# Assessment of Industrial and Municipal Effluent and Urban Run-off Loads Discharged into Lake Victoria from the Uganda Catchment

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**Abstract**

An assessment was carried out to determine the pollutant loads discharged into Lake Victoria from industrial and municipal sources as well as the contribution from urban run-off from the Uganda catchment from 1997 to 2000. This study was part of the Lake Victoria Environmental Management Project (LVEMP). The paper outlines the outcome of a case study which was the first ever done to quantify pollution loading into Lake Victoria emanating from municipal /urban and industrial sources located in the entire part of the lake catchment of Uganda. Similar work was carried out simultaneously in Kenya and Tanzania. Most urban centres and fishing villages with a potential pollution threat to Lake Victoria were identified. Similarly, factories in Kampala, Jinja and Entebbe with potential pollution threats have been identified. The results show that urban centres contributed a daily load of 6.17 tonnes BOD, 1.43 tonnes of nitrogen and 0.98 tonnes of phosphorus. 1.88 tonnes BOD, 0.26 tonnes of nitrogen and 0.13 tonnes of phosphorus are discharged daily from the 124 fishing villages with a total discharging human population of 92,000. Industrial loads reaching the lake were estimated to be 1 tonne BOD, 0.1 tonnes nitrogen and 0.1 tonnes phosphorus per day. Contrary to the previously long held perception that industries were responsible for much of the pollution loading entering the lake, this study demonstrated that the major pollution loading entering the lake was actually from the urban centres; they accounted for nearly 70 % of BOD and 80 % of other nutrient loads. Kampala accounted for about 60 % of the discharging population and 65 % of the total BOD load. Pollution management strategies proposed for urban centres should therefore focus on improved garbage collection and sanitation, particularly in the Nakivubo catchment of Kampala. There is a need also for a more proactive approach for the protection of wetlands since the study showed the significant role they play in the reduction of pollution loads. Sanitation improvements advocated include:

improved operation and maintenance of the existing municipal wastewater treatment works, strengthening of process engineering expertise (Cleaner production) and greater on-site sanitation coverage. Similar sanitation recommendations apply for fishing villages, but here, the strategy should be focused on improving the ability of fishing village communities to help themselves and access existing sanitation programmes. The strategy for industry is the use of the Pollution Control Manual produced for training and guidance, strengthening of process design capacity, a staged approach to treatment plant development, and strengthening of Discharge Agreements.

**Keywords:** Pollution loads, Municipal waste, Urban run-off, Fishing villages, Industrial effluent, Lake Victoria

## INTRODUCTION

The Lake Victoria Environmental Management Project (LVEMP) was conceived and established as an international response to threats to the lake arising from human activity (World Bank, 1996). A multidisciplinary approach was adopted in an attempt to identify and quantify the key issues that were negatively affecting the lake ecosystem with a view to generating sustainable measures for the overall management of the lake. One of the approaches was implemented under the Management of Industrial and Municipal Effluent and Urban Run-off Component of the project. One of the aspects affecting the lake ecosystem arises from the discharges emanating from the several big and small towns, fishing towns/ villages, industrial establishments, domestic garbage and leachates from garbage dumps located within the catchment of Lake Victoria. However, little was known about the actual loads of pollution from these sources (IMWM, 2000). Further, the impact of the intervening swamps and river systems on these generated loads and the actual pollution load entering the lake was not known.

Previous studies in estimating or quantifying the pollution risk to the lake from point sources and their indexing were based on general perceptions, and yet actual data would provide better data for management purposes. The present waste management strategy used by government targets more on industrial discharges as evidenced by an elaborate legislation in the National Environment Statute (1995) and the attendant Sewage regulations (1999) and Discharge of Effluents into Water or land, (1999). The direct contribution from the run-off and stream discharges from the so many urban centres spread over the entire catchment has so far been ignored as a critical contributor to pollution loading to the lake.

This study was aimed at investigating the contributions from these urban centres as well in order to come up with measurable outputs from all sources, which can then be applied in the pollution management of Lake Victoria. The overall objectives of the whole study were: (i) to identify the main sources of lake pollution and quantify their contribution (ii) to assess and classify industrial pollution sources on the basis of their effluent treatment requirements, their availability and effectiveness of existing treatment and location of discharge points (iii) to develop a Geographical Information System (GIS) into which all the data on pollution sources will be incorporated as a tool in the management of pollution (iv) to provide dispersion models as an aid to assessing the impact of specific discharges into the lake system. This paper however, deals with the outputs of objectives (i) and (ii). The results related to the other objectives are presented in different papers. Fig. 1A shows the study area in general while Fig. 1B shows the industrial sources where samples for the study were taken.

