CHAPTER FIVE

Industrial and municipal effluents management in the riparian region of the Ugandan portion of Lake Victoria

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ABSTRACT. *The Industrial and Municipal Waste Management component of the Lake Victoria Environmental Management project carried out an assessment to determine pollutant loads from point sources, which included industrial and municipal effluents and urban run-off from the Uganda catchment of Lake Victoria. Identification of pollution hotspots that pose threats to Lake Victoria was done, and the fishing villages were found to have significant impacts because of their high number, high population density and proximity to the lake. Similarly, factories in Kampala, Jinja and Entebbe with potential threat were identified. The results show that each day 14.17 tons of BOD, 2.91tons of Nitrogen and 2.21 tons of phosphorus are discharged into the lake from urban centres, while 2.96 tons of BOD, 0.37 tons of nitrogen and 0.19 tons of phosphorus are discharged daily from 124 fishing villages with a total population of 92,000. Industrial loads reaching the lake were estimated to be 2.52 ton of BOD, 0.34 tons nitrogen and 0.11 tons phosphorus per day. These values show that the major threat comes from urban centres, which are responsible for nearly 70% of BOD and 80% of the nutrient loading into Lake Victoria. Kampala city accounts for about 60% of the discharging population and 65% of the total BOD load. Studies on the use of natural and constructed wetlands showed that they can play a significant role in further reduction of pollutants from municipal and industrial effluents.*

Pollution management strategies proposed for urban centres focus on improved garbage collection and sanitation, particularly in the Nakivubo catchment of Kampala and more proactive protection of wetlands. Sanitation improvements advocated include improved operation and maintenance of the existing municipal wastewater treatment works, strengthening of process engineering expertise, use of wetlands to polish effluents and greater on-site sanitation coverage. Similarly, sanitation recommendations apply for fishing villages but here the strategy is to focus on improving the ability of fishing village communities to help themselves through awareness raising programs and how to lobby for local development funding. The strategy for industries is adoption of Cleaner Production and use of the Pollution Control Manual for training and guidance, strengthening of process design capacity, a staged approach to treatment plant development and strengthening of discharge agreements.

Key words: Lake Victoria, urban runoff, industrial wastes, fishing villages, pollution loads, tertiary effluent treatment

INTRODUCTION

The Management of Industrial and Municipal Effluents and Urban Run-off is one of the components of the Lake Victoria Environmental Management Project (LVEMP). It is implemented by the National Water and Sewerage Corporation (NWSC) and consists of four subcomponents, namely Industrial and Municipal Waste Management, Tertiary Municipal Effluents Pilot Project, Tertiary Industrial Effluents Pilot Project and Priority Investments in Waste Management (for the rehabilitation of the Bugolobi Sewage Treatment Works). Increased human population and rapid urbanization within the Lake Victoria basin has resulted in increased discharges of industrial and municipal effluents and urban run-off. This invariably poses a bigger problem to the lake ecosystem, which is the recipient of much of the effluents (Kansiime *et al*. 1995).

The work done under this component aimed at identifying and quantifying municipal wastewater pollution from major and small towns and pollution originating from industries in the Lake Victoria catchment in Uganda. Pilot studies were conducted on the use of natural and constructed wetlands in treatment of municipal and industrial effluents, respectively (COWI and VKI 1998; LVEMP 2001). Infrastructural improvement was carried out on the existing municipal sewage treatment system in Bugolobi, Kampala.

MATERIALS AND METHODS

Study area

Two criteria were used for the selection of point sources in assessing the pollution loading into Lake Victoria. These were: towns having population more than 10,000 inhabitants, and industries having wet processes. For all the point sources identified the following information was collected: Name of sub-catchment where the point source is located, town where the point source is located, Global Positioning System (GPS) coordinates of the point source. The point sources identified were categorized as industrial processes such as factories of dairies, beverages, fish, breweries, abattoir, oil and soap, batteries and steel and enamel. Also, streams draining the urban centres; municipal effluents from wastewater treatment facilities and fishing villages along the shoreline of Lake Victoria were identified as important sources of pollution into Lake Victoria. The different discharge methods from each of the point sources were identified. These were direct discharge into Lake Victoria; discharge into the lake through a river, or a stream; discharge without any sewerage facilities; discharge from wastewater treatment facilities; and discharge through wetlands into Lake Victoria. For larger towns the wastewater was typically discharged through a combination of the most of the above mentioned options.

Pilot projects

Tertiary Municipal effluent treatment

Kirinya wetland is located at the edge of Jinja west at the northern shores of Lake Victoria. It receives effluent from the stabilisation ponds of NWSC. The major activity of this pilot project was the distribution of the final effluent from the stabilization ponds over the wetland (Figures 1 and 2). This distribution was intended to increase the contact surface area and the retention time between the wastewater and the wetland treatment system. Construction of the wastewater distribution system was completed in February 2002 and routine monitoring of the water quality entering and leaving the wetland was carried out till end of 2004.

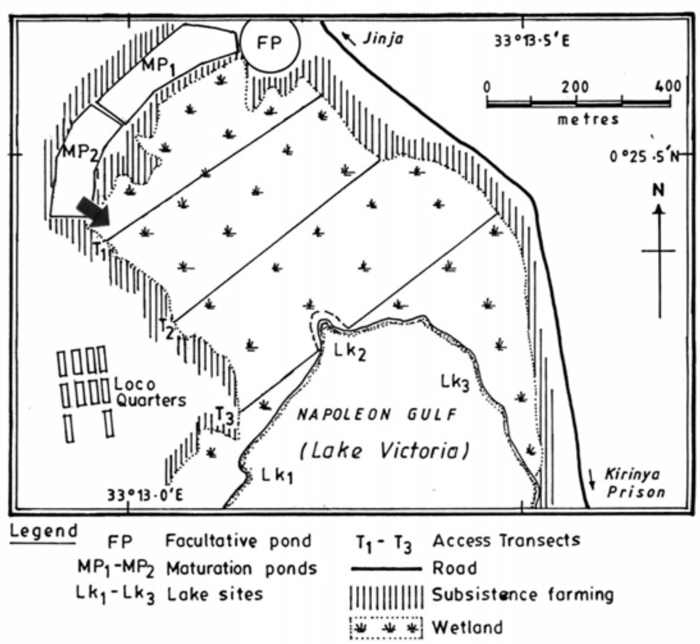


FIG. 1. *The location of Kirinya stabilisation ponds, the wetland and access transects. The arrow shows where wastewater was entering into the wetland at the beginning of the project.*

Tertiary Industrial effluent treatment

The pilot plant was built at Portbell, Luzira (Kampala) and it comprises of a sedimentation tank, Upflow Anaerobic Sludge Blanket (UASB) and a constructed wetland. The plant was aimed at assessing the capacity of a constructed wetland to strip pollutants from industrial wastewater and demonstrating to other industrialists this relatively low cost but effective technology. The UASB and sedimentation tank, were incorporated to reduce the large BOD and suspended solids concentrations to levels that can be handled by the wetland plants. Different compartments of the wetland were planted with various wetland plants (macrophytes) whose treatment efficiencies were assessed.

FIG. 2. *Wastewater distribution pipe at the edge of the wetland*

Water sampling and analysis was done according to standard methods (APHA 1995). Samples were picked at inlets and outlets to cells 2-1 and 1-1 located at 5m and 25m from weir respectively, and the outlet of cells 2-2 and 1-2, 45m from the inlet weir.

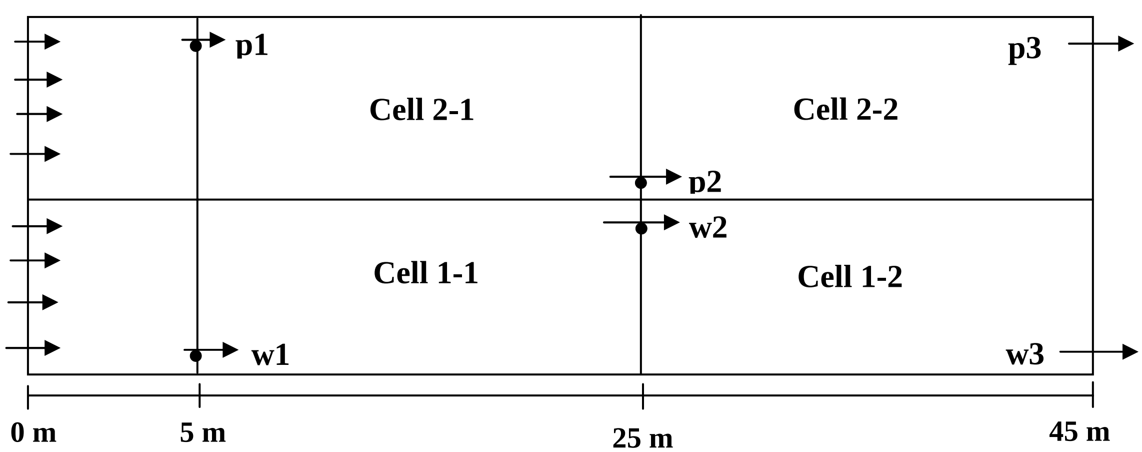


FIG. 3. *Sketch diagram showing the outline of the constructed wetland plant and the sampling points.*

Parameters measured

Physico-chemical parameters namely, pH, electrical conductivity, total suspended solids, temperature, dissolved oxygen and flows, biochemical oxygen demand (BOD), and chemical oxygen demand (COD) were measured. The nutrients measured were total phosphorus, total nitrogen, nitrate, orthophosphate and ammonium nitrogen. Also, microbiological parameters namely total and faecal coliforms were measured. All analytical procedures were standard for physico-chemical and biological parameters as provided by APHA (1995).

Pollution Loading

The methods used included on site measurement, run-off load coefficient, loads derived from sanitation and garbage collection information and industrial pollution loads based on production figures. On Site measurements were done in large urban centres, where there was continuous run-off in the form of rivers, streams and drainage channels. Regular monitoring was carried out at a single point that captured most of the drainage. The monitoring was carried out during both dry and wet seasons.

