CHAPTER FOUR

Non-point pollution into the Uganda catchment of Lake Victoria

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ABSTRACT. *Estimates of nutrient loading are essential for understanding primary productivity and ecosystem function and for planning nutrient management strategies. This is particularly important for Lake Victoria which is believed to have reached a critical degradation stage. The objectives of this study were to establish the spatial and temporal variations in river chemistry and nutrient loads, to estimate the loads from the catchment and atmospheric deposition into Lake Victoria. Two sub-catchments, namely Katonga and Bukora, were considered in this study. Rivers draining the two sub-catchments were sampled from 1998 to 2004 intensively during the rainy periods, and at least monthly for other remaining periods of the year. Water samples were analysed for seventeen water quality parameters including Total Suspended Solid (TSS 105^oC and TSS 500^oC), Total Nitrogen (TN) and Total Phosphorus (TP). Concurrently rainfall samples were collected from Bukasa, Entebbe and Lolui stations representing the three isohyets zones of Lake Victoria for atmospheric wet deposition estimation. Atmospheric deposition samples collected and analysed for the seventeen parameters, including TSS, TN and TP that are reported in this study. Results show that TSS, OM and TN concentrations were catchment dependent. Bukora had significantly higher concentrations for TSS and OM, and lower TN concentrations compared to Katonga ($P<0.01$). The TP concentrations were similar in Katonga and Bukora, and increased linearly with time ($p=0.05$). The concentration of TSS fluctuated during the six years of study, with peak in 2000 for Bukora and 2001 for Katonga ($p<0.05$). TSS also fluctuated significantly only in Bukora and showed a peak in 2001 ($p<0.05$). The two sub-catchments loaded 2.1 t/day of total nitrogen, 0.3 t/day of total phosphorus in average for the six years, confirming the relatively small contribution of the catchment into the lake compared to atmospheric deposition, which loaded 26.4 t/day of TN and 5.6 t/day for TP from the wet deposition.*

Key words: Soil erosion, Water pollution, Nutrient transfers, Ecosystem function, Fish diversity, Atmospheric deposition.

INTRODUCTION

Lake Victoria is undergoing biodiversity, physical and chemical degradation compared to its status about four decades ago when Talling (1966) made his observations

(Ochumba *et al.* 1989; Hecky 1993; Muggide; 1993; Lehman and Branstrator 1993). Although it is recognized by the scientific community that the lake is enriched with nutrients, there are conflicting reports on the magnitude of nutrients received from different sources and the dynamics of nutrients in the lake.

One school of thought considers that the lake has become a eutrophic ecosystem. This status is illustrated by the proliferation algal blooms and the water hyacinth, native fish species disappearance, deoxygenation of deep waters, etc. Increasing nutrient loading due to human population growth and associated land-use changes, trophic alterations from top-down cascade of predatory interactions due to the introduction of Nile perch and cichlid species, and climatic changes are hypothesised as causes of the observed changes. The catchment is highly perceived to be responsible for Lake Victoria water quality degradation status. Lehman and Branstrator (1993) estimated that total N load from the catchment area by rivers was of 1 g NO_3-N m^{-2} yr^{-1} for the lake surface, and they estimated that it was 7 times the atmospheric input (based on a single estimate of TN in rain during their study). This is however inconsistent with recent studies, which incriminate atmospheric deposition as the main source of nutrients into the lake (LVEMP 2002; Tamatamah *et al.* 2005). Alternatively others have suggested that the differences observed in different time periods are part of the natural variability of the system although the paleolimnological study of Verschuren *et al.* (2002) clearly indicates that the water quality of Lake Victoria has changed over the last century as a response to population growth and agricultural activity in the basin.

Knowledge of the magnitude of nutrients coming from different sources is necessary for most management planning (Young *et al.* 1996). The concern over the recent observations on Lake Victoria require improved understanding about the rates of inputs of sediments and nutrients to the lake and identifying the factors controlling those rates of inputs. This study was intended to establish the spatial and temporal variations in river chemistry and nutrient loads, to estimate the loads from the catchment and atmospheric deposition into Lake Victoria, and to contribute, together with the programs in Kenya and Tanzania, to the establishment of the lake nutrient balance.