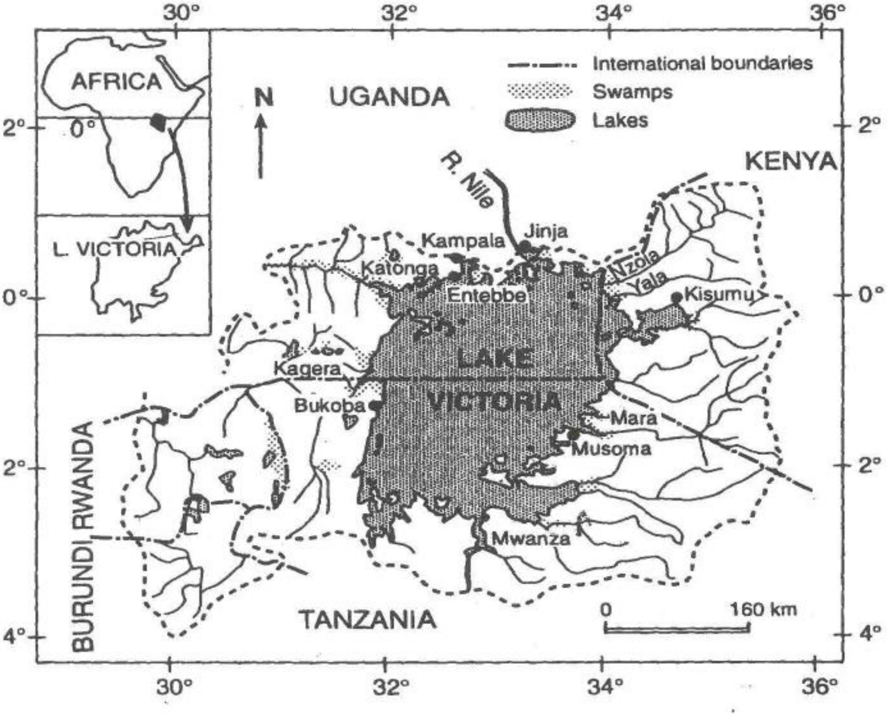


Figure 1A. Lake Victoria catchment area (Study area on the Uganda catchment side)

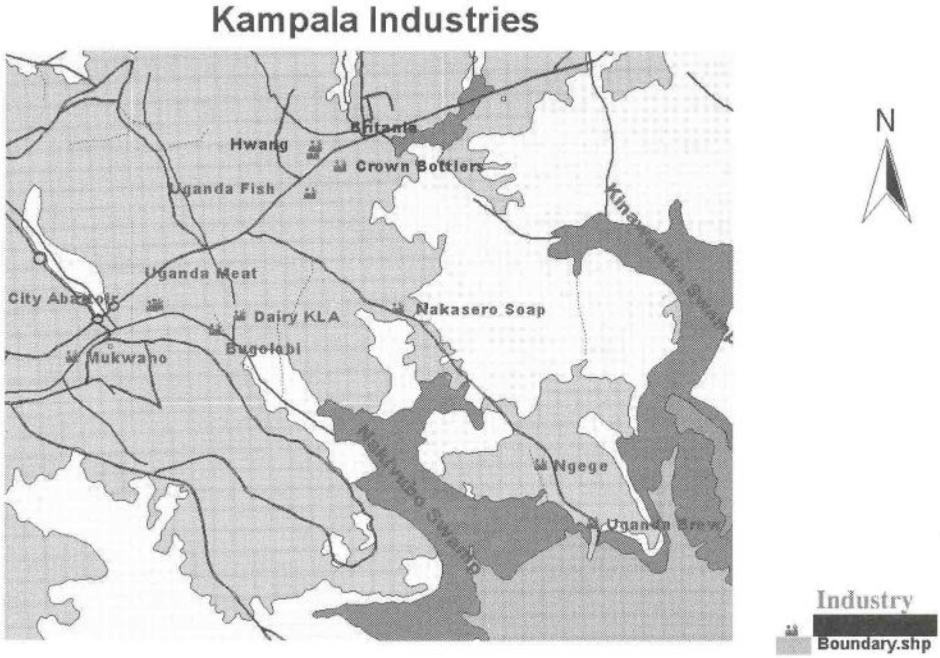


Figure 1B. Industrial pollution sources in Kampala

## MATERIALS AND METHODS

Several strategies were employed in the course of this study and included: review of existing data; planning and execution of field surveys, development of a database, use of GIS and models as tools to help quantify loads and analyse data, and evaluation of pollution control strategies. Other strategies adopted were: quantification of the loads produced; assessment of load reduction based on engineered and natural treatment systems; and derivation of total loads to the lake from main point sources. Based on the findings pollution management strategies were proposed.

Manual and automatic sampling, and compositing techniques were used in sampling of rivers, lakes and effluent. Water and effluent samples were analysed at the National Water and Sewerage Corporation's (NWSC) Central Laboratory, Bugolobi, Kampala. The analytical methods and quality assurance systems applied were as in COWI/VKI, (1998); Wallingford (EA), (1997); Kansiime *et al.*, (1995) and APHA, (1992). A GARMIN 12 Global Positioning System (GPS) was used to determine geographical locations of the sampling points within accuracy of 5 to 8 metres.

## Pollution Loads from Urban Centres and Fishing Villages

### Mapping

The Urban centres in all the districts in the catchment; because of their proximity to the lake pose a potential threat to the lake. They were located using maps obtained from the Uganda National Biomass Project under the Forestry Department. Rivers flowing towards the lake were also identified. Particular attention was paid to those rivers that drained areas where urban centres are located.

Field reconnaissance visits were made to the larger urban centres. During these visits, river and urban run-off sampling points were identified, GPS locations recorded and where possible samples were taken and flows measured. The course of the rivers was also noted with particular emphasis to whether they flowed through swamps / wetlands before discharging to the lake. Only those urban centres that were considered to have substantial potential to pollute the lake were included in the final shortlist.

### Wastewater and runoff discharges

Quantification of the pollution loads from urban centres was done using three methods namely: -

1. Direct Field Measurement; this method was used only at locations where there was a clear single point that captured most of the drainage or at locations where an already established network of stream and drain monitoring points are regularly monitored.

2. Run-off Load Coefficients; information obtained in method 1 was used to derive run-off load coefficients, which could then be applied to other urban centres.

3. Loads Derived from Sanitation and Garbage Collection Information; estimation of the potential load from domestic waste and uncollected garbage.

The total potential load from domestic wastewater discharged to the environment was estimated using per capita load factors for key parameters: biochemical oxygen demand ($BOD_5$), total suspended solids (TSS), ammonia ($NH_4^+$-N), total nitrogen (TN) and total phosphorus (TP). These were factored into the levels of sanitation available in the urban centre (i.e. the percentages of population served by sewers, septic tanks, pit latrines, etc.) and the reduction extent of pollutant parameters that would be achieved by each sanitation option. In this paper emphasis is laid on $BOD_5$, TN and TP. The number of locations where urban pollution loads could be measured directly (method 1) were rather few generating insufficient data to derive a reliable set of run off coefficients. This main method used for calculating urban loads therefore was method 3.