Run-off load coefficient method was used in estimating pollution loading where flow measurements were not taken. The run-off load coefficients were derived for the parameters of interest based on the data collected from selected urban centres and flow measurement taken during rainfall events. Coefficient values were expressed in terms of personal equivalents (p.e.) based on the population of the study area. In deriving the coefficient values (high, low, average or median) factors such as road surface, slope of the terrain, soil type, and water table were taken into consideration. Cities and large towns were assigned high coefficients while small towns and villages with little paving and low vegetation cover were assigned low values.

Another technique was used to estimate potential pollution loading from untreated domestic wastewater and uncollected garbage from urban centres and fishing villages based on the population. Population was estimated from the 2002 census data using population growth factor. Total loadings for BOD, TN, and TP were estimated based on the per capita load factors. Loadings from untreated sewage and uncollected garbage were then totaled. The standard figures, indicated here, were used in computing total pollution loading from municipal wastewater: BOD: 30-40 g/p.e/day, TN: 5 g/p.e/day and TP: 2 g/p.e/day

Assessment of the wastewater pollution loading for industries without measurements for wastewater production was based on the standard load per production unit for the particular type of industry and the actual production value. Wastewater pollution was determined based on production values (World Bank 2000). Basic loads, defined as the actual wastewater pollution production generated at the individual point source (total wastewater production from towns and industries) were calculated from the loads described above.

Reduction in basic pollution load before the wastewater reaches the nearest recipient was assessed depending on the discharge methods. For each urban centre identified, except for the lakeshore settlements, the pathway by which liquid waste find its way into Lake Victoria was assessed. In the wetland system, the length of the pathway and condition of the wetland were incorporated in the ratings. The percentage removal of pollutants and efficiency were assessed and rated ranging from no removal to total removal. Rating factors for removal of each pollutant parameters were assigned. These factors were then applied to the different methods used for load assessment to get final loads to the lake.

Lake background pollution levels were determined to assess whether rivers and streams were acting as pathways for urban pollution and thus posing significant threat to the lake (concentration rather than load values were examined). A comparison was made between pollutant concentrations in rivers/streams flowing to the lake and background concentrations in the lake. The concentrations data collected in the lake was considered as the background lake water quality.

Pilot Projects

Tertiary Municipal effluent treatment

For the tertiary treatment of municipal wastewater by natural wetlands, Electrical conductivity (EC), Nitrates, Phosphorus and faecal coliforms were used as tracers of both wastewater flow and treatment efficiency of the wetland. Baseline data was generated for the wetland before the concentration of the distribution pipe (bio-manipulation) was done. All these parameters were determined according to standard methods for the examination of water and wastewater (APHA 1995). Statistical data analysis was done using SPSS 11.0 for windows.

Tertiary Industrial effluent treatment

The constructed wetland was established to assess its performance in terms of NH_4^+, NO_3^-, Total-phosphorus, Biochemical Oxygen Demand and Chemical Oxygen Demand removal. The removal efficiencies of these pollution parameters by two different wetland plants, the water hyacinth (*Eichhornia crassipes*) and *Papyrus* were assessed. Sampling and sample handling was according to APHA (1995).

RESULTS

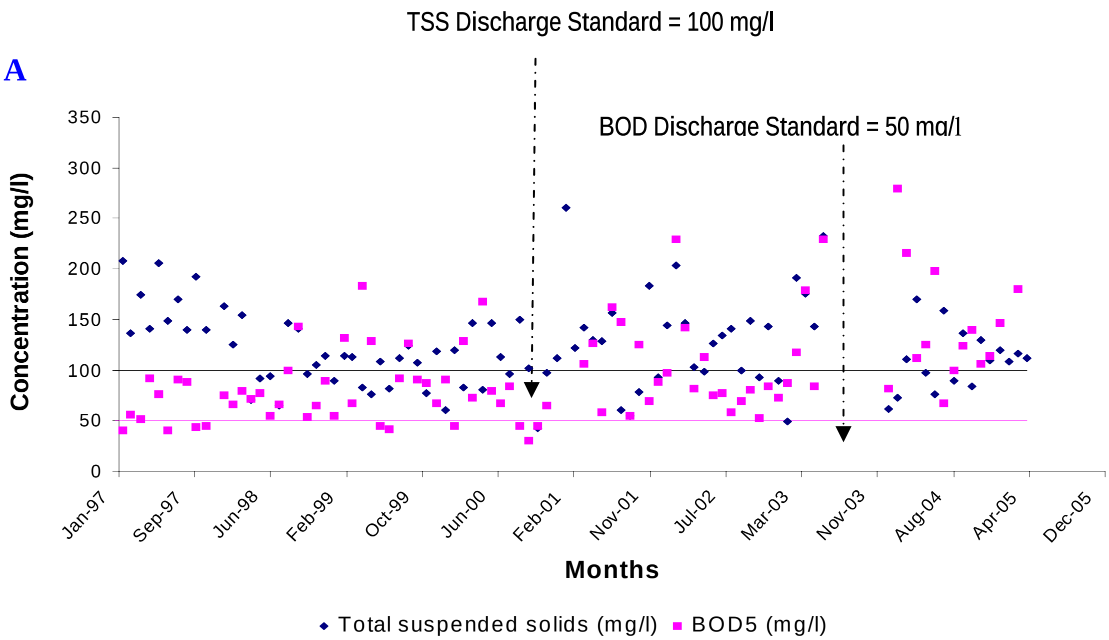
Municipal sewage treatment

The final effluent quality from Bugolobi sewage treatment plant recorded 68% and 89% frequency of non compliance with the national standard for total suspended solids and BOD, respectively. On the other hand, the final effluent quality from the Kirinya wastewater stabilization ponds recorded 77% and 89% frequency of non compliance with the national standard for TP and TN, respectively (Figure 4).

Industrial pollution

Out of the 16 monthly average data sets, non-compliance was: total non-compliance, 50%, 69% and 75% for BOD_5, TP, TN and TSS respectively. COD was 93% of all the time non-compliant. The monitored parameters were most of the time above the national standards for discharge into the environment (Figure 5).

A



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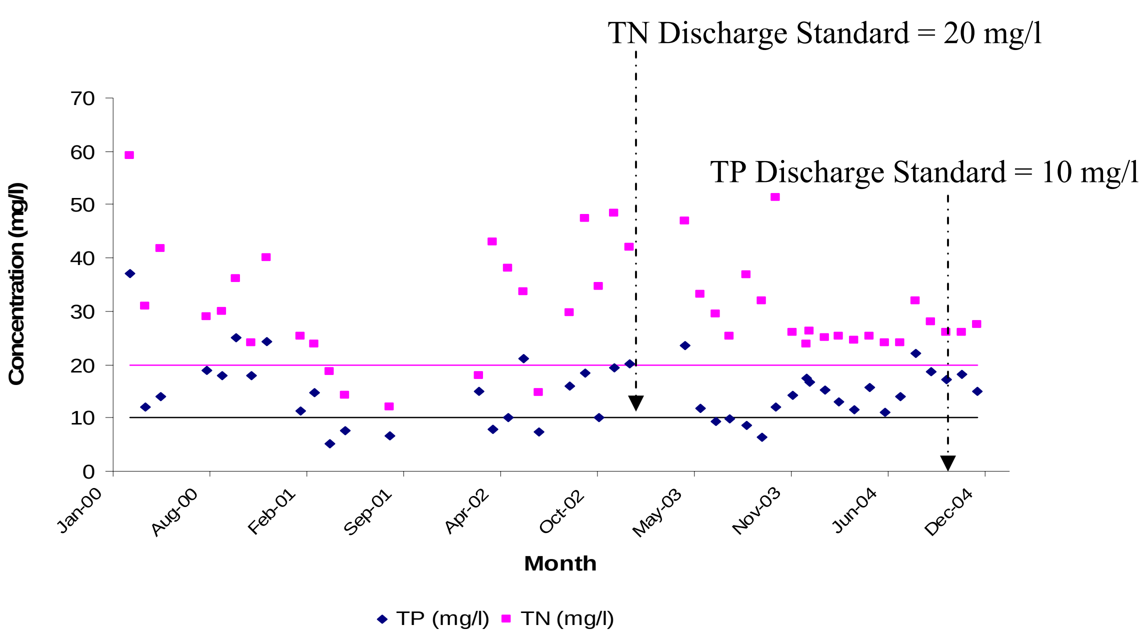

