dysentery and other diarrheal diseases.

Water-washed diseases

Caused by poor personal hygiene and skin or eye contact with contaminated water; include scabies, trachoma and flea, lice and tick-borne diseases.

Water-based diseases

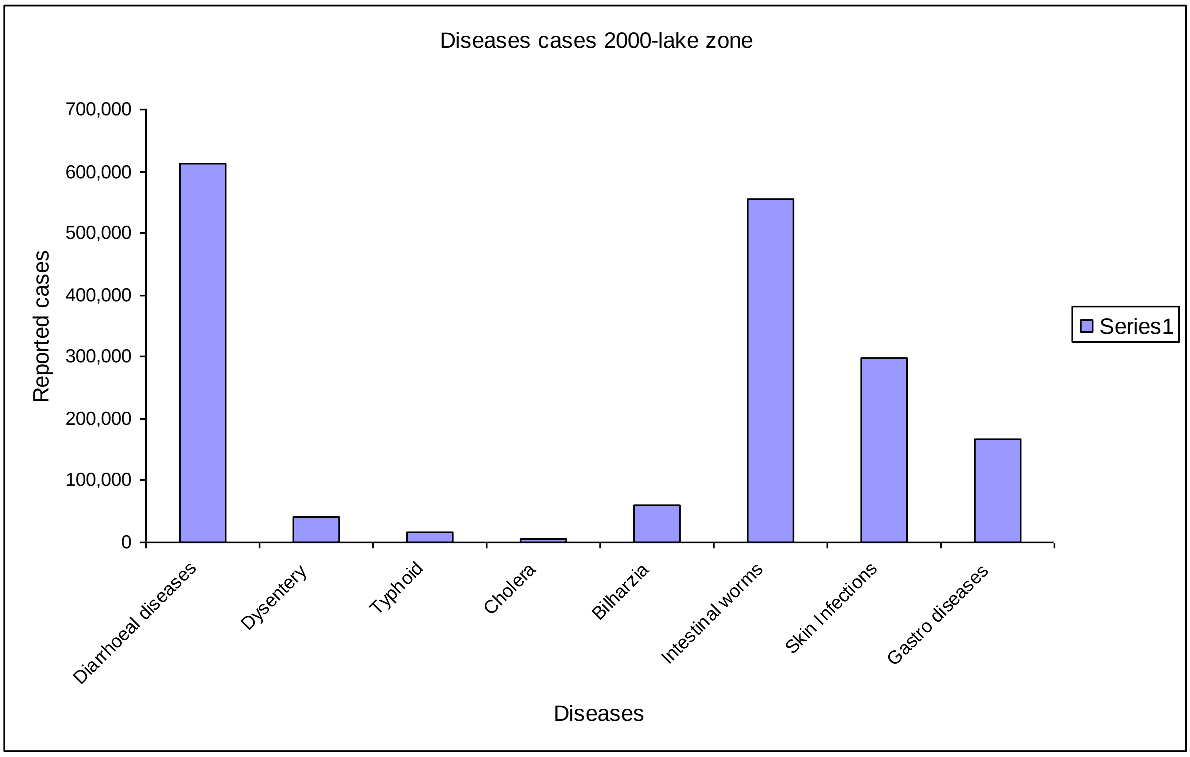
Caused by parasites found in intermediate organisms living in contaminated water; include dracunculiasis, schistosomiasis, and other helminths.

***Water vectored* diseases**

caused by insect vectors, especially mosquitoes, that breed in water; include dengue, filariasis, malaria, onchocerciasis, trypanosomiasis and yellow fever.