**Solid Waste Leachates**

Pollution loads leaching into the environment from uncollected biodegradable garbage were determined using, where available, actual figures on garbage collection or typical average values where data was not available. In either case, the figures were factored in the default percentages of biodegradable material in garbage, water content, and composition to derive loads from uncollected garbage.

**Discharging Population**

Population data applied in the load estimation was derived from the 1991 census (Population and Housing Census, 1991) and were projected forward to the year 2000 using the 1991 growth rates. In fishing villages an allowance was made for transient and daytime populations.

**Background parameter Levels**

In deciding whether rivers were acting as pathways for urban pollution and thus a significant threat to the lake, a comparison was made between pollutant concentrations in rivers flowing to the lake and background concentrations in the lake. The lake concentration levels were based on data collected from sites in the main body of the lake water during surveys.

**Load from Industrial Establishments**

Loads from industry were determined from the survey information and actual measurement. These loading rates are for raw loads before treatment and are specific to Uganda. The types of processes assessed cover a large percentage of the polluting industries in operation in Uganda. Wastewater treatment facilities at the surveyed factories ranged from ultra modern, top of the range to no treatment at all. Factors to estimate pollution reduction through treatment processes were generated based on interpretation of information from measured data, literature such as Metcalf & Eddy (1991) and upon professional experience in wastewater treatment. Where direct survey data was not available, the default values given in the literature were used to derive final effluent loads (World Bank, 1998).

### Pollution reduction by wetlands and river systems

For each urban centre the pathways by which liquid waste finds its way into Lake Victoria were identified. With exception of lakeshore settlements including all fishing villages, all the discharges from the other urban centres invariably involved passage through, streams, rivers and wetlands. These systems are known to have a purifying effect on pollutant loads (Matagi, 1993; Kansiime & Nalubega, 1999). Wetland systems are very complex and the magnitude of their purifying effect can be variable (Vymazal *et al.*, 1998 & 2001; Kansiime & Nalubega, 1999; Okurut, 2000). Consequently, with the pollutant loads passing through different wetland systems, it was not possible to determine the efficacy of each and every intervening river/wetland system. Instead, for the different parameters, reduction efficacies were based on performance characteristic of wetland systems from previous studies in the region (Kansiime & Nalubega, 1999; Okurut, 2000). The efficacy values of 60 - 65% BOD, 47 -51% TN and 30 - 35% TP, as reported in the earlier studies were used in the computation of pollution reduction by the different wetland systems considered in this study.

## RESULTS

### Discharging Population

The discharging population from the 103 urban centres considered in this study were computed using the 1991 census data and applying population growth rates of 4% (high), 3.5% (normal) and 2 % (rural). In Kampala and other large towns, the daytime population increases by almost 50% (Wegulo *pers.comm*) and which is equivalent to 25% increase in the resident population. In fishing villages, including allowance for market days, the average increase in daytime population is about 64 %, equivalent to 32 % increase in the resident population (Source: *Interviews with Local Council Chairmen: Wakawaka, Dimo and Kiyindi Fishing Villages*). The total population contributing to pollution loads (discharging population) was computed using the projected daytime population ratios in the lake basin urban centres as 1.22 million and 92,000 for the 124 fishing villages considered. Figure 2 shows the population aggregated per district. Special consideration was given to some urban centres such as Kampala, Jinja, and Busia that have parts of urban centre outside the Lake Victoria catchment.

## Background concentrations in the Lake and Rivers

Surveys of rivers and inshore lake areas showed that most waterways close to urban centres were polluted to varying degrees compared to the main Lake Victoria. Lake baseline concentrations ranged from; 100 -150 mg/l for total dissolved solids, 4 – 9 mg/l dissolved oxygen, 3 – 6 mg/l BOD, 0.1 – 1.0 mg/l total phosphorus, < 0.2 mg/l total nitrogen and faecal coliform 3 – 8 no/100 ml.

**Discharging Population-Lake Victoria Catchment, Uganda part**

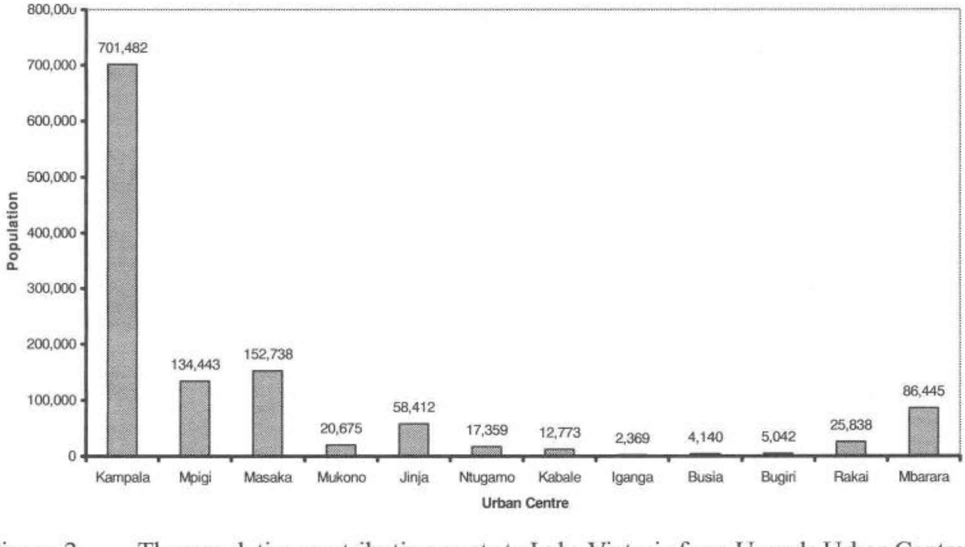


Figure 2. The population contributing waste to Lake Victoria from Uganda Urban Centres

The typical water quality status of the various streams/rivers entering Lake Victoria are summarised in Table I. Rivers in Masaka town and River Ruizi in Mbarara show incipient signs of pollution as evidenced by the faecal coliform counts. However, neither Masaka nor Mbarara towns have any significant impact on Lake Victoria but there is danger that the water supply source in these towns may be compromised. In comparison, less pollution was recorded in the rivers in other districts within the catchment.