***FIG. 4.** Wastewater treatment final effluent quality for Bugolobi (A) and Kirinya (B) treatment plants.*

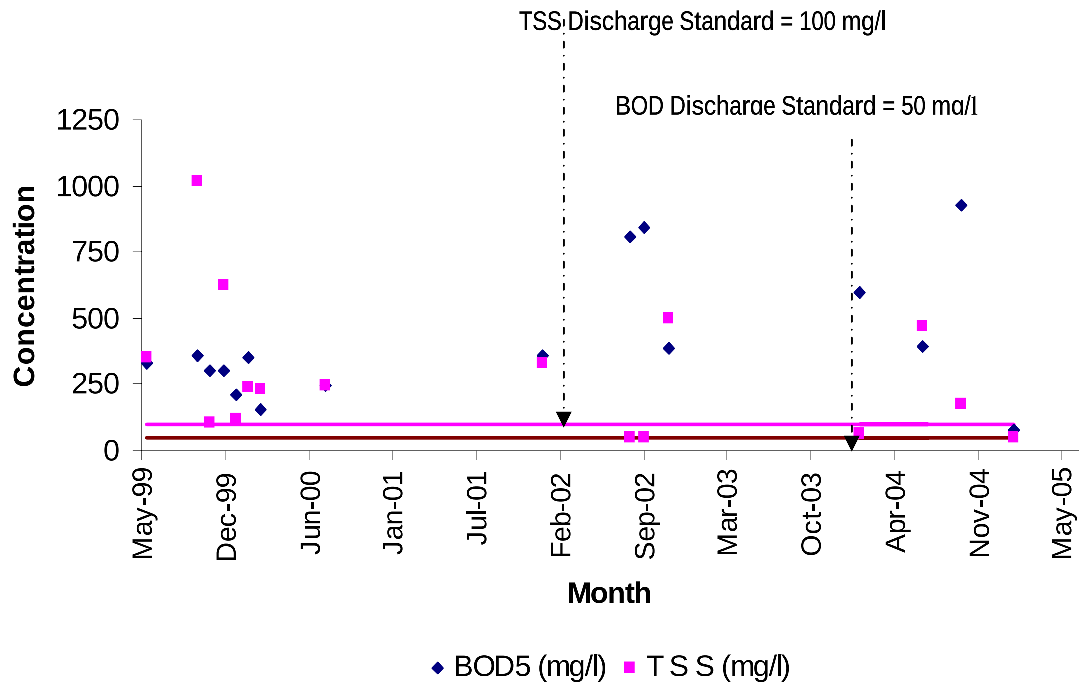

***FIG. 5a.** Uganda Breweries BOD and TSS levels in the final effluent.*

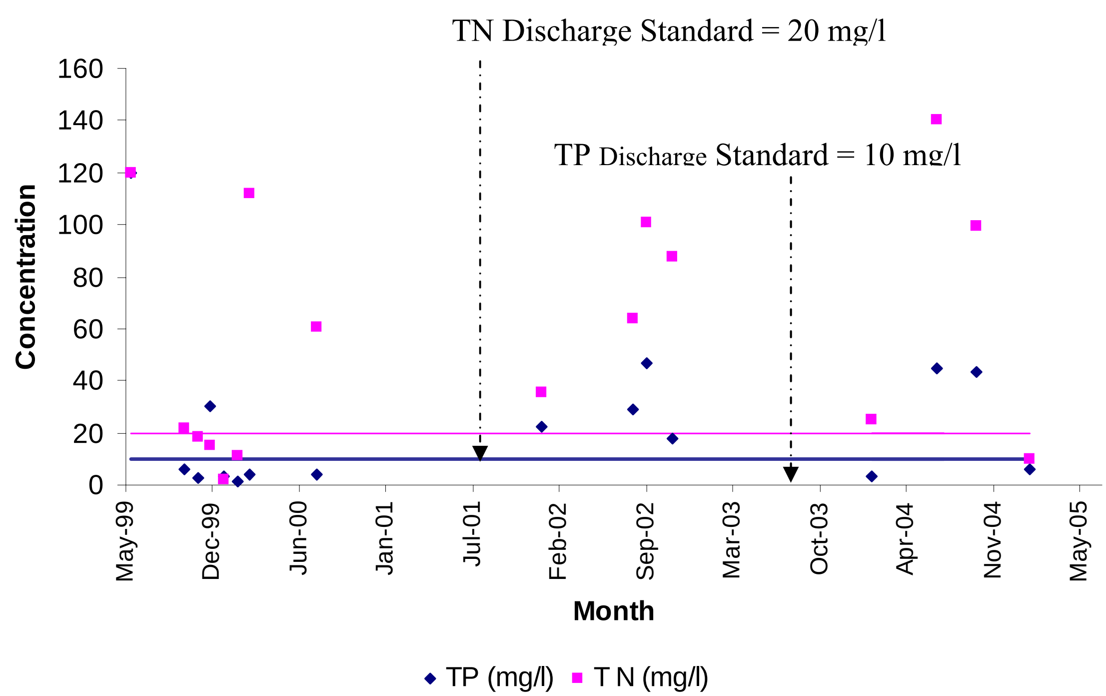

***FIG. 5b.** Uganda Breweries TN and TP levels in the final effluent.*

Load Discharged to Lake Victoria

The pollution loading is categorized according to whether it is from urban centres, industries or fishing villages. Kampala, Masaka, Rakai and Mpigi districts account for 82% of the BOD load, 86 % of the total Nitrogen load and 87% of the phosphorus load discharged from urban centres and fishing villages. Fishing villages account for about 25% of the BOD load, 20% of the Total Nitrogen load and 15% of the phosphorus load discharged from urban centres and fishing villages.

The estimated urban population in Uganda that contributes to the pollution load into the lake is about 1,220,000 (2002 Population Census). The total pollution load discharged to the environment, but not directly to the lake was calculated for all three categories of waste generation sources. Percentage contribution of the sources to the total pollution loading is shown in brackets (Table 1).

TABLE 1. *Pollution loading (Kg/day) from main point sources.*

Point Source Type	BOD	TN	TP
Urban Centres	50,313	6,289	3,145
Fishing Villages	2,325	291	146
Industry	7,056	2,184	683
Totals	**59,694**	**8,764**	**3,974**

The estimated total loads discharged from urban centres, fishing villages and industry into Lake Victoria after passing through wetlands, river systems and other natural purification systems is summarized in Table 2.

TABLE 2. *Pollution loading (Kg/day) reaching Lake Victoria after passing through natural filtration systems.*

Point Source Type	BOD	TN	TP
Urban Centres	14,166	2,911	2212
Fishing Villages	2,960	366	190
Industry	2,520	341	105
Totals	**19,646**	**3,618**	**2,507**

Based on the data collected, Kampala accounts for about 65% of the BOD and 73% of the total Nitrogen and 73% of the phosphorus load discharged from the 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. Contributions from urban centres in other districts are relatively small.

Urban Pollution Loading

The loads are represented by district and the summary of these loads is given in Table 3. These loads are based on domestic wastewater and garbage generation and do not take into account industrial loads.

TABLE 3. *Basic Pollution Loading (Kg/day) from Urban Centers*

Urban (City/Town)	Population Year 2000	Pop'n Est. Year 2005	Pollutant Loads (Kg/day) BOD	TN	TP
Busia	37,601	46,061	18.42	2.30	1.15
Entebbe	83,592	102,400	4,095.99	512.00	256.00
Jinja	97,354	119,258	2,862.20	357.77	178.89
Kampala	688,830	843,817	33,752.6	4,219.09	2,109.54
Lukaya	10,200	12,495	478.43	59.80	29.90
Masaka	101,663	124,537	4,981.51	622.69	311.34
Mbarara	73,000	89,425	3,576.99	447.12	223.56
Mpigi	11,167	13,679	547.17	68.40	34.20
Totals	**1,103,406**	**1,351,673**	**50,313**	**6,289**	**3,145**

Industrial Pollution Loading

The largest polluters that discharge eventually into Lake Victoria and the load that they discharge into the environment are shown in Table 4. Results show that Uganda Breweries accounts for about 80% of the BOD load, 85% of the COD load, 93% of the suspended solids load, 60% of the total nitrogen load and 82% of the phosphorus load discharged by factories into the lake.

Pilot projects

Tertiary municipal effluent treatment

Figure 6 shows the wastewater flow before and after the distribution of the wastewater. Electrical conductivity (EC) was used as a tracer. The EC reduced from transect 1 towards transect 3 indicating improvement in the water quality as the water flows through the wetland towards Napoleon Gulf. Apart from the EC in transect 1, non parametric statistical analysis (Mann Whitney U test, $p \leq 0.05$) of the pooled transect data indicates that the values after bio-manipulation were significantly lower than before.

TABLE 4. *Pollution Loading (Kg/day) from selected Industries.*

Factory	BOD	TN	TP	Receiving environment
Uganda Breweries	3,562	2,042	105	Lake Victoria
Britania Products	975	1,427	5	Kinawataka wetland
Mukwano Soap and Oil	22	13	1	Nakivubo wetland
City Abattoir	420	1,868	42	Nakivubo wetland
Uganda Meat Packers	276	744	24	Nakivubo wetland
Nakasero Soap Works	48	16	1	Nakivubo wetland
Greenfield Entebbe	112	121	10	Lake Victoria
Hwang Sung Fish Factory	74	33	10	Kinawataka wetland
Century Bottlers	299	82	9	Namanve-Wankolokolo
Uganda Fish Packers	423	24	163	Kinawataka wetland
Ngege Fish Factory	322	151	37	Nakivubo wetland
Crown Bottlers	523	133	11	Kinawataka wetland
Total	7,056	6,654	418	