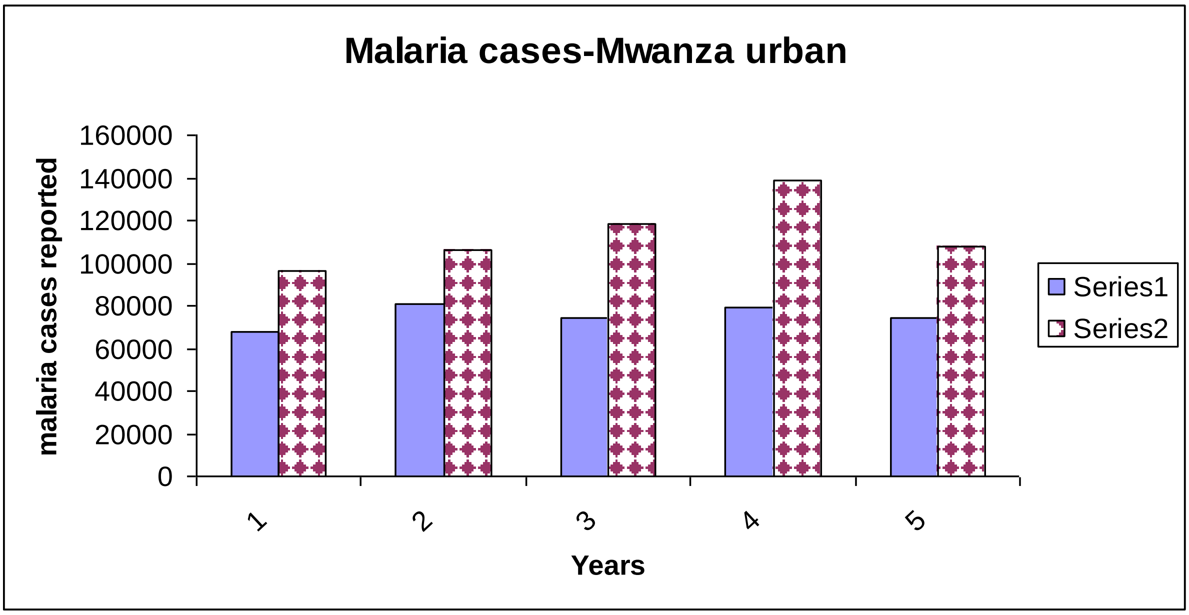
a) Bilhazia

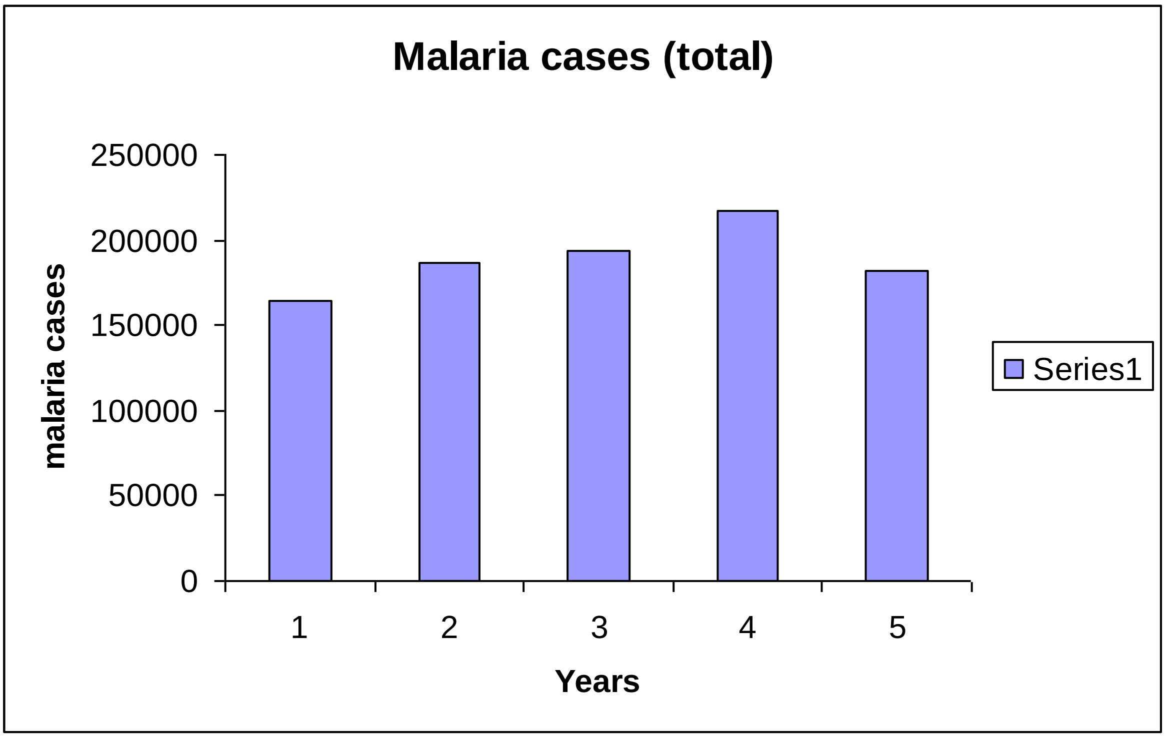
b) Malaria



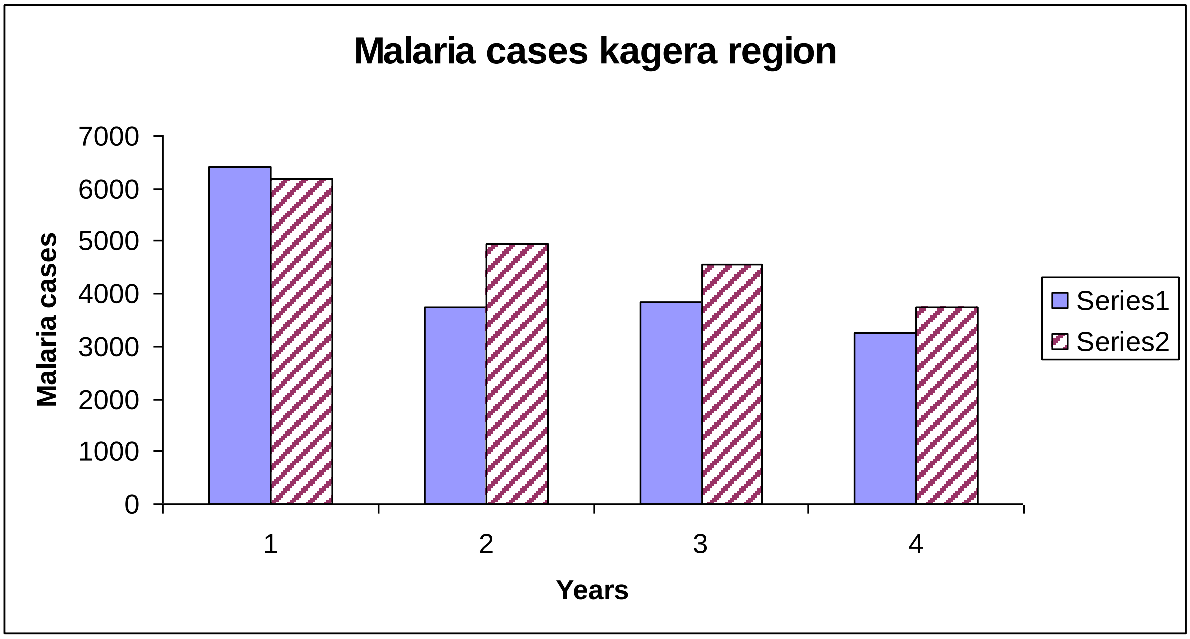
Water vectored diseases

Malaria



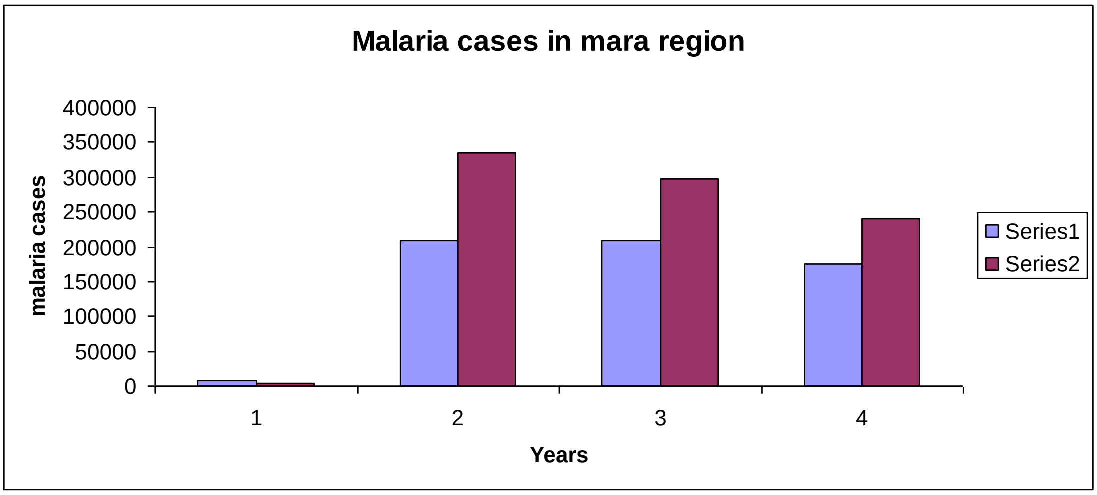


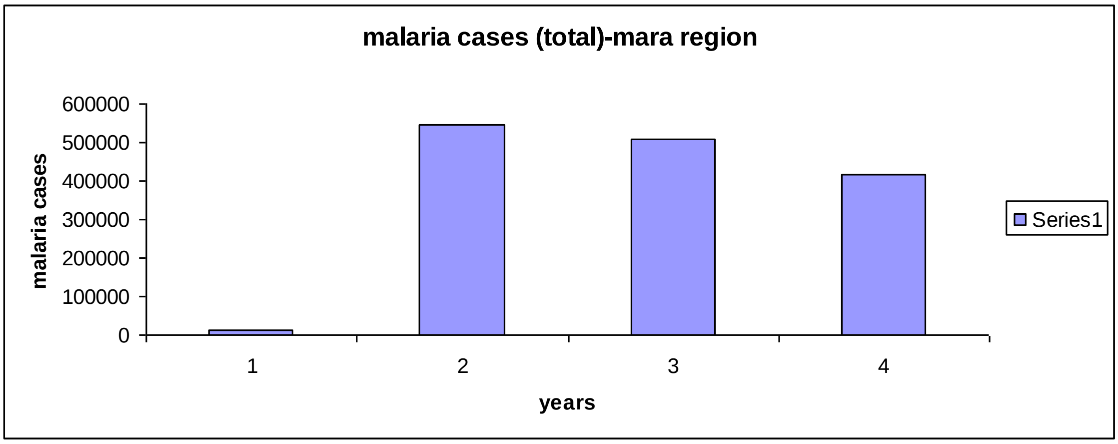
Mwanza urban



Bilhazia

Musoma data





DISCUSSION

Bacterial contamination

Bacterial contamination is a serious concern in near shore areas and shoreline settlements. This presents a health hazard from pathogenic micro-organisms where water supplies are not disinfected.