Table I. Typical water quality values of rivers outside Kampala

| Dist. | Catchment | River | $BOD_5$ | TN | $NH_4^+$-N | TP | Faecal Coli. | Discharge |
|---|---|---|---|---|---|---|---|---|
| | | | mg/l | mg/l | mg/l | mg/l | No./100ml | L/s |
| BSA | Sio | R.Sio | 13 | 11.9 | 5.3 | 1 | 26,000 | |
| MSK | Katong | R.Katabazungu | 12 | 29.9 | 0.9 | | 96 | 72 |
| MSK | Katonga | R. Nakayiba | 20 | 11.4 | 3.0 | 1.65 | 8,800 | 88 |
| MSK | Katonga | R. Nabajuzi | 15 | 36.4 | 24.3 | 2.31 | 50 | 361 |
| MBR | Bukora | R.Ruizi | 6 | 1.6 | 0.5 | 4.35 | 2,000 | 7,667 |
| MPG | N.Shore | R. Kajjansi | 90 | 16.8 | 0.0 | 1.08 | 380,0000 | 33 |
| MPG | Katonga | R. Katonga | 12 | 15.0 | 1.3 | 3.90 | 6 | 420 |
| MKN | N.Shore | R. Nabirye | 35 | 34.1 | 22.7 | 8.60 | 90,000 | 50 |
| RKI | Kagera | R. Kagera | 3 | 8.3 | 1.3 | 2.13 | 3,000,000 | 200,000 |
| RKI | Bukora | R. Bukora | 5 | 1.1 | 0.8 | 1.38 | 1,800 | 227 |
| Lake Victoria background level | | | 3-6 | 0.2 | | 0.1-1.0 | 3 - 8 | |

## Urban and fishing village pollution loads

Data obtained using domestic wastewater and garbage generation based on calculation estimates show that sewage loads (g/person/day) were: $BOD_5$ – 40, TSS – 60, $NH_4$ – N – 3, TN – 5 and TP – 2.5. They were derived from measured data values from NWSC database (1999) and from reports of COWI/ VKI (1998). These values are characteristically lower than those applied in Europe and USA (Metcalf and Eddy, 1991). These parameter values were used for calculation of the expected waste loads generated by the discharging population referred to in Fig. 2. Sanitation coverage in the urban centres and Fishing villages variable. There was no conventional sewage system in all Fishing Villages (FV) and Small Towns (ST) and for the larger parts of the big urban centres. Pit latrine coverage was about 30 % and 50 % in FV and ST respectively. 70 % FV and 45 % ST do not have any form of sanitation (Ministry of Water, Lands and Environment and Ministry of Health databases, 1999). The total pollution loads reaching the environment (Table II) from the urban centres was computed using these coverage values and the performance ratios of different types of the available sanitation facilities (Metcalf & Eddy 1991; NWSC Database, 1999, 2000).

The highest organic nutrient loads discharges come more from bigger urban centers such as Kampala and least in the smaller, less populated centers such as Bugiri.

Table II. Pollution loads from urban centres and fishing villages

| District | Discharges from urban centres (kg/d) | | | | Discharges from Fishing Villages (kg/d) | | | |
|---|---|---|---|---|---|---|---|---|
| | BOD | TSS | TN | TP | BOD | TSS | TN | TP |
| Kampala | 10101 | 15152 | 1424 | 633 | | | | |
| Mpigi | 2958 | 2904 | 273 | 121 | 247 | 252 | 48 | 23 |
| Masaka | 3360 | 3299 | 310 | 138 | 137 | 164 | 17 | 9 |
| Mukono | 455 | 447 | 42 | 19 | 464 | 622 | 57 | 29 |
| Jinja | 1285 | 1262 | 119 | 53 | 387 | 543 | 48 | 25 |
| Kalangala | | | | | 247 | | 32 | 19 |
| Kabale | 281 | 276 | 26 | 12 | | | | |
| Iganga | 52 | 51 | 5 | 2 | 219 | 307 | 29 | 15 |
| Busia | 91 | 89 | 8 | 4 | 26 | 39 | 4 | 1 |
| Bugiri | 111 | 109 | 10 | 5 | 100 | 131 | 13 | 7 |
| Rakai | 568 | 558 | 52 | 23 | 55 | 76 | 7 | 3 |
| Mbarara | 1902 | 1867 | 175 | 78 | | | | |
| Total | **21165** | **26014** | **2445** | **1088** | **1882** | **2134** | **255** | **131** |

## Pollution loads from Industry

Industrial load estimates generated from routine monitoring data, information collected using a questionnaire and detailed surveys were computed based on load estimate basis per tonne of product and amount of water used per day. These are shown in (Table III).