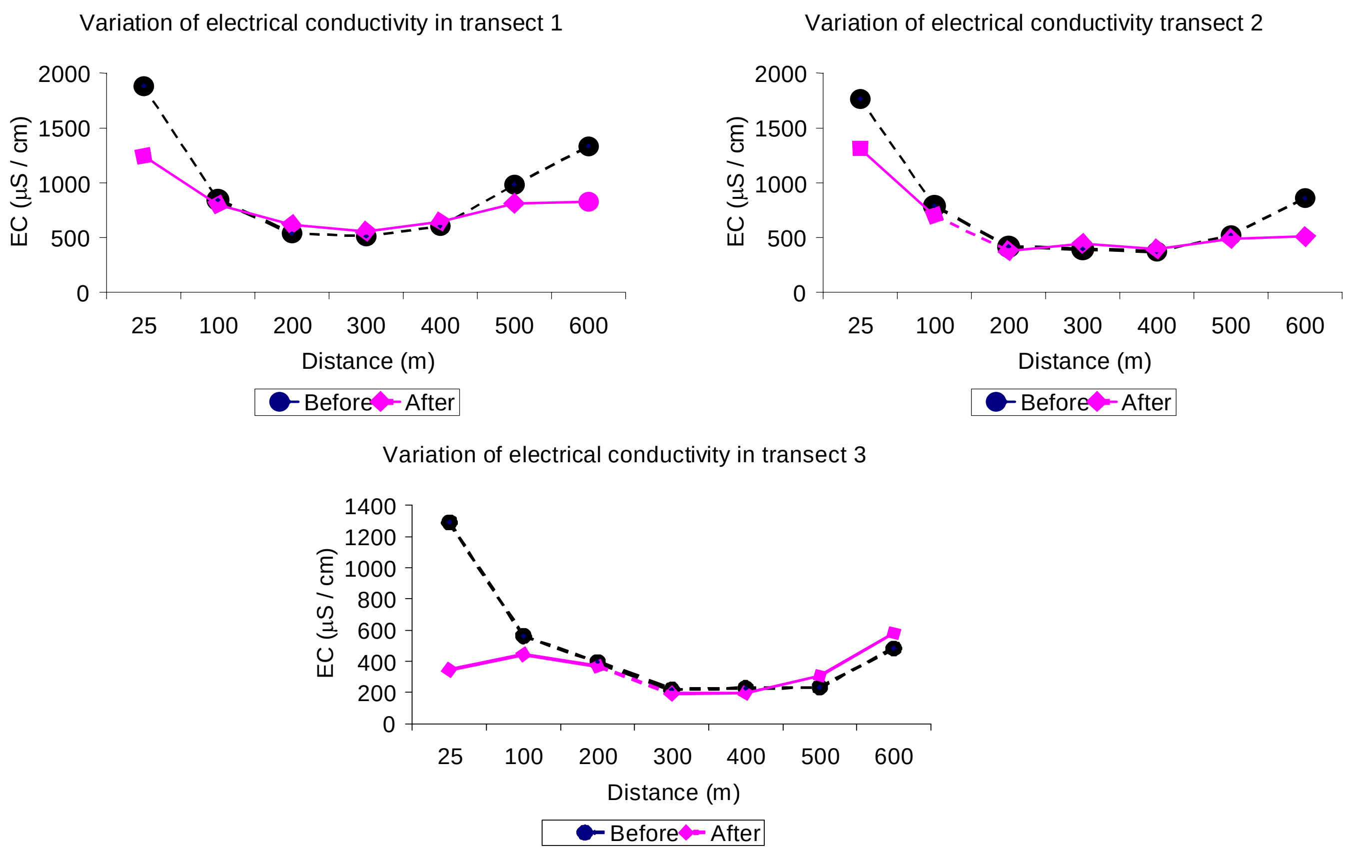

FIG. 6. *Variation of electrical conductivity (indicator of water flow) along the transects in the wetland before and after the distribution of wastewater.*

The variation of faecal coliforms distribution along transects 1 and 3 is shown in Figure 7. Generally, the faecal coliforms levels along transect 1 are lower after bio-manipulation. Lower numbers were recorded along the sections 25 – 100 m and 400 – 600m in transect 3 after the bio-manipulation. The higher values mid way transect 3 after bio-manipulation compared to those before suggests that more water is reaching and is evenly distributed along transect 3.

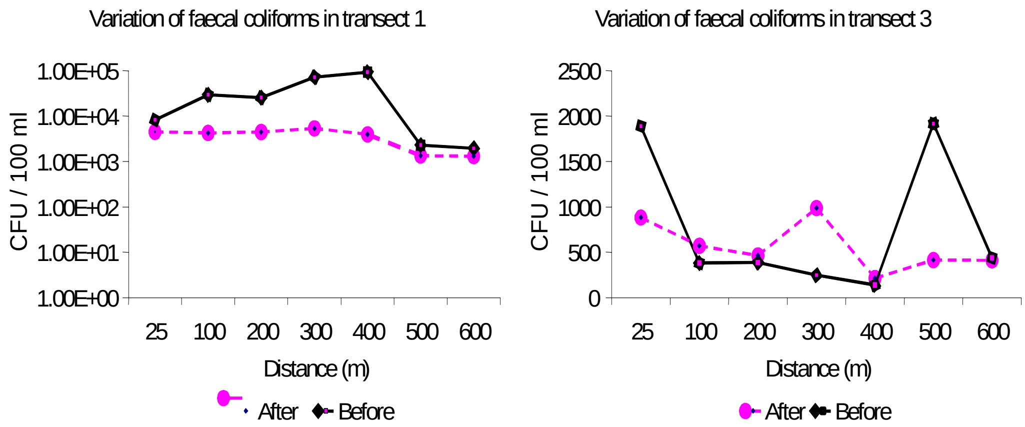

FIG. 7. *Variation of faecal coliforms along transects in the wetland before and after the distribution.*

The concentration of nitrogen and phosphorus along transects 1 and 2 are significantly higher (Mann Whitney U test, $p<0.05$) after bio-manipulation whereas that along transect 3 was lower (Figure 8). It seems there is a release of these nutrients probably due to mineralisation of plant material, which could have been accelerated by more water flow along the wetland after the bio-manipulation.

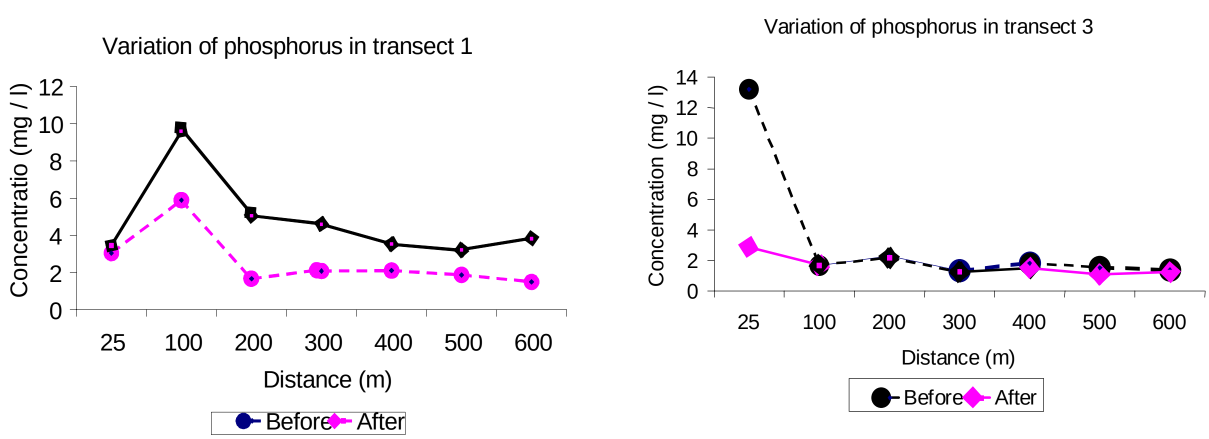

FIG. 8. *Variation of phosphorus concentration along transects before and after the distribution of wastewater.*

Tertiary industrial effluent treatment

There was an increase in the pH average values in the wetland system with higher values in system 2 than in system 1 (Table 5). On the other hand there was a general reduction in BOD, ammonia and COD in both the water hyacinth and papyrus setups.

TABLE 5. *Average Variation of Wastewater along the Wetland cells.*

Parameter	Influent	Water Hyacinth			Papyrus		
		W1	W2	W3	P1	P2	P3
pH	5.93	6.12	6.20	6.29	6.20	6.33	6.45
EC (μS/cm)	1344	1115	1036	948	1246	1172	1056
COD (mg/l)	2998	1834	1530	1415	1637	1366	1332
BOD_5	****	1364	****	721	1415	****	841
$N\text{-}NO_3$ (mg/l)	3.82	3.82	3.49	3.28	3.57	3.12	2.45
NH_3 -N (mg/l)	3.40	3.40	2.99	2.85	2.75	2.31	1.46

The variation of key wastewater quality parameters with depth is presented in Figure 9. There was a reduction in the COD with depth and along the wetland cells.

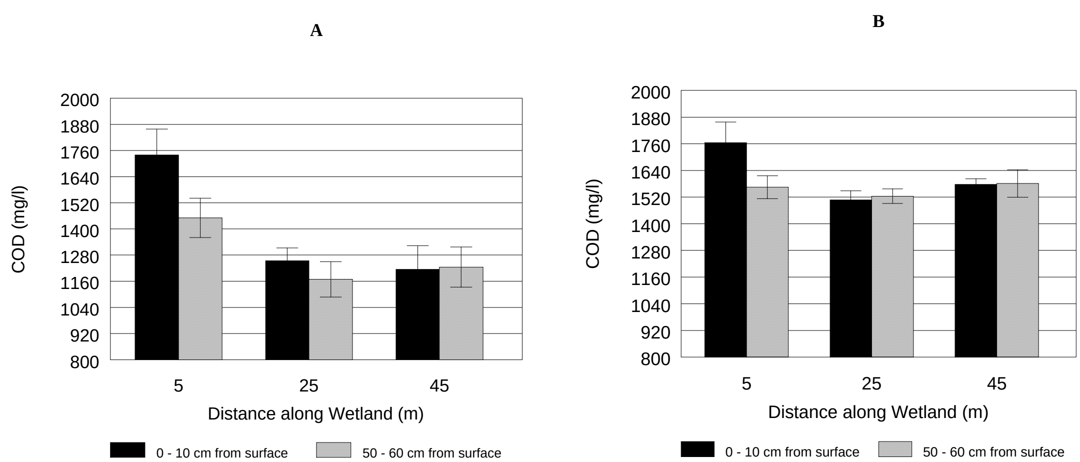

FIG. 9. *Variation of COD with depth in (A) Water hyacinth (B) Papyrus cells.*

The slightly higher COD values observed near the surface was probably due to the litter of the dead plants and other organic materials releasing nutrients and ions back into the water. The higher values near the bottom of the wetland were probably due to settlement or sedimentation.

There was a reduction in BOD_5 with depth. The higher BOD_5 values observed within a depth of 0 - 10 cm at the inlet of both the water hyacinth and papyrus cells and at

20 m (Figure 10) along the water hyacinth cells were probably due to decayed plants and other organic materials. However, at 40m along the water hyacinth cells and from 20 to 40 m along the papyrus cells, BOD_5 increase with depth was probably due to settlement of particles towards the outlets of the wetland cells.