Bacterial contamination is continuing problem in near shore areas, particularly as a result of stormwater run-off from urban centres and agriculture farms. This presents a health hazard from pathogenic micro-organisms where water supplies are not disinfected. For example, "The concentrations of faecal coliforms (E. coli bacteria) occurring in the lake waters are frequently in excess of limits recommended for both drinking water and recreation"

The presence of faecal coliform bacteria in surface waters indicates that faecal material of humans or other warm-blooded animal has been introduced into the water at some point. Potential sources are numerous -- agricultural runoff, urban storm water, inadequate or neglected septic systems, sanitary waste from boats (less likely) and waterfowl and other wildlife. Beyond these actual sources, soils and aquatic sediments are reservoirs for faecal coliform bacteria (Heufelder, 1997; Stephenson, 1982).

Chakula Barafu station is close to the City centre, therefore, Urban runoff was associated with elevated levels of faecal coliforms observed in that station. Another explanation for higher levels of faecal coliforms measured at Tilapia and Kirumba stations was suspected to be human activities like fish processing, washing cargo handling, and local boat making which carried out either at the lake shores or near the lake. Agricultural activities are carried out to the shore land in Mwanza gulf. In these areas farmers brought fertile soils to fertilize shore land and animal manures and pesticides are also used (Alley, 2002). This practice may probably contributed to the higher counts of faecal coliforms measured in Luchelele intake.

Capri-Point water intake is surrounded by hills and no agricultural activities carried out in near by areas. This partly could be the reason of low levels of faecal coliforms (300 CFU/100mL) measured relative to the maximum acceptable levels in Surface Water Quality Criteria for Public Water Supplies (2000 CFU/100ml) (Hammer, 1975). Miringo station is close to Mirongo river which discharges in the lake more than 5,000 cubic metres of untreated sewage per day (Mnyanga and Semili, unpublished), its contribution to the degradation of water in Mwanza gulf could have a significant impact on the public using water from that area.

Comparison with data before and after closure of the bypass

Pollution caused by faecal contamination is a particularly serious problem, due to the potential for contraction of disease from the pathogenic (disease-causing) organisms found in faecal matter. Shigella (dysentery), Salmonella (gastrointestinal illness), Pseudonomas auerognosa (swimmer s itch), and certain E. coli species (i.e. 0157) are examples of bacterial pathogens. Giardia and Cryptosporidium are examples of common protozoan pathogens.

In addition to implying health risks, the presence of faecal coliform bacteria in surface waters may also be an indicator of environmental concerns. Most often, faecal coliforms enter a water body through non-point source pollution (not from a single source, like a sewer pipe). This type of pollution can include silt, nutrients, organic material or toxins that are present throughout the watershed. A watershed is all the land around a stream, river, or lake that drains precipitation runoff to that water body.

Higher levels of faecal coliforms recorded in this study confirm the previous studies which reported degradation of water quality in Lake Victoria. (Kling et al., 2001 Lung'ayia, et al., 2000; Verschuren et al., 1998; Kandoro and Hamza,1998; Hecky et al., 1994; Hecky, R E 1993; Lehman et. al, 1993; Muggide, 1993; Lowe-Mc Connell 1992; Bugenyi and Balirwa, 1989). This re-emphasizes the need for urgent action to take measures to control deterioration of the water environment for sustainable social and economical development. in general and water supply in particular.

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THE WATER QUALITY SYNTHESIS REPORT:

IMPACTS OF WATER QUALITY CHANGE ON BENEFICIAL USES OF LAKE VICTORIA (TANZANIA)

By: Mnyanga V.P, Rutagemwa D.K. Semili P.M. and Mwanuzi F.L

Abstract:

During the LVEMP implementation period 1997 through 2005, the impacts of Water Quality change on beneficial uses of Lake Victoria were investigated. The study area covered the southern Lake Victoria basin located in Tanzania. The data and information were collected through water quality monitoring in the lake, rivers, and municipal and industrial effluents, questionnaires, interviewing a wide range of stakeholders, and review of published data and data collected by health facilities and Water Supply Authorities.

Water quality parameters analyzed by LVEMP included nutrients especially phosphorous and nitrates, phytoplanktons and zooplanktons. Some species of phytoplankton like algae produce complex organic compounds, which can cause tastes and odours. They can form a mat on surfaces resulting in clogging or binding of the filter. Some algae produce slime in their outer layers causing slippery surfaces and bad odours. Colour can be caused by the by-products of algae of all types and usually indicates taste and odour problems. Algae can cause the corrosion of concrete or metal structures. As algae grow and die they can bring about changes in the characteristics of the water, which can interfere with the treatment processes. This was evidence from the cost of water treatment cost experience by MWAUWASA. Some algae species present in Lake Victoria are toxic like the blue-green algae thus poisoning fish and livestock. Also, *Anabaena* and *Anacystis* which can cause skin problems and hay fever respectively are also observed in Lake Victoria waters.

From the analysis impacts that were identified includes; 1)drinking water impairment leading to high treatment costs; 2)appearance/outbreak of water related diseases which in a way reduce the workforce and increased medical bills; 3)food web contamination leading to bioaccumulation in higher trophic levels; 4)loss of fish habitat due to increased pollution/eutrophication; 5)inefficient food webs resulting from occurrence of other dominance species which are not easily ingestible by lower and or middle trophic levels; 6)loss of biodiversity and proliferation of unmanageable macrophytes such as water hyacinth.

These impacts are major impediments to the socio-economic well being of the Lake Victoria riparian communities and need to be addressed in order to sustain the beneficial uses of the lake and eradicate poverty.

Keywords: Lake Victoria, Water Quality Change, Beneficial Uses, Negative Impacts, Riparian Communities, Social-economic Wellbeing.

INTRODUCTION:

The African Great Lakes are considered to be dynamically fragile ecosystems that are relatively resistant to minor changes with which they have co-evolved but vulnerable to major perturbations such as over fishing, the introduction of alien species and pollution. Lake Victoria is the second largest fresh water lake in the world and the largest of its kind in Africa. The lake is rich in biodiversity, of which fisheries is a major resource for the riparian communities and for export. During the last two decades the lake has encountered numerous problems and extensive resource exploitation which has constrained its productivity resulting in the drastic decline of biodiversity in general and fisheries in particular. The lake is also an avenue for transport and is increasingly, becoming a tourist destination due to sport fishing, scenic beauty and wildlife of the area. A hydroelectric power plant that supplies electricity to Uganda, Kenya, Tanzania and Rwanda is located at lake's outlet to the White Nile (Lung'ayia, *et al*., 2001). Lake Victoria also plays an important role in moderation of the climate, through the action of hydrological cycle.

Since 1920s Lake Victoria has undergone successive dramatic changes. Intensive non-selective fisheries, extreme changes in the drainage basin vegetation, industrialization, agricultural developments, dams and the introduction and invasion of exotic species are among the factors that have led to the destruction of the native and endemic components of the lake. These have been followed by a progressive build-up of physical and chemical changes in the Lake. For instance, to date there are substantial increases in the chlorophyll concentration and primary productivity as well as decreases in silica and sulphur concentrations compared to values measured 30 years ago (Hecky, 1993). Other evidences in the ecological changes of Lake Victoria are a shift in the phytoplankton community towards dominance of blue-greens and an enhancement of algal blooms. In some shallow depths of the lake anoxic waters have recently been found suggesting significant increases of oxygen demand in the seasonally formed hypolimnion, (Ochumba, 1990). This situation has increasingly resulted in the impoverishment of the lake. The lakes ecosystem has also been particularly affected by the introduction of the Nile perch, *Lates niloticus* during 1950s and the water hyacinth, *Eichhornia crassipes* in 1990s, the consequence of which are detrimental to the lake's biodiversity, especially fish; leading to a shift in the fishery from a multi-species to only two major exotic species, *Lates niloticus* and *Oreochromis niloticus* and the endemic species *Rastrineobola argentea* (Ochumba *et al* 1991).