Table III. Unit Effluent Loads for a Number of Industrial Processes in Uganda

| Industry Type | Load Estimate Basis | BOD | COD | TSS | TN | $NH_4$-N | TP | Water used, $m^3$ |
|---|---|---|---|---|---|---|---|---|
| | | kg | kg | kg | kg | kg | kg | |
| Fish processing | Per tonne of processed Fish | 8.58 | 22.61 | 3.73 | 0.13 | 0.09 | 0.07 | 24.85 |
| Bakery | Per tonne of product | 0.33 | 1.18 | 1.18 | 0.01 | | | 0.20 |
| Confectionery | Per tonne of product | 7.16 | 23.28 | 0.21 | 0.10 | 0.05 | 0.01 | 4.00 |
| Fruit juices | Per cubic metre of product | 2.16 | 2.32 | 1.00 | 0.03 | 0.02 | 0.01 | 2.99 |
| Dairy products | Per cubic metre of product | 1.81 | 3.68 | 1.68 | 0.12 | 0.06 | 0.05 | 4.44 |
| Abattoirs | Per tonne of dressed carcass | 7.00 | 22.38 | 29.41 | 1.57 | 0.51 | 0.63 | 13.10 |
| Soap works | Per tonne of product | 1.44 | 3.71 | 0.32 | 0.11 | 0.07 | 0.01 | 2.00 |
| Breweries | Per cubic metre of product | 4.35 | 17.49 | 9.23 | 0.30 | 0.10 | 0.45 | 5.94 |
| Soft Drinks | Per cubic metre of product | 2.07 | 7.76 | 0.71 | 0.03 | 0.02 | 0.05 | 6.97 |

The industrial effluent loads that finally get discharged by the major industries to the environment were computed by multiplying the unit rates given in Table III and the daily production figures obtained from the industry. The discharges derived are given in Table IV. From the data, Uganda Breweries contributed the bulk of the discharge into the lake.

Table IV. Summary of main industrial loads discharged to the environment

| Factory Name | BOD | COD | TSS | TN | $NH_4^+$-N | TP | Receiving Environment |
|---|---|---|---|---|---|---|---|
| | kg/day | kg/day | kg/day | kg/day | kg/day | kg/day | |
| Uganda Breweries | 835 | 3,355 | 1,770 | 57.5 | 20.0 | 86.3 | Lake Victoria |
| Britania Products | 227 | 388 | 21 | 10.3 | 0.7 | 0.4 | Kinawataka wetland |
| Crown Bottlers | 177 | 661 | 61 | 2.5 | 1.7 | 4.1 | Kinawataka wetland |
| Ngege Fish Factory | 163 | 430 | 67 | 2.6 | 1.7 | 1.0 | Nakivubo wetland |
| Mukwano Soap & Oil | 155 | 400 | 32 | 12.6 | 7.9 | 0.4 | Nakivubo channel |
| City Abattoir | 154 | 492 | 647 | 34.5 | 11.2 | 13.8 | Nakivubo channel |
| Uganda Meat Packers | 70 | 223 | 293 | 15.6 | 5.1 | 6.3 | Nakivubo channel |
| Nakasero Soap Works | 41 | 105 | 9 | 3.2 | 2.0 | 0.1 | Nakivubo wetland |
| Greenfields Fish, EBB | 28 | 73 | 5 | 0.8 | 0.6 | 0.3 | Lake Victoria |
| Hwang Sung Fish | 24 | 63 | 9 | 0.5 | 0.4 | 0.2 | Kinawataka wetland |
| Century Bottlers | 24 | 89 | 4 | 2.9 | 1.6 | 0.6 | Namanve wetland |
| Uganda Fish Packers | 23 | 61 | 9 | 0.5 | 0.4 | 0.2 | Kinawataka wetland |
| Entebbe Dairy | 1 | 2 | 1 | 0.5 | 0.4 | 0.2 | Lake Victoria |
| **Totals** | **1,922** | **6,342** | **2,928** | **144** | **53.7** | **113.9** | |

**All these major industries apart from 2 are situated in Kampala*

## Total discharge to Environment (streams, wetlands & land)

The combined total pollution load discharged into the environment from the three categories of waste generation sources - urban centres, fishing villages and industry- was: BOD 25,400 kg/d; TN 2844 kg/d and TP 1325 kg/d. A graphical illustration for each parameter is shown in Fig. 3.

These results clearly show that the biggest pollution threat to the receiving environments is from the urban centres as they account for 83 % BOD, 86% N and 82 % P discharged into the environment. The implication here is that, the focus of any pollution management interventions should be on urban centres.

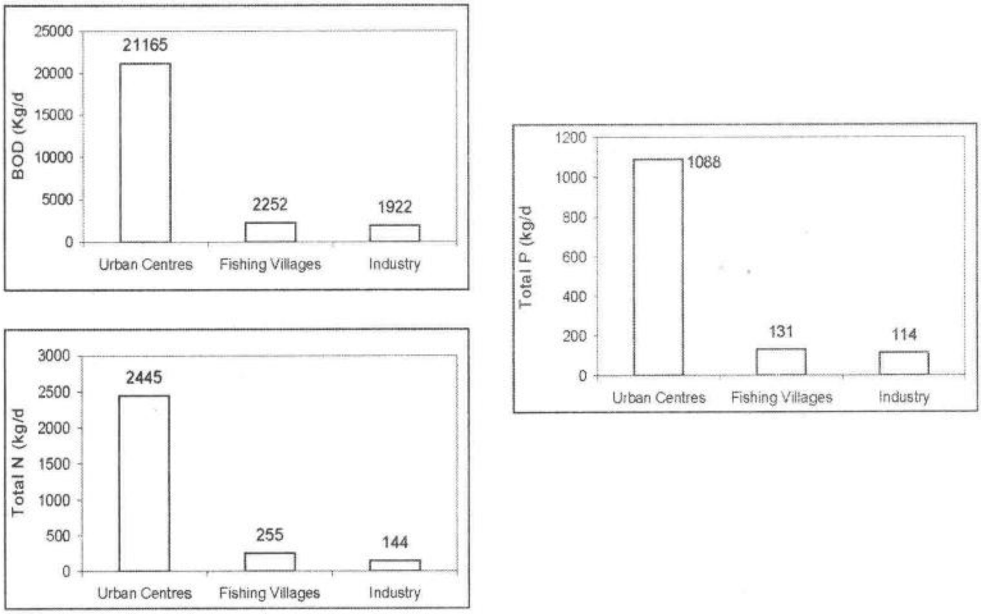


Figure 3. Total loads of BOD, TP and TN discharged from the urban centers, Fishing Villages and Industries to the environment

## Pollution Load Reduction

The pollution load reduction efficiency by these systems was assessed based on a simple model illustrated in Figure 4.