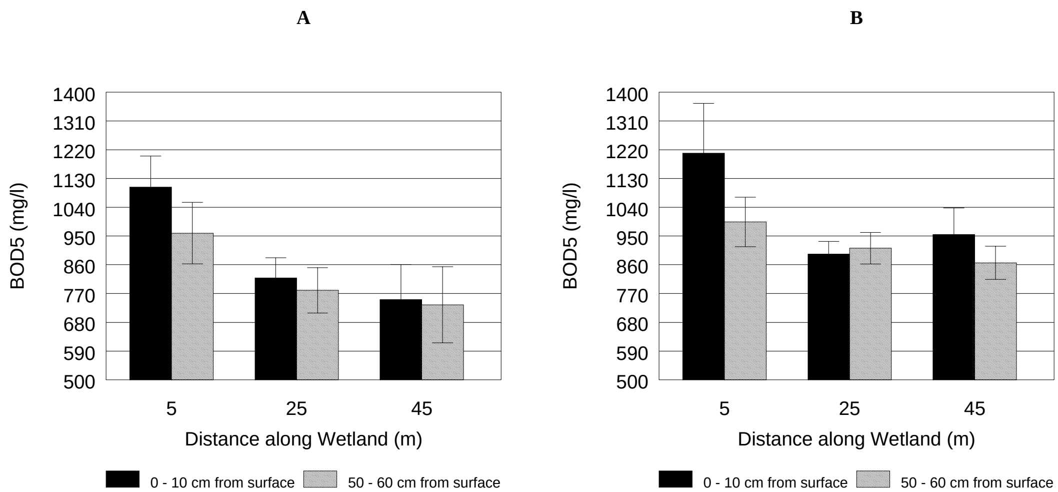

FIG. 10. *Variation of BOD_5 with depth in (A) Water hyacinth (B) Papyrus cells.*

The near-surface average ammonia-nitrogen were lower at the inlet of both the water hyacinth and papyrus cells than those recorded near the bottom (Figure 11) would probably have resulted from the aeration effect where in the presence of adequate oxygen, the ammonia-nitrogen is converted to nitrate-nitrogen.

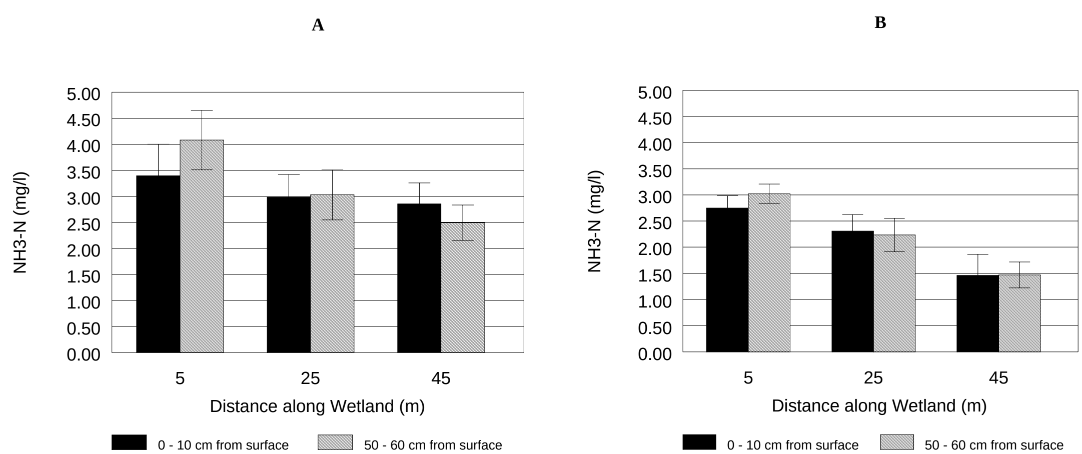

FIG. 11. *Variation of NH_3-N with depth in (A) Water hyacinth (B) Papyrus cells.*

Slightly higher nitrate-nitrogen values were recorded near the surface in papyrus cells and at the inlet of the water hyacinth cells than near the bottom.

Wastewater Characteristics

Figure 12 presents the wastewater characteristics. Generally, pH (5-8), temperature (22-30 ^{o}C) and nutrient levels in the constructed wetland were sufficient to support growth of the macrophytes since they were within the optimal range. In contrast, the high COD like BOD cause plant stress that in a way affects plant growth, and therefore the removal efficiencies of the different parameters.

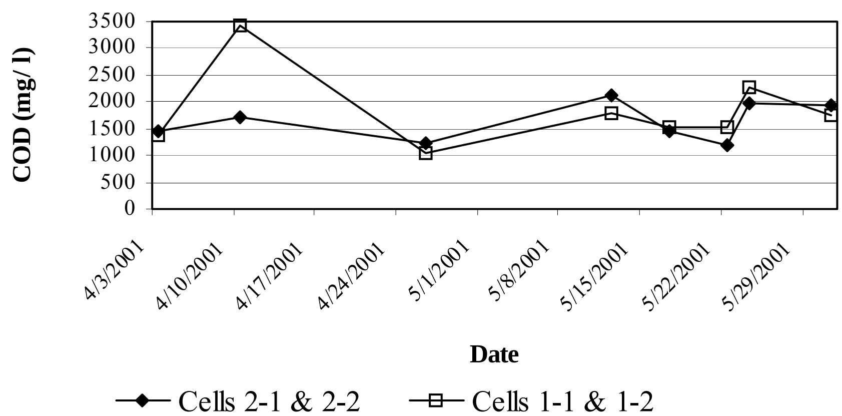

FIG. 12a. *COD of inflow into the constructed wetland.*

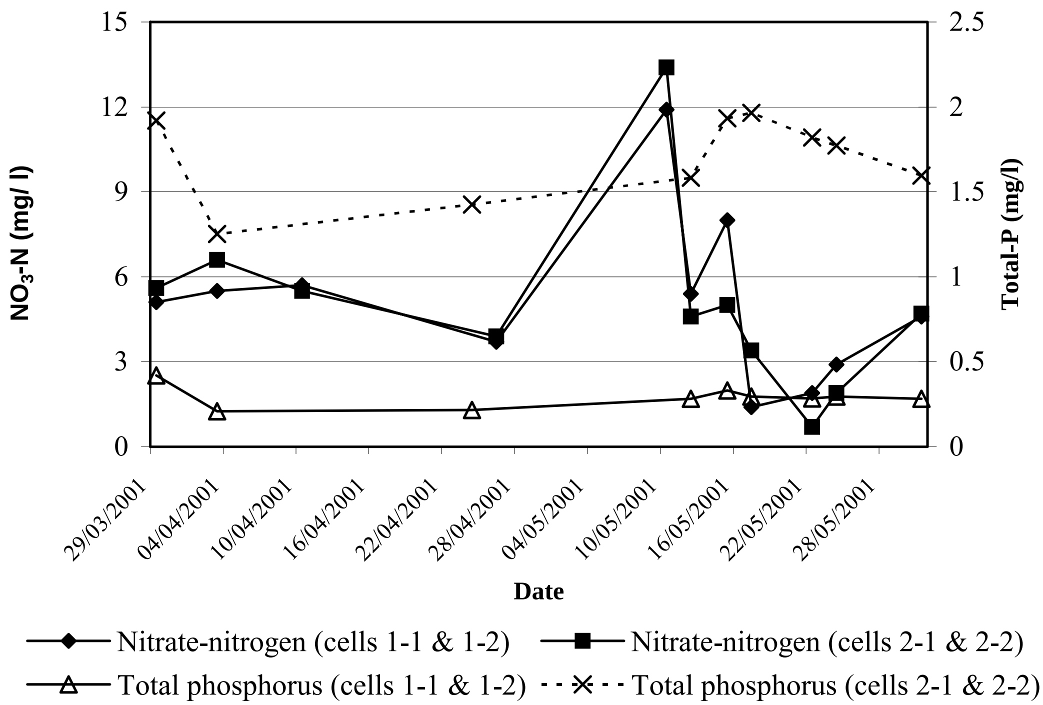

FIG. 12b. *Total Phosphorous and Nitrate-nitrogen in inflow into the constructed wetland.*

DISCUSSIONS

Pollution Management Strategies

The strategies adopted in reducing the pollution loading into Lake Victoria are highlighted.

Municipal Waste Management

At present only a small percentage (about 10) of the sewage generated in the large urban centres is collected and treated at central wastewater treatment facilities. About 50 to 70 % of wastewater is treated in pit latrines or septic tanks. Small urban centres rely largely on pit latrines (50%) with some septic tanks (about 5%). The remainder of human waste is discharged directly to the environment. In this regard, the NWSC component has embarked on raising awareness of the local communities in small towns and fishing villages about improving sanitation habits.

Wastewater Treatment Facilities

Management of the central wastewater treatment facility at Bugolobi is being improved to bring the performance to optimum to cope up with the expansion of the sewerage network. The high non conformity of the effluent quality to the national standard is probably attributed to the frequent break down of the system and increased loading in the system due to increased sewer network. This is because by collecting wastewater in sewers and failing to treat properly, pollution loads are concentrated into a single stream, which is transferred more directly to receiving waters without necessarily improving the quality of the effluents.

Because the frequency of final effluent quality exceeding the national standards is high, performance of the sewage treatment has to be improved through rehabilitation of the poorly functioning and non-functioning units. Addition of a maturation pond after humus tanks to polish effluent quality, from the conventional plant, has been planned for to deal with non-compliant TP and TN quality.

This is the same reason why effluent from Kirinya wastewater treatment ponds has to be polished by use of the bio-manipulated Kirinya natural wetland. Results of the tertiary municipal effluent pilot study show substantial improvement in effluent quality through transects of the bio-manipulated wetland. Control of septic sludge tankers (cesspool emptiers), which is used to discharge in a relatively uncontrolled way to sewage works, is now in place. Trade effluent discharge agreement procedure is being administered and controlled as more factories get connected to the sewer. Staff training should be conducted and expertise in processing wastewater treatment be put in place to operate the treatment plant.