The water quality of Lake Victoria has for the past forty years or so been degenerated by several environmental problems. Local communities around the Lake dispose their waste directly or indirectly into the Lake and thus endangering the life of the Lake and all the people who use the Lake as the source of their food and energy, drinking, washing, irrigation and transport. The continuing dumping of raw and semi-treated municipal and industrial wastes into the Lake will also cause a cumulative pollution by chemicals and heavy metals, which are dangerous to the life of the Lake, and those lives directly or indirectly linked to it. Poor agricultural practices and overgrazing also pollute the resource. Fertilizers and pesticides are the main constituents of agricultural residues and are the main causes of agricultural pollution. The common method of cultivation in the Lake Victoria basin is that of ridges in some areas '*sesa'.* Ridges made along the hills rather than across are source of soil erosion, which as pollution increases becomes destructive and unsustainable. Livestock keepers with their herds tend to migrate and concentrate where there is enabling environment and mechanisms, and where there are minimum natural constraints. It is a pride around Lake Regions to keep many herds of cattle even if the owner leads a very poor life. Actually they are considered to be rich and heavy weights in the society. In the process it leads into overgrazing and hence into environmental problems. In order to alleviate the ongoing environmental pollution and degradation in the Lake Victoria Basin, integrated strategic interventions are needed particularly in fisheries, agriculture, water resources management, energy, land use, conservation and human settlements. There is a tremendous variation in the type of settlement between the different villages along Lake Victoria shoreline, and it is immediately obvious that none of the villages can be taken as representative. They vary from large, long-established villages with a minority of fishers to temporary fishing camps consisting almost entirely of fishers. However, in spite of this there are also fundamental similarities between most of the fishing villages: in social structure, local economy, patterns of behaviour and attitudes. This is partly due to the common fact of an economy dominated by fishing but with an important agricultural subsistence component, and partly to the high degree of social mobility, which tends to facilitate cultural homogeneity. In fact, it might be more accurate to view the coastline as one large and more heterogeneous community rather than to concentrate on separate village.

Very few industries and urban centers in the Lake Victoria Basin have installed onsite wastewater treatment facilities thus discharge raw (untreated) effluent into the existing receiving water bodies including the Lake. Industries, which happen to have treatment systems, make use of waste stabilization ponds as their treatment facilities. When the industries were built, majority of the proprietors were not aware of wastewater problems. To make the matter even worse even some of the City/town Council officials did not either bother or think about the waste management. Among the few with plants, almost all do not monitor their effluents (self evaluation) regularly. However, LVEMP has put in place a monitoring programme with a definite sampling frequency in the Lake Victoria Basin. The results from the monitoring programme indicate that most of the industries do not comply with the set effluents standards. Thus, level of compliance to the effluent standards is very low. The problem is attributed by failure of industries to comply with the laid down legislation, lack of legislation enforcement, lack of experts on environmental issues, inadequacy of appropriate facilities and meagre budget allocated to such activities. Furthermore, awareness on the importance of compliance and knowledge on effluent standards is very low to most industrialists. However, introduction of Cleaner Production Technology by LVEMP into these industries has demonstrated relief on dependence of the expensive, uneconomical and inefficient "end of pipe" (EoP) treatment.

Lake Victoria basin has about 600 shoreline settlements which include fishing villages, fish landing sites, piers, beach resorts etc. Sanitary conditions in the shoreline settlements are very poor and the Lake water along the settlements show high faecal coliforms counts (indicators of recent faecal pollution). In many places the “in-law taboo”, high construction costs and lack of awareness forces people to defecate in the bush (free range) or in the Lake. Household’s structure toilets, but they are nicknamed as “choo cha daktari” meaning doctor’s toilet, which is shown when health inspectors go around inspecting the situation of health and sanitation in household (Mnyanga 2002). Fish camp owners and those with semi-permanent/permanent homes in the settlements provide limited and rudimentary sanitary facilities. While some members of the communities appreciate that the Lake is a finite resource, others view it as indestructible and inexhaustible and care the least about preventing pollution (LVEMP 2001c). Fish cleaning waste, and liquid and solid waste from eating areas, market, households etc. find its way to the lake as collection methods are not always effective. Nevertheless, the lake is recognized by most people as being the source of their livelihood. The formation of Beach Management Units (BMUs) and introduction of micro-projects co-managed by the local communities and LVEMP in these settlements is a way forward in the improvement of the sanitary conditions.

The impacts of water quality change on beneficial uses are manifold and depend on the type and concentration of pollutants (Nemerous and Dasgupta, 1991). Soluble organics, as represented by high BOD waste, deplete oxygen in surface water. This can result in fish kills, the growth of undesirable aquatic life, and undesirable odours. Trace quantities of certain organics cause undesirable tastes and odours, and certain organics can be biomagnified in the aquatic food chain. Suspended solids decrease water clarity and hinder photosynthetic processes, if solids settle from sludge deposits, changes in benthic ecosystem results. Colour, turbidity, oils, and floating materials influence water clarity and photosynthetic processes and are aesthetically undesirable. Excessive nitrogen and phosphorus lead to algal overgrowth with contaminant water processes. Chlorides cause a salty taste in water; and in sufficient concentration, water usage must be limited. Acids, alkaline, and toxic substances can cause fish kills and create imbalances in stream ecosystems. Thermal discharges can also cause imbalances and reduce the stream water assimilative capacity stratified flows from thermal discharges minimize normal mixing patterns in receiving streams and reservoirs (Liu and Lipták, 1997). Poor sanitary conditions and polluted water are associated with the Water borne and other water related diseases. The diseases common in the Lake Victoria basin include malaria, cholera, typhoid, dysentery, diarrhoea, intestinal worms, amoebiasis, and Bilharzias (Mnyanga 2002).

The Lake Victoria basin is used as a source of food, energy, drinking and irrigation water, shelter, transport, and as a repository for human, agricultural and industrial waste. With the populations of the riparian communities growing at rates among the highest in the world, the multiple activities in the lake basin have increasingly come into conflict. This has contributed to rendering the lake environmentally unstable. The lake ecosystem has undergone substantial, and to some observers alarming changes, which have accelerated over the last three decades.

This chapter focuses on the impacts of water quality change on beneficial uses of Lake Victoria . It reveals results of the studies conducted before, during and parallel to

LVEMP1 (1997- 2005). The impacts herein have turned out to be among the major impediments to the socio-economic well being of the Lake Victoria riparian communities and need to be addressed in order to sustain the beneficial uses of the lake and eradicate poverty.

METHODOLOGY:

The data and information on impacts of water quality change on beneficial uses of the Lake Victoria on the Tanzanian side were collected through water quality monitoring in the lake, rivers, shoreline settlements, and municipal and industrial effluents, questionnaires, interviewing a wide range of stakeholders, consultations with various experts, experience of the authors, and review of published data and data collected by health facilities and Water Supply Authorities. The reported information in this chapter is not limited to LVEMP1 contribution, but from various sources including data accumulated by projects prior to LVEMP1.

RESULTS AND DISCUSSIONS:

Water quality parameters analyzed by LVEMP included nutrients especially phosphorous and nitrates, phytoplanktons and zooplanktons. Some species of phytoplankton like algae produce complex organic compounds, which can cause tastes and odours. They can form a mat on surfaces resulting in clogging or binding of the filter. Some algae produce slime in their outer layers causing slippery surfaces and bad odours. Colour can be caused by the by-products of algae of all types and usually indicates taste and odour problems. Algae can cause the corrosion of concrete or metal structures. As algae grow and die they can bring about changes in the characteristics of the water, which can interfere with the treatment processes. Some algae species present in Lake Victoria are toxic like the blue-green algae thus poisoning fish and livestock. Also, *Anabaena* and *Anacystis* which can cause skin problems and hay fever respectively are also observed in Lake Victoria waters.