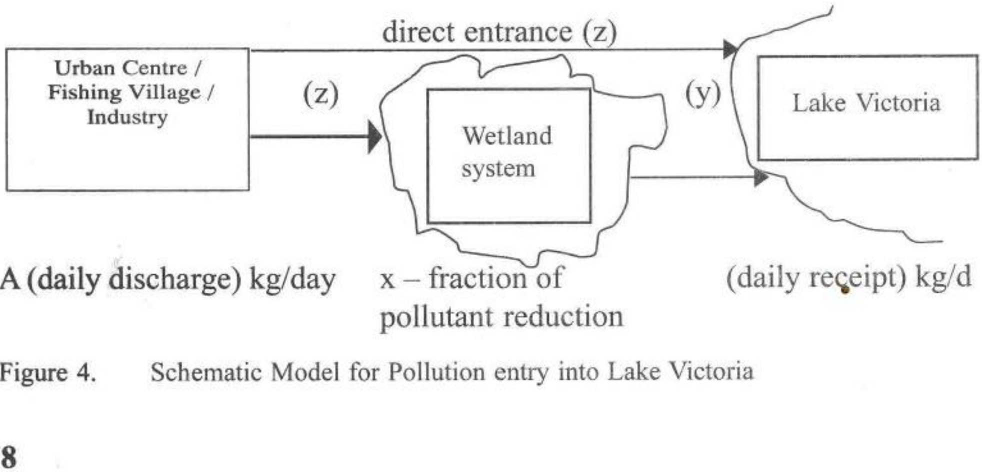


Figure 4. Schematic Model for Pollution entry into Lake Victoria

The reduction of pollution was calculated depending on whether there is an intervening system between the source and the lake. Where there was no intervening wetland/river system between the pollution source and the lake (z), the pollution load (A kg/d) from source was considered to be reaching the lake. In cases where there is an intervening wetland /river system between the pollution source and the lake, pollution reduction was considered to occur in the systems. The fraction of pollutant removed by these intervening system (x) was a function of the system itself. For this study, the factors were derived by interpolation of pollutant reductions results earlier reported for Nakivubo Wetland by COWI/ VKI (1998), Kansiime & Nalubega (1999), Okurut (2000) and other studies reported elsewhere.

**Pollution loads entering Lake Victoria**

The final pollution loads that enter the lake (C kg/d) were computed by multiplying the fraction reduction factors given in Table (VI) with the loads generated from urban centres, fishing villages and industry (A kg/d), discussed above, on a case-by-case basis depending on the nature of the wetland/river system. The outputs from the three different sources are shown in Tables (V – VII).

The computed pollution loads from the urban centres in the catchment clearly showed that Kampala district contributes 65 % of the total urban pollution entering the lake. The aggregate contribution from Mpigi district based urban centres was 20%. The pollution contribution from other urban centres within the catchment was negligible. It is worth noting that the intervening wetland in Kampala reduced the wastewater loads entering the lake.

Uganda Breweries contributes 80 % of the BOD load, 85 % of the COD load, 93 % of the total suspended solids load, 60 % of the total nitrogen load and 82 % of the phosphorus load discharged by the industries into the lake.

The combined total pollution loads entering the Lake Victoria from each point source are shown in Figure 5. Urban centers come out as the main pollutant contributor to Lake Victoria on the Uganda side, followed by the fishing villages and least by industries.

Table V. Calculated Urban Loads to Lake Victoria by District

| District | Loads to Entering L. Victoria (kg/d) | | |
|---|---|---|---|
| | BOD | TN | TP |
| Kampala | 4,141 | 1,069 | 746 |
| Mpigi | 1,263 | 180 | 113 |
| Masaka | 294 | 55 | 38 |
| Mukono | 220 | 31 | 20 |
| Jinja | 176 | 71 | 48 |
| Ntugamo | 0 | 0 | 0 |
| Kabale | 0 | 0 | 0 |
| Iganga | 23 | 5 | 3 |
| Busia | 23 | 7 | 5 |
| Bugiri | 19 | 6 | 4 |
| Rakai | 18 | 4 | 3 |
| Mbarara | 0 | 0 | 0 |
| Totals | 6177 | 1428 | 980 |

Table VI. Calculated fishing village loads to Lake Victoria

| District | Discharging Loads to Entering L. Victoria (kg/d) | | | |
|---|---|---|---|---|
| | Population | BOD | TN | TP |
| Mukono | 18,757 | 463 | 57 | 29 |
| Jinja | 15,305 | 386 | 48 | 24 |
| Mpigi | 14,796 | 348 | 45 | 23 |
| Kalangala | 14,826 | 247 | 32 | 19 |
| Iganga | 11,217 | 220 | 28 | 15 |
| Masaka | 6,578 | 136 | 17 | 9 |
| Bugiri | 4,058 | 100 | 12 | 6 |
| Rakai | 2,107 | 55 | 7 | 3 |
| Busia | 1,073 | 18 | 2 | 1 |
| Kampala | 698 | 27 | 3 | 2 |
| Totals | 89,415 | 2,000 | 251 | 131 |