Garbage Collection

Data indicated that only 30 to 40% of garbage is collected and considerable amount of garbage is burnt. About 40% of the garbage remains uncollected and thus may contribute to the pollution of the lake. In regard to that, urban authorities have involved private sector participation in garbage collection as a strategy in improving solid waste management. Furthermore, the role of women in the management of waste at source is being encouraged. Effort is being made to discourage the burning of garbage, as this leads to acidification of rain, and contributes to dry deposition on the lake.

Urban runoff

Urban runoffs carry untreated municipal and industrial wastes and uncollected garbage into the rivers and wetland systems and eventually into Lake Victoria. In order to reduce on the pollution due to urban runoff, the following are being implemented:

- Improved garbage collection through private sector participation
- On site treatment of domestic waste and use of ecological sanitation toilets.
- Wise use of wetlands to reduce their encroachment and degradation and where necessary gazetting of the wetland is done, for example, Nakivubo wetland.

Fishing villages

The survey conducted indicated that fishing villages have less than 20% of pit latrines coverage. Most human waste is discharged directly into the environment. This has got a direct bearing to the public health and water quality of the lake. Garbage collection is also poor. In terms of central garbage collection probably less than 40% of garbage is collected. This has negatively impacted on the lake water quality as considerable quantity of garbage is washed into the lake after rainfall. Poor sanitary conditions and garbage collection have resulted in high prevalence of water-borne and related diseases like bilharzia, scabies, diarrhoea, cough and malaria.

In regard to poor garbage collection and sanitation management at the fishing villages, the following strategies are being implemented: Through public awareness meetings, local communities have been educated in ways of improving sanitation in fishing villages such as use of ECOSAN toilets and micro-projects were initiated to address the issue of lack of toilets. Waterborne toilets in Lukaya town and ECOSAN toilets in Dimo (Masaka district) and Musonzi (Kalangala district) were constructed as pilots for other fishing villages to learn from. Environmental management committees have been set up in fishing villages and are expected to work with the beach management units (BMUs) in enforcing cleanliness and environmental management in general at the fishing villages. Garbage volume reduction by encouraging domestic composting of solid waste, which in these communities has very high biodegradable fraction is being done. Village communities are being encouraged to build strong self-help groups to address their organizational capability and improve fishing village prosperity. Promotion of private sector participation in waste management is also taking place.

Industrial effluent

Most factories do not have effluent treatment plants, even where they are existing, most industrial wastewater treatment plants are poorly designed and constructed. Of those that have wastewater treatment plants, few, if any, of those examined were achieving effluent discharge standards. The following strategies are therefore being implemented:

- Promoting the use of the Pollution Control Manual as a guide for all government officers involved in industrial pollution control.
- Preparing pollution control pamphlets, based on the Pollution Control Manual, for distribution to factory managers or owners.
- Strengthening the process design capability in Uganda both among consultants and pollution management agencies.
- Adopting a stager approach to pollution control enforcement e.g. emphasis on well-designed and constructed primary treatment instead of poorly designed treatment plant.
- Promote the use of constructed wetlands in the treatment of industrial effluents. Tertiary Industrial Effluent Pilot study was carried at Port Bell using factory effluent from Uganda Breweries Ltd (UBL) with results showing good performance of the system. Application of the pilot project was adopted by UBL, with some modifications, in designing facilities for treatment of the factory effluents. The UBL wastewater treatment plant is under construction.
- Facilitating implementation of cleaner production by coordination with the Uganda Cleaner Production Center.

Tertiary municipal effluent treatment

The high values of EC at the western edge of the Kirinya natural wetland (between 25 – 175 µS/cm) along the three transects was attributed to effluents discharged at the edges of the wetland before the bio-manipulation whereas the high values (between 500 – 600µS/cm) was attributed to the leakage of the facultative pond. There is also contribution from the storm water drainage channel located between the facultative and maturation pond 1. The smoothening of the EC curve along transects after bio-manipulation implies that the water was evenly distributed over a large portion of the wetland.

The data collected shows that bio-manipulation improves the distribution of the wastewater across the wetland. The conductivity of the wastewater and faecal coliform numbers smoothened out in the wetland. Before the bio-manipulation, there were high values of conductivity recorded on the western edges of the wetland along the three transects. From the data collected so far, and from the emerging water quality trends, there is need for more data collection so that temporal and spatial variation can be assessed and the impact of bio-manipulation be well documented. The results from this study can be extrapolated to other natural wetlands where city/municipalities like Kampala, Entebbe and Masaka are already discharging their municipal effluents.

The little variation in water quality as indicated by conductivity could be attributed to the irregularity of the wastewater distribution in the whole length of the distribution pipe and the flow patterns in the wetland itself. There were problems due to weak ground that made the supporting pillars sink, resulting in loss of pressure in some sections of the pipe. The wastewater was successfully distributed over the first half (western) part of the wetland and with better distribution systems, even higher treatment efficiencies could be achieved.

Tertiary industrial effluent treatment

The increase in pH could be attributed to photosynthetic activity of both macrophytes and algae. The observed reduction in EC would probably have been a result of plant uptake of nutrients and ions, adsorption onto roots and sedimentation/precipitation. BOD removals observed were probably, due to both sedimentation (settleable BOD), although this could be limited since the water had pre-settled, and oxygen release by the macrophytes during photosynthesis. Overall, biological activity contributes a great deal to BOD reduction. The difference in the removal rates may be due to higher rates of uptake by the water hyacinth compared to papyrus. The observed removals of COD would probably have been a result of sedimentation and uptake by the plants and oxygen release by the plants during photosynthesis. Ammonia reduction observed was probably a result of nitrification while that of nitrate concentrations in the wetland cells is likely due to the conversion of nitrate to nitrogen gas through denitrification. Removals in the macrophyte-based units would further be enhanced by plant uptake.

CONCLUSIONS

1. Pollution loading into Lake Victoria was highest from urban centres (72%) followed by shoreline settlements - fishing villages (15%) and industries (13%).
2. There is continuing increase in industries opening in main cities and towns within the northern shores thus imminent increase in pollution loading from industrial sources.
3. Urbanization and growing human population in urban centres is significant, therefore, increased pollution loads are expected yet there are no clear near future plans by urban authorities to construct more municipal wastewater treatment facilities.
4. Management of solid waste (garbage) in urban centres is poor resulting in accumulated heaps, which are leached by runoff.
5. Pollution in fishing villages is on the increase as more settlements are registered because of the increased income from fish sales to fish processing industries. However, sanitation facilities remain limited, waste management is still poor due to low awareness by local communities.
6. There is high prevalence of water borne and related diseases because of lack of enough sanitation facilities, poor solid waste management and lack of other clean water sources besides the lake.

7. Micro-projects for ECOSAN toilets have not been fully acceptable and adopted by local communities in fishing villages due to religious, cultural and socio-economic issues, which require expert and long term handling.
8. Water Quality Model for Inner Murchison Bay (IMB) showed increasing pollution loading into the bay especially from Nakivubo channel, Port Bell and Gaba fishing village as indicated by EC and faecal coliforms measurements.
9. The deteriorating water quality in the IMB because of discharge of polluted water through the Nakivubo channel/wetland has resulted in increased expenditure on water treatment in Gaba water treatment facilities of National Water and Sewerage Corporation (see chapter 12, on impacts of water quality on beneficial uses – case example of Gaba Water Treatment Works).
10. Tertiary Municipal Effluent Pilot Project bio-manipulation of the natural wetland in Kirinya – Jinja improved effluent quality from the municipal wastewater treatment and can be adopted by other municipalities.
11. Tertiary Industrial Effluent Pilot Project using constructed wetland for treatment of industrial effluent in Port Bell improved effluent quality from Uganda Breweries and could be used for other effluents.

Recommendations

1. There is need for continuity in mapping out and monitoring industrial, municipal and shoreline settlement pollution loading in the catchment so as to assess whether there is improvement or not after mitigation measures are put in place. This is proposed to continue in LVEMP II.
2. Industries ought to adopt cleaner production and where necessary must put in place wastewater pre-treatment plants.
3. All municipalities should have wastewater treatment facilities and ensure compliance with effluent standards.
4. Solid waste (garbage) management in urban centres and fishing villages has to be improved and private operators' involvement should be encouraged.
5. More clean water sources need to be availed to the fishing villages besides lake water.
6. By laws to deal with industries and municipalities whose effluents do not comply with effluent standards should be put in place. Strong enforcement of the set by laws should be ensured.
7. Information dissemination workshops and barazas on cleaner production and effluent pre-treatment (use of pollution control manual) are required for industrialists.
8. It is important that strategic management of Nakivubo channel/wetland be focused on wastewater purification through gazettement, reticulation, bio-manipulation and rejuvenation of the already destroyed wetland macrophytes by encroachers. There is need for continued monitoring and evaluation of extent of improvement or deterioration of water quality in the wetland and IMB.
9. There is urgent need to put in place expert and long term awareness programs on sanitation and waste management for local communities in fishing villages and in

all primary schools. There is need to spread and build public awareness on use of ECOSAN toilets and their technology for sandy and high water table areas.

10. There is need to continue operations and maintenance of the two pilot projects plants for Tertiary Municipal Effluents and Tertiary Industrial Effluents Treatment in Kirinya – Jinja and Port Bell – Kampala, respectively. This is for the purposes of technology transfer, educational excursions, information dissemination to stakeholders and the public.