The results indicate increasing water quality problems and their associated negative impacts and hence deterioration of Lake Victoria waters for various uses. Pollution loads transported by rivers and municipal and industrial effluent streams are increasing and the sanitary conditions along shoreline settlements are poor. Consequently the water along the shoreline settlements was bacteriologically contaminated and the near shore areas along the urban centers of Mwanza, Bukoba and Musoma exhibited elevated BOD concentrations and faecal coliform counts. The following are the major impacts on beneficial uses of Lake Victoria waters:

A. Drinking water impairment /high treatment costs

Water quality in Lake Victoria has declined greatly in the past few decades, owing chiefly to eutrophication arising from increased inflow of nutrients into the lake. Nutrient inputs have increased two to three-fold since the turn of the century, mostly since 1950. Concentrations of phosphorus have risen markedly in the deeper lake waters, and nitrogen around the edges. Stimulated by these and other nutrients, the five-fold increase in algal growth since 1960, and the shift in its composition towards domination by blue-green algae, is causing deoxygenation of the water, increased sickness for humans and animals drawing water from the lake, clogging of water intake filters, and increased chemical treatment costs for urban centers.

Lake Victoria waters contain algae, rooted aquatic plants and other microscopic organisms. Algae produce complex organic compounds, which can cause tastes and odours. They can form a mat on surfaces resulting in clogging or binding of the filter. Some algae produce slime in their outer layers causing slippery surfaces and bad odours. Colour can be caused by the by-products of algae of all types and usually indicates taste and odour problems. Algae can cause the corrosion of concrete or metal structures. As algae grow and die they can bring about changes in the characteristics of the water, which can interfere with the treatment processes. Some algae species present in Lake Victoria are toxic like the blue-green algae, *Anabaena* and *Anacystis* which can cause skin problems and hay fever respectively. It is also known that algal blooms can cause gastrointestinal illness while blue-green algal blooms cause fish and livestock poisoning (AWWA 1998).

All of the water quality problems outlined above impose costs on water users within the Lake Victoria Basin and beyond. They also impose significant damage and costs on all components of the aquatic environments. Most of these costs, however, are difficult to quantify, especially in monetary terms. The situation is attributed mainly by the fact that treatment in most of the water utilities is not adequate. The major problem is that operations are either ‘sluggish or substandard, or they operate at a very low rate of efficiency’ and sometimes with an attitude of “do as we are used to do”. Water Utilities in most of the urban centres drawing water from Lake Victoria depending on the water quality and size of population served use to a maximum of three treatment processes namely screening, plain sedimentation and disinfection. However, Mwanza Urban Water Authority (MWAUWASA) is in the process of installing a full fledged treatment plant of 21 billion Tanzanian shillings from this financial year. This is a testimony of deterioration of water quality in the Lake and as a result the need for heavy investment. This has a bearing in the cost of potable water hence, increase of tariffs to the consumers.

Domestic and industrial users are affected in various ways by water quality problems, depending on the nature of the problem and the users. As indicated above, turbidity is a concern for domestic water supplies. However, many small communities [are] faced with the option of poor quality water or, in some cases, prohibitive treatment costs. For many towns the situation might be summed up by one respondent to the Water 2000 urban water quality survey: "the water is poor but most residents are thankful for having water at all" (MDBMC 1987, 103). Poor quality water can impact on crop production, especially when it is used for irrigation, affecting the health of plants and so reducing the quantity and quality of crops produced. This is particularly evident in terms of the impacts of saline water on many horticultural commodities (see Water and Land

Salinity). Poor quality water also affects the health of farm livestock and, in extreme cases, as with some of the outbreaks of blue-green algae, can cause their deaths (Pazi et. al, 2005).

Table x: Trend of Chemical Use by BUWASA

S/No.	Financial Year	Amount of Disinfectant Used (Kg.)
1.	2001/02	2500
2.	2002/03	3200
3.	2003/04	4700
4.	2004/05	5500
5.	2005/06	4000

Source: BUWASA

B. Water related diseases

Water Quality assessments and sanitary surveys along the shoreline settlements and impact stations around the urban centres have revealed that water borne and water related diseases are very common. The most common diseases occurring mostly during rainy seasons include cholera, typhoid and dysentery. This is associated with faecally polluted waters and poor sanitary conditions along the areas in question. The common water related disease in the shoreline settlements is bilharzias (Schistosomiasis). The diseases are debilitating leading to reduced social economic performance of the communities and hence the associated poverty to the riparian communities

Shoreline Settlements in the Lake Victoria Basin have been identified to be potentially high transmission areas for sexually transmitted diseases (STDs) like gonorrhoea, syphilis and HIV due to increased migrant business people and workers (Muro *et al*, 2005). Fishermen have been reported to be among the high-risk groups for STDs because of their work environment, mobility, young age, drunkenness, low condom use during coitus and relatively large sums of money they earn/carry (Wilson *et al*., 1991, Barongo, *et al*., 1995). They are therefore able to attract partners who are willing to provide them with sexual services (Wilson *et al*, 1991). The risk of such men and women being infected with HIV is high because of their behaviour of having multiple partners. Barongo *et al* (1995) reported that the prevalence of HIV among men was 10.9% and among women was 10.7% in shoreline settlements in Magu district. These rates were considerably higher than in ordinary rural villages as reported by Grosskurth *et al* (1995) who, in 1993/94, found the prevalence of HIV to be 3.8% in rural villages, and 7.7% in roadside communities among adults aged 15-54 years in Mwanza region.

Recently, an increase of high risky behaviour has been noted as a result of reduction of fish stock (water quality has a bearing on it) which is currently under threat; thus leading to poverty in these fishing communities (Medard, 2003). Medard (2003) showed that some women take risks in order to get 'a day meal' by resorting to establishing sexual relations with gillnet boat owners, beach seiners and crewmembers to get fish once landed. Other women move to beach seines and camps to sell their bodies in order to support themselves and their families. High mobility rates and drunkenness as were shown by others (Appleton, 2000; Medard, 2003) to be among other high-risk factors that also contributed towards high rate of promiscuity in fishing communities.

As a result of the addition of nutrients, mass-developing cyanobacteria are proliferating in the Lake Victoria. A number of cyanobacterial genera, e.g. *Anabaena*, *Aphanizomenon*, *Cyanodictyon*, *Cylindrospermopsis* and *Microcystis* have been recorded from Lake Victoria. As a part of the gram-negative cell wall, cyanobacteria more or less produce lipopolysaccharide endotoxins. The presence of endotoxins in the tap water may cause a malaria/influenza-like syndrome when the water is inhaled as aerosols as e. g. during showering. The symptoms of the illness include fever, malaise, dizziness and upper respiratory tract infection. The syndrome may be misdiagnosed as influenza, malaria or Legionnaires' disease. Additionally, a study undertaken by the University of North Carolina and sponsored by AWWARF has found no clear-cut evidence that THMs harmed women, but that brominated compounds and total organic halides in drinking water might modestly increase the risk of miscarriage (IWA 2005).

The above diseases for sure can weaken people and reduce their capacity to work (nguvu Kazi). Thus affect socio-economic development of the Lake Victoria Basin. Suitable drugs for treating the sick may not always be available in health facilities and therefore people (particularly in rural communities) live in poor health conditions as it was observed.