Table VII. Summary of residual industrial loads discharging to Lake Victoria

| Factory Name | Load Reduction by Wetland system | BOD kg/day | COD kg/day | TSS kg/day | T N kg/day | NH4-N kg/day | TP kg/day |
|---|---|---|---|---|---|---|---|
| Uganda Breweries | Nil | 835 | 3355 | 1770 | 57.5 | 20 | 86.3 |
| Britania Products, | High | 11.35 | 19.4 | 0 | 1.545 | 0.035 | 0.16 |
| Crown Bottlers, | High | 8.85 | 33.05 | 0 | 0.375 | 0.085 | 1.64 |
| Ngege Fish, Kampala | Fair | 60.31 | 159.1 | 10.05 | 1.482 | 0.629 | 0.78 |
| Mukwano Soap & Oil | Medium | 31 | 80 | 3.2 | 6.3 | 2.37 | 0.292 |
| City Abattoir | Medium | 30.8 | 98.4 | 64.7 | 17.25 | 3.36 | 10.074 |
| Uganda Meat Packers | Medium | 14 | 44.6 | 29.3 | 7.8 | 1.53 | 4.599 |
| Nakasero Soap Works | Fair | 15.17 | 38.85 | 1.35 | 1.824 | 0.74 | 0.078 |
| Greenfields Fish, EBB | Nil | 28 | 73 | 5 | 0.8 | 0.6 | 0.3 |
| Hwang Sung Fish | High | 1.2 | 3.15 | 0 | 0.075 | 0.02 | 0.08 |
| Century Bottlers | Very High | 0.24 | 0.89 | 0 | 0.29 | 0.016 | 0.09 |
| Uganda Fish Packers | Fair | 8.51 | 22.57 | 1.35 | 0.285 | 0.148 | 0.156 |
| Entebbe Dairy | Nil | 1 | 2 | 1 | 0.5 | 0.4 | 0.2 |
| Totals | | 1,045 | 3,930 | 1,886 | 96 | 30 | 105 |

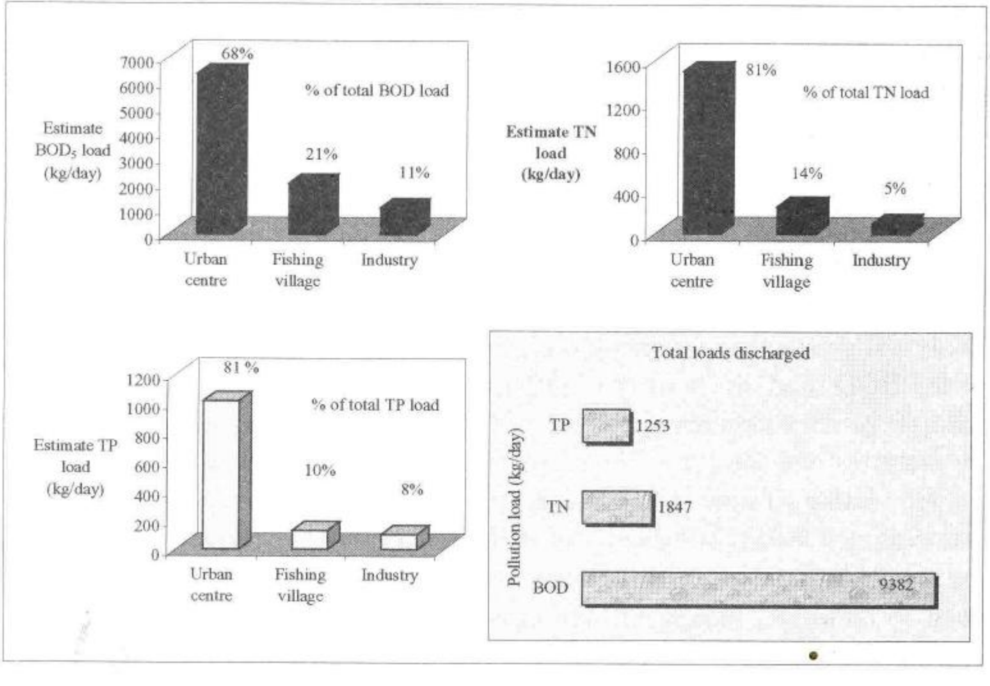


Figure 5. Total industrial and municipal pollution loads discharged into Lake Victoria

## DISCUSSION

The high population in urban centres partly explains the high pollution load. The total human population in urban centres located within the Lake Victoria catchment, is about 1.22 million. Of this population nearly 60 % of this discharging population is located in Kampala district. Kampala accounts for about 65 % of the total BOD load, 73 % of the total nitrogen load and 73 % of the phosphorus load discharged from urban centres into Lake Victoria. Mpigi District accounts for about 20 % of the BOD load, 12 % of the TN load and 11 % of the TP load discharged from urban centres into Lake Victoria. Contributions from urban centres in other districts are relatively small. Management of municipal waste is therefore necessary in ensuring that this trend of events is reversed.

The estimated fishing village loads were based on 124 fishing villages with a discharging population (resident plus transient) of about 92,000. The loads may be lower than actual since the survey did not cover all the fishing villages within the Ugandan catchment. Nevertheless, the estimated loads obtained are valuable as preliminary information for further investigations.

Calculated urban and fishing village loads based on run-off were very low compared to the urban domestic load. This may be due to insufficient run-off data collected to give confidence that the values measured in the field can be extrapolated. Continuous monitoring until a reliable database of run-off data has been built up is therefore recommended. New run-off factors can then be derived and fed into the database so that the results can be improved and compared with the urban domestic calculations.