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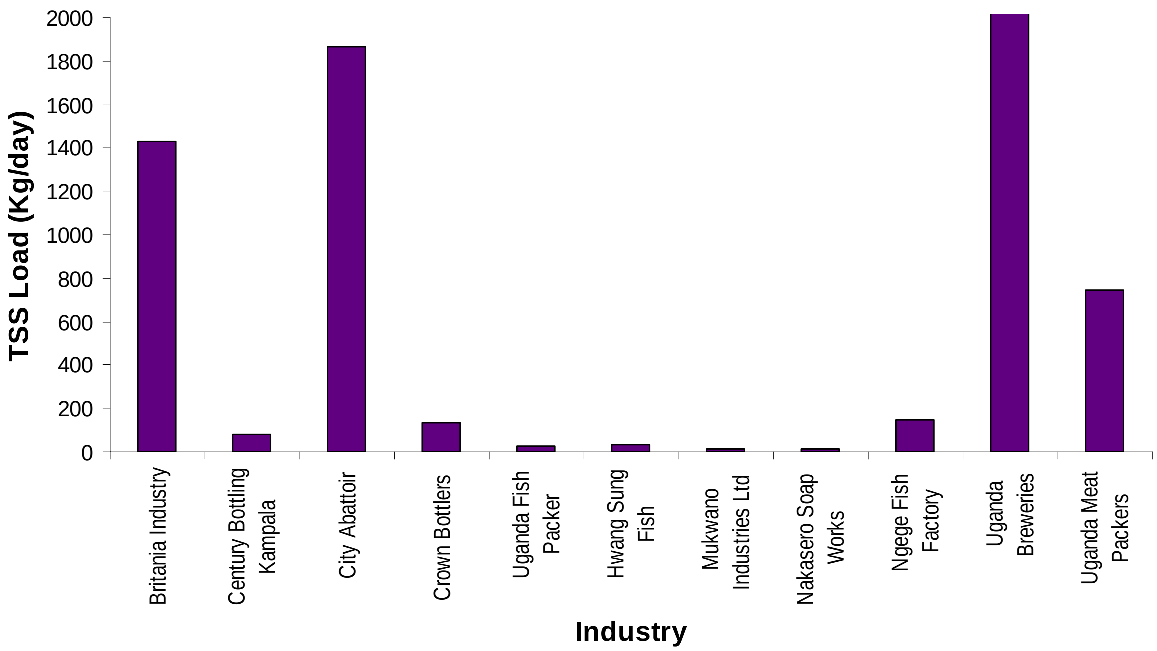
Appendix 5.1: List of Municipal and Industrial Point Sources

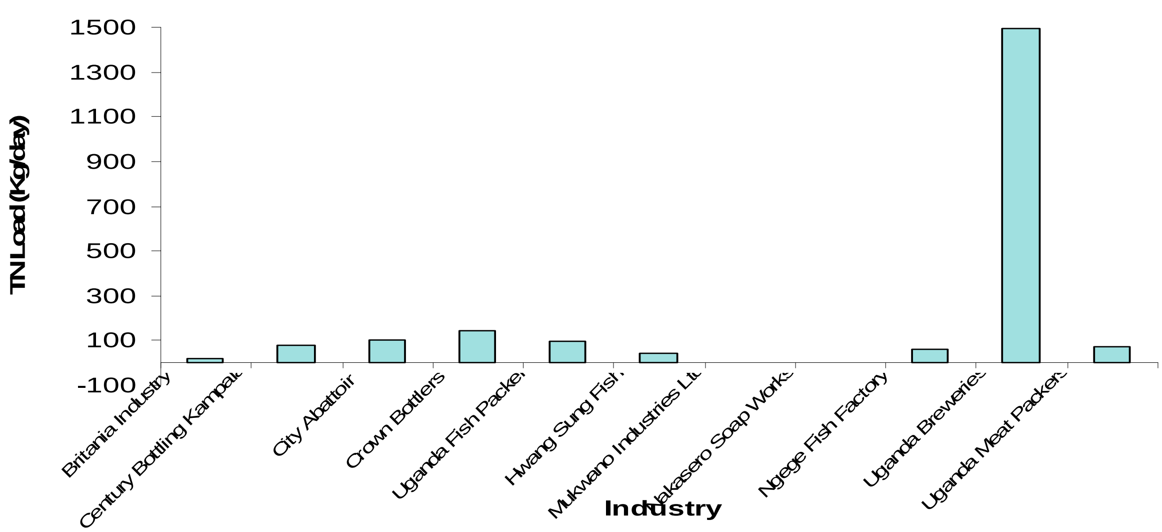
Station Name	Sample Station Type Description	District	Catchment
Century Bottling Co Ltd, Mbarara	Industrial Effluent	Mbarara	Bukora
Country Taste Dairy, Mbarara	Industrial Effluent	Mbarara	Bukora
Dairy Corporation, Mbarara	Industrial Effluent	Mbarara	Bukora
GBK Dairy, Mbarara	Industrial Effluent	Mbarara	Bukora
Mbarara Abattoir, Mbarara	Industrial Effluent	Mbarara	Bukora
Makasa Abattoir, Masaka	Industrial Effluent	Masaka	Katonga
Britania Allied Industries, Kampala	Industrial Effluent	Kampala	Northern Shore
Century Bottling Co Ltd, Kampala	Industrial Effluent	Mukono	Northern Shore
City Abattoir 1, Kampala	Industrial Effluent	Kampala	Northern Shore
Crown Bottlers Ltd, Kampala	Industrial Effluent	Kampala	Northern Shore
Dairy Corporation, Kampala	Industrial Effluent	Kampala	Northern Shore
Gomba Fishing Co. Ltd, Jinja	Industrial Effluent	Jinja	Northern Shore
Greenfields (U) Ltd, Entebbe	Industrial Effluent	Wakiso	Northern Shore
Hwang Sung Fish Factory, Kampala	Industrial Effluent	Kampala	Northern Shore
Jinja Cattle Traders Association	Industrial Effluent	Jinja	Northern Shore
Kengrow Industries Ltd, Jinja	Industrial Effluent	Jinja	Northern Shore
Leather Industries of Uganda, Jinja	Industrial Effluent	Jinja	Northern Shore
Marine & Agro Export Processing	Industrial Effluent	Jinja	Northern Shore
Masese Fish Packers, Jinja	Industrial Effluent	Jinja	Northern Shore
Mukwano Industries Ltd, Kampala	Industrial Effluent	Kampala	Northern Shore
Nakasero Soap Works, Kampala	Industrial Effluent	Kampala	Northern Shore
Ngege Fish Factory, Kampala	Industrial Effluent	Kampala	Northern Shore
Peacock Paints, Kampala	Industrial Effluent	Kampala	Northern Shore
Uganda Animal Feeds, Jinja	Industrial Effluent	Jinja	Northern Shore
Uganda Breweries Ltd, Kampala	Industrial Effluent	Kampala	Northern Shore
Uganda Fish Packers, Kampala	Industrial Effluent	Kampala	Northern Shore
Uganda Meat Industries, Kampala	Industrial Effluent	Kampala	Northern Shore
Uganda Grain Millers, Jinja	Industrial Effluent	Jinja	Northern Shore
Bugolobi Sewage Works, Kampala	Municipal Effluent	Kampala	Northern Shore
Luzira Prison Sewage, Kampala	Municipal Effluent	Kampala	Northern Shore
Kakiika Stream, Mbarara	Municipal Runoff	Mbarara	Bukora
Bukoyolo stream, Masaka	Municipal Runoff	Masaka	Katonga
Katabazungu river, Lukaya	Municipal Runoff	Lukaya	Katonga
Lukaya Kafua Stream, Lukaya	Municipal Runoff	Masaka	Katonga
Nabajjuzi River, Masaka	Municipal Runoff	Masaka	Katonga
Nakayiba R. Kyakumpi, Masaka	Municipal Runoff	Masaka	Katonga
Nyendo drain channel, Masaka	Municipal Runoff	Masaka	Katonga
5th Street Bridge Nakivubo ch, K'la	Municipal Runoff	Kampala	Northern Shore
Banda Stream, Kampala	Municipal Runoff	Kampala	Northern Shore
Botanical Channel, Entebbe	Municipal Runoff	Wakiso	Northern Shore
Buziika Stream, Njeru	Municipal Runoff	Mukono	Northern Shore
DataPro Drain, Entebbe	Municipal Runoff	Wakiso	Northern Shore

Fire Brigade, Nakivubo ch, K'la	Municipal Runoff	Kampala	Northern Shore
Fish Packers stream, Kampala	Municipal Runoff	Kampala	Northern Shore
Gentex stream, Kampala	Municipal Runoff	Kampala	Northern Shore
Jinja Town Main Drain	Municipal Runoff	Jinja	Northern Shore
Kajjansi River, Kajjansi	Municipal Runoff	Wakiso	Northern Shore
Kasanga stream, Kampala	Municipal Runoff	Kampala	Northern Shore
Katosi drain, Fishing Village	Municipal Runoff	Mukono	Northern Shore
Kayunga stream, Kampala	Municipal Runoff	Kampala	Northern Shore
Kilimantogo rail culvert, Kampala	Municipal Runoff	Kampala	Northern Shore
Kitante Stream, Kampala	Municipal Runoff	Kampala	Northern Shore
Kitintale stream, Kampala	Municipal Runoff	Kampala	Northern Shore
Kitoro main channel, Entebbe	Municipal Runoff	Wakiso	Northern Shore
Kyambogo stream, Kampala	Municipal Runoff	Kampala	Northern Shore
Lugogo stream, Kampala	Municipal Runoff	Kampala	Northern Shore
Jinja Main Drain	Municipal Runoff	Jinja	Northern Shore
Mukwano drain channel, Kampala	Municipal Runoff	Kampala	Northern Shore
Railway bridge Nakivubo ch, K'la	Municipal Runoff	Kampala	Northern Shore
Namanve river, Kampala	Municipal Runoff	Mukono	Northern Shore
Railway quarters stream, Kampala	Municipal Runoff	Kampala	Northern Shore
Walukuba stream, Jinja	Municipal Runoff	Jinja	Northern Shore
Wanyange Stream, Jinja	Municipal Runoff	Jinja	Northern Shore
Kalisizo Town Drain	Municipal Runoff	Kalisiso	Sango Bay
Kyotera Town Drain	Municipal Runoff	Kyotera	Sango Bay
Bukora Hydrological Station	River/stream	Rakai	Bukora
Katunguru	River/stream	Rakai	Bukora
Ruizi River	River/stream	Mbarara	Bukora
River Kagera at Kasensero	River/stream	Rakai	Kagera
Katonga River	River/stream	Mpigi	Katonga
Kyebutuka River	River/stream	Mpigi	Katonga
Nakigombe stream	River/stream	Masaka	Katonga
Bwola River	River/stream	Mukono	Northern Shore
Kalungi stream	River/stream	Mpigi	Northern Shore
Kawoya Stream	River/stream	Kampala	Northern Shore
Kiseka Channel, Kampala	River/stream	Kampala	Northern Shore
Kiyindi Bridge, Fishing Village	River/stream	Mukono	Northern Shore
Mwola stream	River/stream	Mukono	Northern Shore
Nabirye stream	River/stream	Mukono	Northern Shore
Nalwire stream	River/stream	Busia	Northern Shore
Namawundo River	River/stream	Mukono	Northern Shore
Nansonzi River swamp	River/stream	Mpigi	Northern Shore
River Sio	River/stream	Busia	Northern Shore
Zirimiti River	River/stream	Mukono	Northern Shore
Dimo Fishing Village	River/stream	Masaka	Sango Bay
Nadikutamada stream	River/stream	Masaka	Sango Bay
Sio River	River/stream	Busia	Sio