C. Food web contamination

One issue of significance is that, even in what appear to be pristine waters, some metals are reaching surprisingly high levels in fish. Metals accumulate in the bodies of animals through the foods they eat. Some metals even increase in concentration as they pass through two or more trophic levels in a process known as biomagnification. Because of this cumulative build-up of toxins in aquatic food chains, humans who consume fish from lakes where bioaccumulation occurs may be exposed to levels of metals associated with adverse human health effects. Other animals at the top of aquatic food chains, such as fish-eating wildlife, are also highly susceptible to metal contamination. Many contaminated water sources contain a number of heavy metals, pesticides and other agricultural chemicals, along with persistent organic pollutants (POPs), many of which remain in the environment for long periods of time and bioaccumulate in the food web, causing many acute and chronic diseases, ranging from severe skin and liver disorders to developmental abnormalities and human cancer.

The Total mercury concentration in fish and invertebrates are relatively low in Lake Victoria compared to those from other large temperate Lakes. In his study Campbell *et al*, 2003 observed that Total mercury concentration increased with size in both Nile perch and Nile tilapia, with the largest piscivore Nile perch having the largest concentration. The low Total mercury concentration in fish and invertebrates seem contrary to high Total mercury concentration in water and are attributed to four probable factors: short food web length, increased growth dilution and tissue turnover in tropical biota, biomass dilution, and the unique biogeochemistry of Lake Victoria. However it is important to point out that any shift in the methylation process, trophic status, or food web structure in Lake Victoria, especially if the Lake becomes increasingly eutrophic and hypoxic (thereby stimulating growth of methylating microorganisms), could lead to increased bioaccumulation of MeHg in the food chain (Campbell *et al*, 2003). Studies conducted between 1996 and 2004 by Ikingura and Akagi (1996); Migiro (1997); DHV Consultants (1998); van Straaten (2000a, 2000b); Ikigura and Akagi (2002); Campbell *et al* (2003); Machiwa *et al* (2003), Machiwa (2003a, 2004); and Kishe and Machiwa (2002) do not indicate a pronounced mercury and other heavy metals pollution in Lake Victoria because of gold mining activities in the basin. However, studies to determine the amount of mercury that actually reaches into the Lake Victoria and its fare are lacking.

Organochlorine pesticides have been used in the Lake Victoria basin for crop protection (mainly cotton) and protection of livestock against ticks. These pesticides have found their way to the environment and aquatic organisms (Rwetabula et., al 2004). According to Ijani *et al* (1997), analytical results from the tissues of the African eagles collected from Lake Victoria area, showed that the kidneys were contaminated with *p,p'*-DDE and *o,p'*-DDE and these organochlorine pesticides, and beta-HCH were also present in the brain and liver tissues.

D. Loss of fish habitat

Lake Victoria is suffering from creeping eutrophication - an influx of nutrients due mainly to deforestation of the lake shore, industrialization and human pollution. Algal blooms and sediments limit light penetration to bottom dwelling organisms, especially in shallow inshore waters, and have contributed to a 4-fold reduction in the lake transparency since the 1960s. The Lake eutrophication and associated deoxygenation has reduced the volume of fish habitats. These nutrients feed large algal blooms that die and sink to the bottom to be consumed by bacteria, which use up oxygen in doing so. The water grows murkier, which suits the perch, because they can see better in low light than cichlids. And crucially, female cichlids can no longer distinguish the markings of males, which is how they select their mates.

The presence of Hydrogen Sulphide in the Lake bottom waters in the offshore was noticed for the first time in March 2004 (LVEMP 2004). This condition was associated with migration of fisherman from the Goziba Island (to the Islands of Ukerewe, Bumbire, Kerebe etc.) due to scarcity of fish in the area. Hydrogen Sulphide is toxic to fish. Thus, the hostile environment caused by the toxic gas in the bottom sediment, and the very low Oxygen concentrations in the near bottom waters should have led to migration of fish to relatively "less deep" waters with favourable conditions (Rutagemwa, 2004).

Elevated lake temperatures accelerate chemical reactions and microbial processes such as denitrification–nitrification. This affects nutrient cycling and availability and as well as algal biomass development and oxygen availability (hypoxia in sheltered bays and deeper waters affects fishery production). Low oxygen conditions directly affect distribution of organisms including invertebrates and fish in Lake Victoria. Bottom water oxygen depletion (anoxia) is thought to have forced haplochromine and tilapiine fish species into the surface waters where they experienced heavy predation by the predatory Nile perch.

The enormous swamplands of East Africa form buffers that provide water quality regulation in receiving waters. They are often dominated by papyrus, and represent a habitat of great ecological importance. Catchment activities, particularly devegetation (biomass harvests), burning, and so on, easily lead to changes in structural components in surface water. In Lake Victoria, just as in North American lakes, eutrophication has become manifest as the fish fauna change (Hecky, 1993). Apart from the perceived "top-down" effects of exploitation and species stockings on species diversity and water quality, catchment impacts on aquatic ecosystems caused by environmental degradation (e.g., of watersheds and airsheds) are directly related to human socioeconomic objectives, and may explain many of the changes in water quality and species assemblages in Lake Victoria.

E. Inefficient food webs

Lake Victoria from 1960s has recorded reduced silica and elevated P and N concentrations. This has led to a shift in dominance from microalgal communities dominated by diatoms such as *Aulacoseira (Melosira)* and green algae to blue-green algae (BGA). *Aulacoseira* formed the main food of the native commercially important tilapiine *Oreochromis esculentus*, and its reduction might have affected stocks of this species. The dominance of BGA including toxic forms, could have led to reduction of available food for the native fish species. BGA are less digestible and provide poor quality food that may have contributed to the reduction or loss of planktivorous haplochromines and tilapiines that once flourished in Lake Victoria.

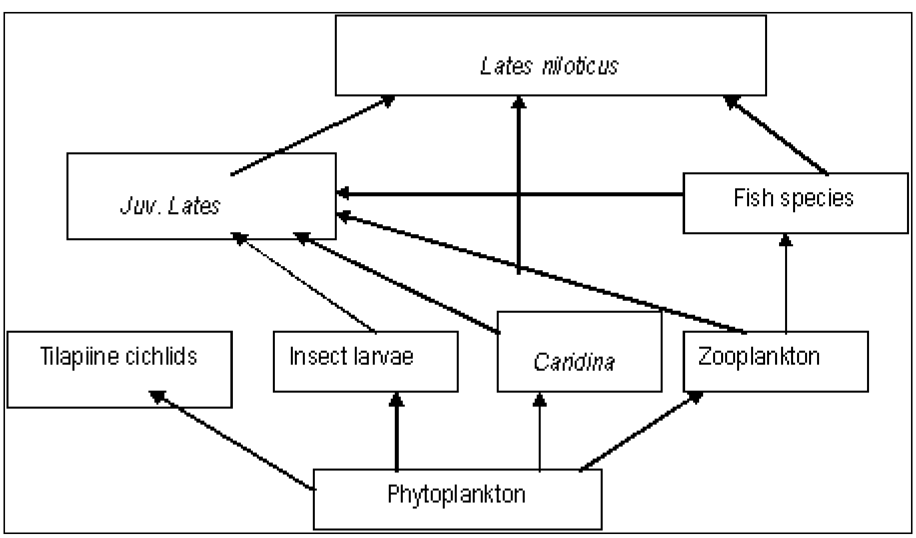

Fig. 1. A schematic diagram showing a food web in Lake Victoria

The fishery has transformed from a broadly based multi species to one based on three dominant species; a small sardine- Nile species *Rastrineobola argentea*, Nile tilapia, *Oreochromis niloticus*, and the Nile perch, *Lates niloticus*. Those changes have shown an impact on the food web. This transformation in one way or another is linked to the introduction of the Nile perch in the 1950s and eutrophication condition in the Lake. Through the *Lates niloticus* predation on indigenous fish stocks, the original food web has been disrupted; most of the zooplanktivorous fish went missing (Witte *et al.*, 1992). Consequently planktonic food has not been fully utilized and signs of eutrophication are imminent (Heckey and Bugenyi 1992; Muggide 1993).