Table VII shows that one factory, Uganda Breweries, accounts for about 80 % of the BOD load, 85 % of the COD load, 93 % of the total suspended solids load, 60 % of the total nitrogen load, and 82 % of the phosphorus load discharged by factories into the lake. The regulating authority must quickly address this matter. Siting of new industries should be done with due consideration of a pre-treatment facility or presence of an intervening wetland/river system. During the study all the industrial discharges were covered. Industrial inspections will need to continue, industrial load data continuously reviewed and updated. Special attention should be given to the following industry types:

Abattoirs; Tanneries; Food Factories; Breweries; Soft Drink Bottlers; Fish Factories; Dairies and Oil and Soap factories.

## CONCLUSIONS AND RECOMMENDATIONS

Urban pollution control strategy for the protection of Lake Victoria needs to focus on Kampala followed by other large lakeshore urban centres. The importance of wetlands in protecting the lake is clear. The results of this paper clearly show that the main strategies in managing urban pollution should be to:

### (i) Protect wetlands from encroachment and degradation

There is an active programme to protect wetlands. Nevertheless, encroachment still continues. City and town councils need to be more proactive in protecting wetlands; failure of which definitely spell disaster for Lake Victoria.

### (ii) Improve garbage collection

Improvement of garbage collection in Kampala needs to be focused on the poorer, densely populated areas especially in the Nakivubo Channel and Kinawataka catchments. Other garbage management interventions need to be adopted together with community awareness and training.

### (iii) Improve sanitation

Sanitation improvement should aim on improving focus performance of the existing municipal wastewater treatment plants so that they meet effluent discharge standards on a continuous basis and improving the coverage of on-site sanitation facilities.

In Fishing villages, management focus should be on garbage collection and disposal, and sanitation. Additional strategies advocated are to help the village communities to help themselves and access existing rural sanitation improvement programmes through the building of strong community groups; and helping these groups to develop their organisational capability. In addition, since many persons from the private sector benefit from these communities, promotion of their participation in community affairs should be encouraged. Finally raising community hygiene and environmental awareness should continue.

The strategy for management of industrial effluent should focus on:

(i) Promoting the Pollution Control Manuals (PCM) as a guide for all government officers involved in industrial pollution control;

(ii) Preparing pollution control pamphlets, based on the Pollution Control Manual, for distribution to factory managers or owners;

(iii) Strengthening the process design capability in Uganda, both among consultants and pollution management agencies;

(iv) Adopting a staged approach to pollution control enforcement. For example, it is better to insist on well-designed and constructed primary treatment than to allow poorly designed primary plus secondary treatment;

(v) Strengthening the effectiveness of Discharge Agreements by applying the recommendations given in the Pollution Control Manual and

(vi) Promote cleaner production practices.

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## REFERENCES

APHA, (1992) Standard Methods for Examination of Water and Wastewater. 18th Edition. American Public Health Association, Washington, DC.

COWI/VKI, (1998) Final Report on Kampala Water Quality Monitoring Programme (Murchison Bay Water Quality Project). *Ministry of Natural Resources and National Water and Sewerage Corporation.*

Discharge of Effluents into Water or Land (1995). The Uganda Gazette No. 7. Statutory Instruments Supplement. No. 4

IMWM, (2000). Industrial and Municipal Waste Management component 33-month Technical report. Lake Victoria Environmental Management Project. *Ministry of Water, Land and Environment and National Water and Sewerage Corporation.*

Kansiime, F., Kateyo, E. and Okot-Okumu, J., (1995). Effects of Pollution of Inner Murchison Bay (Lake Victoria – Uganda) on the Distribution and Abundance of Plankton.

Kansiime, F. and Nalubega, M., (1999) Wastewater treatment by a natural wetland: Nakivubo Swamp, Uganda. *A.A Balkema Publishers*, Rotterdam, The Netherlands. 300pp.

LVEMP, (1999) Mid-Term Review, Sub Component: Management of Industrial and Municipal Effluents and Urban Run-off. *Ministry of Water, Land and Environment and National Water and Sewerage Corporation.*

MWLE and Ministry of Health Databases (1999).

Matagi, S.V (1993) The effect of pollution on faunal distribution in Bwaise and Nakivubo Channel. MSc Thesis, Makerere University.

NWSC, (1999). National Water and Sewerage Corporation, Water Quality Database, 1997 – 1999.

NWSC, (2000) National Water and Sewerage Corporation, Water Quality Database, 1999-2000.

Okurut, T. O., (2000) A Pilot Study on Municipal Wastewater Treatment Using a Constructed Wetland in Uganda. PhD Thesis, IHE Delft and Wagenigen University.

Population and Housing Census, (1991) District Summary Series. The Population and Housing Census. Statistics Department, Ministry of Finance and Economic Planning, Entebbe, Uganda.

Metcalf and Eddy, (1991). Wastewater Engineering, Treatment, Disposal, Reuse (Eds.) Tchbanoglous and Burton, Inc. *McGraw -Hill.*

Sewage Regulations, (1999). The Uganda Gazette No. 8. Statutory Instruments Supplement No. 5

Uganda Environmental Statute, (1995) The Uganda Gazette No. 21. Statutory Instruments Supplement No. 5

Vymazal, J., Brix H., Cooper, P. F., Green, M. B and Haberl, R. (Eds) (1998) Constructed wetlands for Wastewater Treatment in Europe. Backhuys Publishers, Leiden, The Netherlands.

Vymazal, J., (Eds.), (2001). Transformation of nutrient in natural and constructed wetlands. Backhuys Publishers, Leiden, the Netherlands.

Wallingford, (1997). Final Report, Kampala Water Supply Extension Project. Lake Water Hydrodynamic Studies in the Murchison Bay Apex of Lake Victoria. *Ministry of Land Water and Environment and National Water and Sewerage Corporation.*

World Bank, (1996) Staff Appraisal. Lake Victoria Environmental Management Project. Report No. 15429 – AFR. *Agriculture and Environment Operations Division, East Africa Department, Africa Region*. 48 pp.

World Bank, (1998) The Pollution Prevention and Abatement Handbook.