The changing water quality of Lake Victoria; current conditions, trends and required action.

CHAPTER 1

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J.O. Okungu[1], D.K. Rutagemwa[2], M. Ssenfuma-Nsubuga[3], J.O.Z. Abuodha[4] F.L. Mwanuzi[5], F.J. Muyodi[6] and R.E. Hecky[7]

[1] LVEMP, Water Quality Management Component, P.O. Box 1922 Kisumu, Kenya
[2] Water Quality Management Component, P.O. Box 211 Mwanza, Tanzania
[3] Water Resources Management Department P. O. Box 19 Entebbe Uganda
[4]School of Environment and Earth Sciences, Maseno University, P. O. Box 333, Maseno, Kenya
[5]Department of Water Resources & Environmental Engineering, University of Dar es Salaam, P.O. Box 35131, Dar es Salaam, Tanzania
[6]Department of Zoology, Makerere University, P.O. Box 7062, Kampala, Uganda
[7]University of Waterloo, Biology Department, 200 University Ave, West Waterloo, Ontario N2L 3G1

INTRODUCTION

The Water quality and Ecosystem Management Components of the Lake Victoria Environmental Management Project (LVEMP) in the three riparian countries (Kenya, Tanzania and Uganda) have made considerable progress towards understanding Lake Victoria water quality and its ecosystem as well as effects of resource utilization and exploitation on the lake and in its basin. 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 report documents and explains the changes that have taken place over the recent decades, and provides 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 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. This regional synthesis report was written by regional scientists and technical experts under the guidance of an international consultant, Prof. Robert Hecky of the University of Waterloo, Canada, together with the National consultants; Dr. Joseph Abuodha of the Maseno University, Prof. Fredrick Mwanuzi of the University of Dar Es salaam and Dr. Fredrick Muyodi of Makerere University. It brings together data, interpretations and recommendations from three national water quality reports. A number of national and regional working sessions were conducted to enable the scientists to complete these reports, and all these were facilitated by the National Executive Secretariats of LVEMP who were supportive through out the process.

Background

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

The overall objectives of the LVEMP 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; 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 maintenance of a healthy Lake Victoria ecosystem and the reversal of increasing environmental degradation.

One of the critical components of LVEMP concerns Water Quality and Ecosystem Management which has 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, establishing a water quality monitoring network throughout the catchment, estimating the effects of changes in land use planning on pollution loads into the lake, developing policies and programmes to control non-point source pollution, improving management of Industrial and Municipal effluents and assessing the contribution of urban runoff to lake 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 the aquatic ecosystem as well as effects of resource exploitation within the lake and its basin. The component has collected considerable amounts of new data and information.

The component, using historical data and the data it initially collected produced an initial report in 2002, which provides a baseline for water quality status at the start of the project and indications of possible change from historic conditions. The data have 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 report will document and explain the changes that have taken place over the recent decades, and it will provide a definitive overview of the present water quality status and continuing trends that may require remedial action. The report provides enough detailed information and spatial resolution to support environmental decision making in regards to spatial allocation of possible remediation of undesirable changes that have reduced beneficial uses of Lake Victoria biological and water resources.

Approach to Synthesis Report

All the available data and reports generated by the component since the start of the project were first collected, collated, updated, reviewed and incorporated to National Water Quality Reports. The National Reports and the analyses contributing to them form the basis of this regional synthesis addressing the following issues:

i) Determine the current state of knowledge of the Lake Victoria water balance;
ii) Use the components of the water budget to estimate current nutrient loads and balances of the lake;
iii) 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;
iv) 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;
v) 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;
vi) 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;
vii) 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;
viii) Determine the role of lake consumers e.g. zooplankton, zoobenthos, microbes and lake flies in the ecosystem dynamics;
ix) 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;
x) Relate the water quality findings with the findings of other Components of LVEMP;
xi) Assess effects of poor water quality on the socio economic aspect of the riparian communities;
xii) Provide data for eventual use in the Lake Victoria Water Quality Model to simulate the future effect of different interventions and management options for the lake.

The above issues are grouped and summarised in different chapters addressing specific issues. Chapter 2 on Capacity Building for Water Quality Management addresses how LVEMP has addressed critical constraints in infrastructure, programmes and technical capacity to improve regional capacity for management of the water quality of Lake Victoria. Chapter 3 presents the water balance of the lake quantifying inputs, outputs and how they affect lake level changes. Increasingly the water balance of the lake is affected by multiple use management objectives that can affect riparian uses around Lake Victoria and also downstream along the Nile. Chapter 4 addresses the critical meteorological processes that set the waters of the lake into motion and change their vertical circulation over the seasons. These movements dictate the transport and mixing of incoming materials through out the lake. Chapter 5 of the report describes the results of the monitoring program on Lake Victoria that for the first time allows a full spatial analysis of conditions throughout the lake. This facilitates comparison with

earlier data that were more constrained to specific locations while providing a comprehensive description of present conditions on the lake that will provide a baseline for future assessments and trends. Chapter 6 examines the lake's most urgent water quality problem, eutrophication, and explains its causes, its severity and possible solutions. Chapter 7 quantifies the sources of nutrients and sediments to Lake Victoria, estimates a nutrient balance for the lake for the first time, and determines the fate of incoming nutrients within the lake. Chapter 8 describes how changing water quality affects the communities around the lake that are dependent on that water quality to meet their daily needs. The lake provides many beneficial services to the communities, but many of these uses are degraded or at risk. Similarly haphazard, poorly planned and unsustainable development will continue to degrade the lakes' uses. Rehabilitation of degraded resources will require an action plan to restore and preserve the beneficial uses of the lake for all the riparian communities sharing Lake Victoria.