There are indications of an increase in phytoplankton, macrophytes, shrimps and benthic organisms in Lake Victoria. Many of these rapid changes in the lake's ecosystem are probably the effects of the increase of the Nile perch and the disappearance of the haplochromines. The original fish fauna in Lake Victoria included many primary and secondary consumers. Currently, secondary and tertiary consumers dominate. The food web in the sub-littoral and offshore areas of the lake changed considerably due to the stock replacements. Many communities living around Lake Victoria are under intense pressure to meet escalating needs for animal protein. As requirement for fish protein is rising rapidly in relation to increasing human populations, Ribbink *et al* (1985) predicted that these fish communities will be subjected to even greater fishing pressure in the future.

F. Loss of biodiversity

Biodiversity may be defined as the totality of genes, species and ecosystems in a region also described as the degree of variability in nature expressed in the organisms such as plants, animals, fungi, microbes and the ecosystems of which they are part (Okey-Owour, 1998). Lake Victoria is best known to scientists for its more than 600 endemic species of haplochromine cichlids, representing one of the most rapid, extensive, and recent radiations of vertebrates known (Greenwood 1974, Kaufman 1992, Seehausen 1996, Kaufman et al. 1997). In addition, a rich assemblage of noncichlids inhabits the basin. The fish stocks of the lake were subjected to three major series of events: (1) Fishing intensified over the century, associated with new technologies (e.g., commercially produced, artificial-fiber nets; outboard motors; increasingly destructive fishing gear), diversification of markets (especially the export of Nile perch), and increased numbers of fishers. (2) The introduction of nonindigenous fishes influenced community composition and functional relationships in the lake. (3) Increased human population density and its consequences—agricultural and industrial activity, change in fish composition, and shoreline deforestation—all contributed to a change in lake trophic state from mesotrophic to eutrophic (Hecky 1993).

Reduced transparency (low visibility) interferes with mate choice (using visual cues – bright colours in males) in haplochromines, leading to hybridisation and decline in species diversity. And crucially, female cichlids can no longer distinguish the markings of males, which is how they select their mates. As male colour becomes obsolete as a signal for mate choice, Ole Seehausen of the University of Bern, Switzerland and colleagues are finding that the reproductive barriers are breaking down between some cichlid species which sport different colours, and hybridisation is taking place. Red and blue males of different species are giving way to males of a dull brown, and losing their ecological specialisations - the difference in their feeding habits, for instance - in the process. Hybridisation can lead to a loss of diversity and is, therefore, generally seen by biologists as a bad thing. But it could also be a force for successful adaptation, and eventual recovery of diversity, Seehausen argues. "By reshuffling the genes of two species, it can generate the genetic raw material for new species with new specialisations - a novel combination of a certain feeding behaviour with a particular habitat, say." If that combination can fill an ecological niche not yet fully exploited by other species, the hybrid could establish itself and thrive. There is evidence that that is happening in Lake Victoria. A handful of the 200 or so species once thought to be extinct seem to be reviving. But, says Seehausen, "Many of the reviving populations look like recombinants of pre-existing species." Seehausen speculates that the lake's coastal bays and gulfs, where the water is murkiest, act as a "hybridisation belt". Individuals of novel genetic makeup are engendered here, and those that are well-adapted to life in the altered lake may then move out into clearer, open waters, where there is a greater choice of niches to exploit, and the females can see. Both ecological and sexual selection then act to enforce their genetic isolation one from the other - creating new species. The key, then, is to have this balance between hybridization and diversifying pressures, between murky and clear. The lake is grossly over-murky now. But, says Seehausen, "If the water clarity can be improved again, it may yet be pushed back to levels where more diversity would again be promoted."

Even if the lake does recover its former diversity quickly, it will not be the same diversity. For one thing, it will never now be rid of Nile perch. There is also the major threat posed by eutrophication to consider. Human beings, like cichlids, are distinguished by their adaptability, but if eutrophication continues at the rate it is, then the lake will one day stop providing both drinking water and protein. "A lake without oxygen would be a disaster for about 30 million people," says Goldschmidt.

The effects of Nile perch on the Lake Victoria fish community were perhaps most eloquently illustrated by Ligtvoet and Witte (1991). In that work the authors diagram the pre and post Nile perch sub-littoral food webs, thus describing the loss of more than 300 species and several functional groups. Most notable is the disappearance of molluscivores, parasite eaters, detritivores, scale eaters, epilithic algae scrapers, paedophages, and specialized insectivores. However, as several authors have pointed out, Nile perch, Nile tilapia (*Oreochromis niloticus*), some catfish (*Synodontis sp.*), and the schooling cyprinid *Rastrineobola argentea* now dominate the lake and have diversified their diet (Batjakas et al., 1997; Hughes, 1986; Ogari and Dadzie, 1988; Ogutu-Ohwayo, 1990; Olowo and Chapman, 1999). Understanding the functional role of fish diversity in Lake Victoria therefore requires a system simulation using a common currency.

Studies in Tanzania by Witte *et al* (1992) revealed some vital information on the dynamics of the haplochromine cichlid fauna and ecological changes in the Mwanza Gulf of Lake Victoria. Witte *et al* (1990) also reported on reproductive strategies of zooplanktivorous haplochromine cichlids from Lake Victoria before the Nile perch boom. Further work by Dawes (1986) revealed that Lake Victoria indigenous fish species, especially cichlids, face extinction.

One of the major moral dilemmas of today concerns its use of natural resources. On the one hand there is the need to satisfy the nutritional requirements of a growing human population. On the other there is the need to conserve existing genetic, specific, and ecosystem biodiversity for future generations. These two imperatives are frequently in conflict because the maximization of human societal needs for food, goods, and infrastructure involves the disruption of existing habitats and living aquatic communities. Efforts to resolve this conflict have been encouraged in a number of international forums including the Convention on Biological Diversity (CBD).

G. Nuisance macrophytes growth

Aquatic macrophytes alter sediment, water quality, physical condition, and population dynamics of the ecosystem by plant growth, metabolism, and decay. Macrophytes also provide food, shelter, and substrate for a variety of organisms in the aquatic system. Bacteria, algae, protozoan, rotifers, and invertebrates inhabit underwater leaves and stems (Engel, 1990). Rotifers and small crustaceans filter bacteria, algae, and detritus from water flowing by the plants. Snails, certain leeches, and many insect larvae scrape algae and detritus on the foliate or beneath it. They in turn are consumed by other aquatic insects, fish, water birds, and some furbearers. Aquatic macrophytes alter the physical environment by intercepting water movements and sunlight. Dense vegetation provides relatively quiet area near shore and blocks turbulence from breaking waves, longshore currents, and runoffs. High energy shores, exposed to erosion from winds and waves, become calm depositional plains after plant growth (Engel, 1990). Plants at the water surface blunt the wind, reducing its potential to stir the bottom. In terms of casting shade and blocking water movement, plant beds reduce the amount of heat transfer to the bottom. The foliage acts as a barrier to separate warm water at the surface and cool water at the bottom. Also, density differences between cold and warm water masses help maintain this separation. The temperature gradients create warm and cool microclimates for colonizing organisms (Engel 1985). Animals unable to withstand warm water can approach the shore under macrophytes; others can be repelled by heat radiated from surface foliage. Cool bottom water can also reduce photosynthesis in lower leaves and delay hatching of fish eggs, whereas warm surface water can speed up the development of invertebrates. Microclimates which are caused by macrophytes growth thus restructure the ecosystem (Engel, 1990). Sediment supplies nitrogen (N), phosphorus (P), and micronutrients to aquatic macrophytes. Researchers report that various species of freshwater aquatic macrophytes not only extract nutrients from the sediment but also release them into the surrounding water (Carignan and Kalff, 1980). As a result, high productivity and biomass turnover of rapidly growing macrophytes can result in high rates of sediment nutrient loss (Barko, 1993). Thus, nutrient uptake by aquatic macrophytes may significantly reduce sediment nutrient availability.