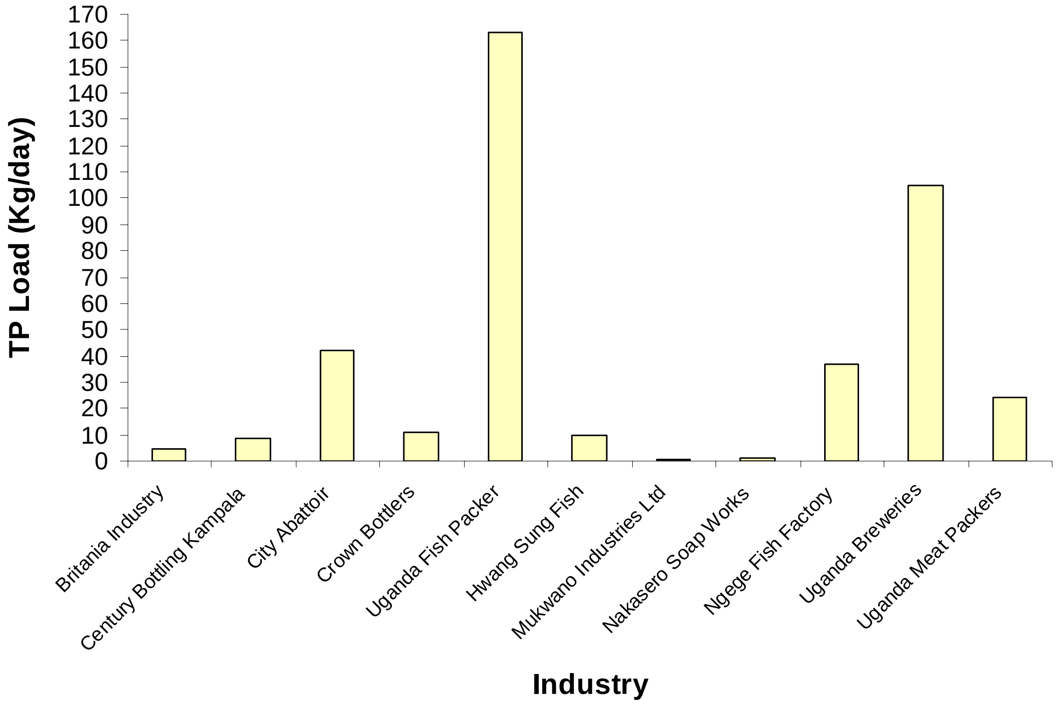
Appendix 5.2: GRAPHICS FOR INDUSTRIAL EFFLUENT LOADING



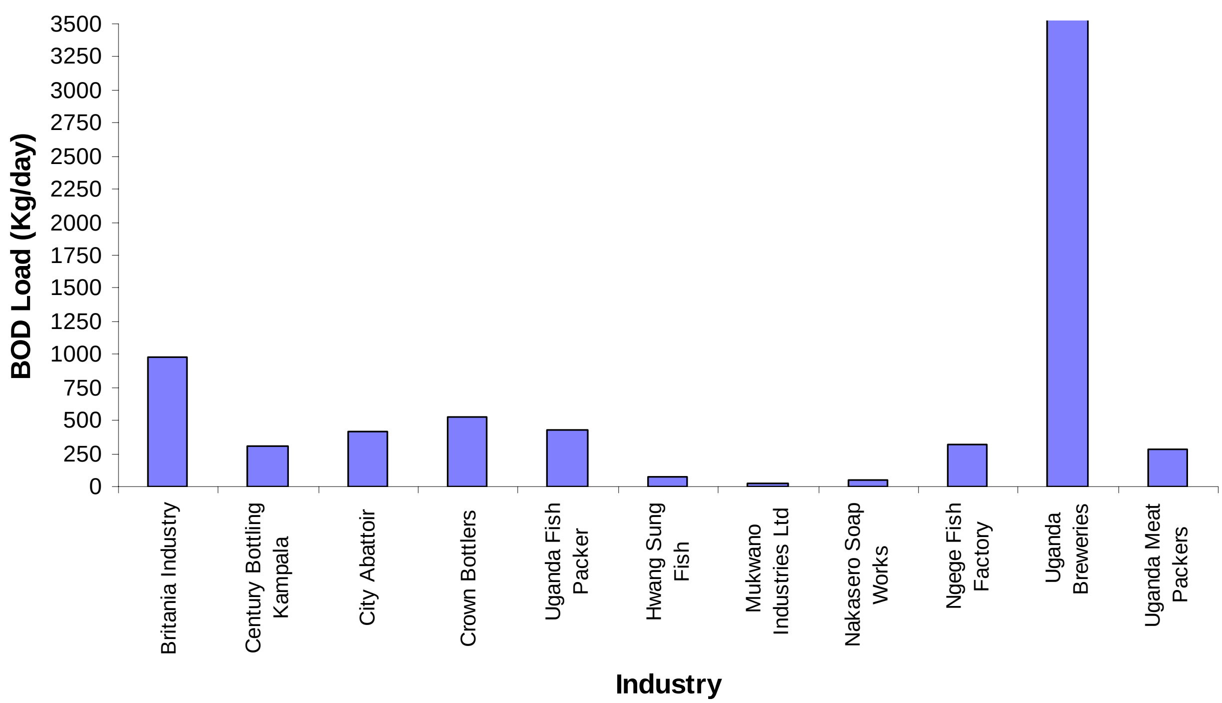
Appendix 5.2a: **Total Suspended Solids Loads from Selected Industries**



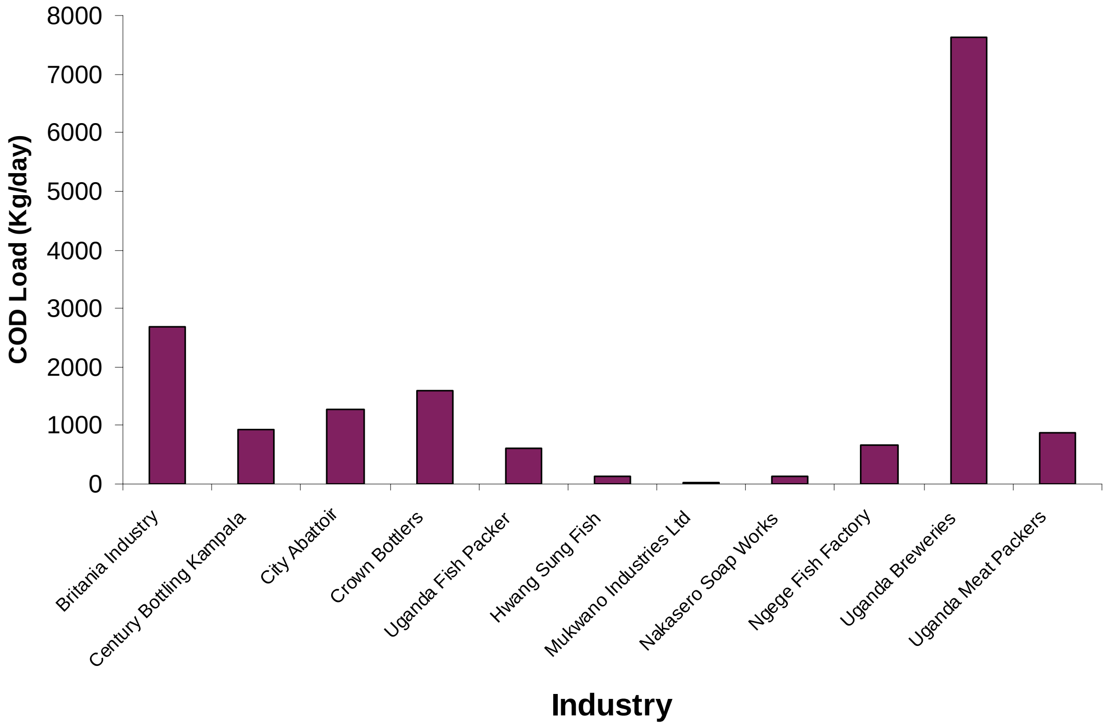
Appendix 5.2b: **Total Nitrogen Loads from Selected Industries**



Appendix 5.2c: Total phosphorus Loads from Selected Industries



Appendix 5.2d: BOD Loads from Selected Industries



Appendix 5.2e: **COD Loads from Selected Industries**