The State of Lake Victoria Environment before 1997

Prior to the initiation of LVEMP activities in 1997, the regional capacity 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, information on the lake's water quality was based on spatially limited and infrequent data collected by local and international researchers mostly on *ad hoc* basis. Most of the research at that time was undertaken in the northern and eastern sectors of the lake in Uganda and Kenya and only a few were carried out in the western and southern sectors 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 provided a baseline 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 so that we have perspective on the lake's modern condition.

The Lake Victoria ecosystem has increasingly degenerated since early 1960s both in water quality and in the diversity of its fishery. These changes were driven by high population increase, their associated activities and economic development and species introductions both planned and unplanned. Population growth and the activities required to sustain the increasing population resulted in increased flows of pollutants and nutrients to the lake and its tributaries from the catchment leading to pollution, siltation, eutrophication of the lake and water-related public health problems. This has been the experience of lake basins around the world that have experienced rapid population growth and economic development. The lake has also since the late 1980s been invaded by the water hyacinth which presented a challenge to the coastal activities and environmental managers through choking of waterways and intakes and interrupting the fishery. These in combination with other problems in turn resulted into decline in biodiversity, deoxygenation of the deeper waters of the lake, 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 faecal coliform bacteria, 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 pesticide pollution. The small-scale gold mining activities in Mwanza and Mara regions and increased use of mercury in recovery of gold by artisanal miners posed potential contamination of waterways (leading to the lake). Modern mining activities using closely controlled cyanide-based processes for gold extraction have also grown along side the increasing artisanal mining activities. 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 primarily are driven by land based activities and secondarily from lake-based activities. They are 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).

Because the level of fertilizer uses in agricultural areas around the catchment was generally low, the main rural source of the nutrients was 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 changes in the chemical forms of these compounds 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.

High population growth coupled with poverty and lack of appropriate agricultural methods also increased pressure on land and natural resources in general. The farmers resorted to cultivating in areas with steep slopes, riverbanks, forests and wetlands. These activities contributed to increased soil erosion, decreased nutrient retention in soils and wetlands, and thus increased mineral and biogenic sedimentation in the lake. Overgrazing and deforestation also contributed significantly to soil erosion. Deforestation, mainly related to clearing of land for agriculture, the rising need for timber used for construction, demands for wood fuel for cooking and smoking fish increased in proportion to the population growth. The loss in permanent vegetation cover has resulted accelerated runoff and increased exposure of soils to sheet and gully erosion. The clearing of forests is largely done by burning and demands for fuel wood also require burning. Consequent to the burning is the mobilization into the atmosphere of many compounds including those of nitrogen and phosphorus in gaseous and particulate forms that can be transported from the catchments and deposited to the lake. Increasing tillage

of the land also exposes the soils for periods of the year to wind erosion which can also contribute to nutrient transport from the catchments.

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 total phosphorus rose markedly in the deeper lake waters and total nitrogen and total phosphorus rose in the near shore areas. Stimulated by these nutrients algal growth increased (Fig. 1) and its composition shifted towards domination by heterocystous blue-green Cyanobacteria (Hecky 1993; Hecky and Bugenyi 1992). 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). By the early 1990's, the lake algal growth was nutrient saturated as high phosphorus concentrations enable nitrogen fixing Cyanobacteria to dominate and algal growth became light limited due to self shading effects of the increased algal abundances (Mugidde 1993; Mugidde *et al.* 2003). Algal blooms and increased primary production can lead to higher oxygen consumption as excessive growths of algae decay and cause deoxygenation of deep waters (Hecky et al 1994) and increasing reports of fish kills associated with these blooms (Ochumba and Kibaara 1989). Apart from the increased abundance of algae dominated by the potentially toxic species, the water hyacinth since 1989 began 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. Because it floats on the surface, the plant cannot be light limited as the algae are, and can therefore out compete the algae in nutrient-rich areas. The dense cover of water hyacinth can shade algal populations but also these stands can also cause deoxygenation of waters beneath them and cause shallow water conditions of low or no oxygen.

FIG. 1. 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 fish species, the de-oxygenation of the lake bottom posed threats even to fish in shallower portions of the lake, as periodic up welling of hypoxic water caused massive fish kills. (Ochumba 1990, Ochumba & Kibaara 1989). These symptoms of environmental degradation were known already in the late 1980's based on limited studies available the extent of these conditions throughout the great expanse of Victoria were not know. Also, although the many of the causes of eutrophication were known from international experience and research, the rates of enrichment, its sources and its numerous effects in the Lake Victoria basin were not well quantified so it was not possible to estimate economic and ecological costs nor to determine if and what restoration activities would be necessary to reverse the undesirable trends.

LVEMP Implementation

Lake Victoria Environmental Management Project is as a multidisciplinary environmental project funded by the World Bank, the Global Environmental Facility and the three riparian states of Kenya, Tanzania and Uganda. One of the components of LVEMP is Water Quality and Ecosystem Management. The component is comprised of three sub-components namely In-lake Water Quality Monitoring, Management of Industrial and Municipal Waste, and Management of Pollution Loading into Lake Victoria. The objectives of this report are to provide: 1) the first detailed regional synthesis of data generated during LVEMP by national components and published in the LVEMP National Water Quality Reports in order to inform and guide regional policy development, 2) to present a regional consensus on the current state of the lake and identify any negative trends affecting the beneficial uses of the Lake Victoria, and 3) to recommend possible and appropriate actions for regional implementation to restore or improve those beneficial uses. This document will provide a critical benchmark for environmental management of Lake Victoria by providing a comprehensive baseline against which the effects of future management or neglect can be evaluated.

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