Aquatic macrophytes growth also alters the sedimentation rate of the water. Sedimentation rates are generally much greater in macrophyte beds than in the open water systems due to the filtering capacity of macrophytes (Barko, 1993). As a result, aquatic macrophytes not only reduce the turbulence in the water but also stabilize the sediment. As suspended sediment is removed from the water column, light penetration increases, so more light becomes available for photosynthesis by aquatic macrophytes. The value of pH increases in macrophyte beds during periods of photosynthesis. Elevated values of pH near the sediment surface tend to increase rates of phosphorus release from sediment, which can stimulate algal production. Algal production on macrophyte leaf surfaces becomes an excellent source of food for grazing invertebrate communities. The growth of invertebrate population can result in an increase in fish population. Besides, the structural complexity of macrophyte beds can influence fish communities of aquatic systems directly. These beds provide refugees for smaller fish, and are thus important in predator-prey relationships. To sum up, aquatic macrophyte communities can potentially influence bed geometry as well as biomass distribution in aquatic systems (Barko, 1993).

- **Water Hyacinth**

Increased nutrient loads into the Lake Victoria seem to have spurred water hyacinth infestations, particularly in bays receiving municipal sewage, urban run-off, and wastewater from industries, agricultural activities and shoreline settlements. Waters rich in nutrients especially Nitrogen and Phosphorus create conducive conditions for water hyacinth proliferation (Katagira et al., 2002). In such conditions, the weed can grow so quickly that the surface covered by mats doubles every 4-7 days (LVEMP 2004). Healthy mats of water hyacinth become substrate of secondary growth for weeds such as *papyrus species* and other similar plants resulting in formation of solid mats, which are heavy and too difficult to allow for useful socio-economic activities to be undertaken. Its enormous reproductive capacity cause annual re-infestation from seed and rapid coverage of previously treated bare water causing problems to infested water bodies. Water hyacinth has had both negative and positive impacts on the Lake Victoria since its establishment in the lake. The negative impacts include interference with fishing operations especially in the bays where fish are landed; unemployment and diminished incomes and food for riparian communities a situation that results in emigration of fishers to other water bodies; deterioration of water quality; Increased operational costs for commercial vessels; Blockage of commercial transport routes and communications between islands; Physical interference to water supply for rural communities; Physical threats to water-based utilities, especially the national hydroelectric power station in Uganda, and to water intakes, in addition to increased operational costs for purifying and pumping the water; interference with operation of fishing boats and gears. Other negative impacts include interference with recreational activities and increased water loss through excessive evapotranspiration hence reduction in Lake Levels. Since the mat occupies the inshore areas, these areas are blocked and the dense weed growth destroys fishing grounds through lack of light, nutrients and oxygen. At the same time fresh water snails like *Biomphelaria* species, which is an intermediate host for *Schistosomiasis* (bilharzias) are bound to be attached to the roots of the plant. It serves as habitat for dangerous organisms such as venomous snakes, hippopotamus, crocodiles and mosquitoes (Burton 1960;

Seabrook 1962; Spiral *et al* 1981; Gopal 1987; Viswan *et al* 1989). Water hyacinth shades out, smothers and replaces many species of native water plants in shallow water areas hence interference with biodiversity. The weed is also hazardous to tourism industry in the lake region. It prevents beaches and lake shore from being used for swimming and other water sports, says Dr. Geoffrey Howard, coordinator for Eastern Africa Wetlands Conservation Programme.

On the other hand water hyacinth has some positive impacts in Lake Victoria. These include the abatement of pollution since the plant has the capacity to accumulate heavy metals and phenols including cadmium, lead, magnesium and nickel. The plant also flourishes better with good supply of nutrients especially near sewage outflows. In other words it is a good bio-indicator of pollution.

CONCLUSIONS:

Lake Victoria is of great economic worth to the three riparian countries and of great scientific and cultural significance to the global community, mainly with respect to its unique water characteristics and waterborne biodiversity. However, the ecological health of the Lake has been affected profoundly as a result of prolific growth of algae, and degradation of water quality because of pollution from land-based activities including dumping of untreated effluents by several industries resulting from a rapidly growing population; the introduction of non-indigenous species (both fish and plant weeds); clearance of natural vegetation along the shores, a booming fish-export industry; and the disappearance of several fish species native to the lake. It is also facing the typical consequences of these problems: Potentially vast and irreversible environmental damage, hardships among the poor, and serious health concerns.

Water quality parameters analyzed by LVEMP included nutrients especially phosphorous and nitrates as a measuer of eutrophication, phytoplanktons and zooplanktons. Some species of phytoplankton like algae produce complex organic compounds, which can cause tastes and odours. They can form a mat on surfaces resulting in clogging or binding of the filter. Some algae produce slime in their outer layers causing slippery surfaces and bad odours. Colour can be caused by the by-products of algae of all types and usually indicates taste and odour problems. Algae can cause the corrosion of concrete or metal structures. As algae grow and die they can bring about changes in the characteristics of the water, which can interfere with the treatment processes. This was evidence from the cost of water treatment cost experience by MWAUWASA. Some algae species present in Lake Victoria are toxic like the blue-green algae thus poisoning fish and livestock. Also, *Anabaena* and *Anacystis* which can cause skin problems and hay fever respectively are also observed in Lake Victoria waters.

The Lake Victoria as a receptacle microbial waste load competes with its uses as a water resource of which the direct use for consumption causes the main health problem. It is also functioning as a sink for nutrients causes eutrophication which can lead to fish kills.

Moreover, cultivation of riparian wetlands destroys breeding grounds for fish and reduces the wetland capacity to filter out nutrient loads, both with negative effects for fish stocks.

From the analysis impacts that were identified includes; 1)drinking water impairment leading to high treatment costs; 2)appearance/outbreak of water related diseases which in a way reduce the workforce and increased medical bills; 3)food web contamination leading to bioaccumulation in higher trophic levels; 4)loss of fish habitat due to increased pollution/eutrophication; 5)inefficient food webs resulting from occurrence of other dominance species which are not easily ingestible by lower and or middle trophic levels; 6)loss of biodiversity and proliferation of unmanageable macrophytes such as water hyacinth. These impacts are major impediments to the socio-economic well being of the Lake Victoria riparian communities and need to be addressed in order to sustain the beneficial uses of the lake and eradicate poverty.

RECOMMENDATIONS:

The current situation is not sustainable and the negative impacts will continue to grow if not addressed. These impacts can be addressed through stronger and consistent enforcement of Clear standards and regulations, adoption of cleaner technologies, upgrading treatment facilities, investment in infrastructure, public education and public pressure. There is a consensus among scientists that if an accelerated push to save the lake is not made soon, this much-needed body of water will cease to sustain life.

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