MATERIALS AND METHODS

Water quality and discharge measurements

This study was conducted in two major western sub-catchments of Lake Victoria namely: Bukora and Katonga situated on an extremely old Buganda surface (Figure 1). Bukora sub-catchment is drained by two rivers namely: Kisoma and Bukora. Kisoma is small micro-catchment, near the lake within Bukora sub-catchment covering 147 km2 (Majaliwa 2005). Bukora covers an area of 8392 km^2 and Katonga 15244 km^2. The topography is characterized by hills and ridges that are highly dissected by streams and drainage ways (Lufafa *et al.* 2003). The native vegetation is woodland with papyrus mart, which has been significantly modified by human activities (Lufafa *et al.* 2003). Climate is tropical wet and dry with annual precipitation of 930 mm for Katonga and 882 mm for Bukora.

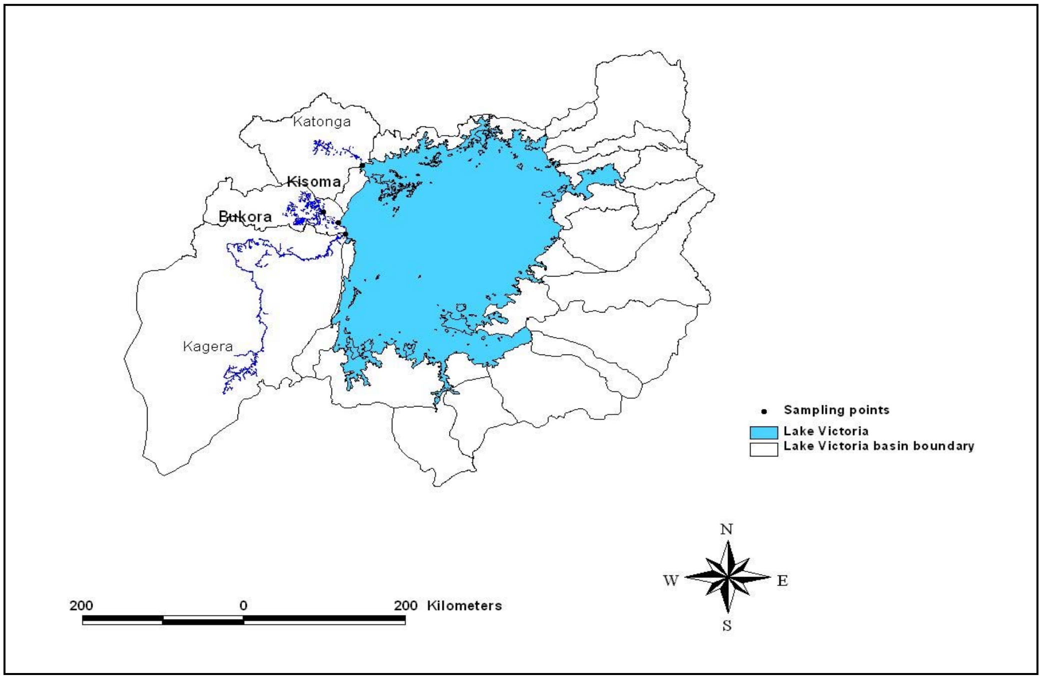

FIG. 1. Distribution of sampling point in the studied areas

Non-point pollution into Lake Victoria is of two forms: terrestrial and atmospheric. The terrestrial catchment loads were estimated for the major rivers draining each of the sub-catchment. Emphasis was laid on having simultaneous water quality and flow measurements, allowing calculation of transports of the pollutants through the river systems and in particular, the discharges into the lake. River Bukora, Kisoma and Katonga were sampled regularly from 1998 to 2004. Sampling at all sites was done once a month during the dry season, and more intensively during the growing seasons of 2000 to 2002 at Bukora and Kisoma. A total of 215 Samples were collected at Bukora, 41 at Katonga, and 77 at Kisoma. Because of the inaccessibility near shore, sampling points were located within the sub-catchment. The upstream drainage basin covered 88% and 91% of Bukora and Katonga watershed respectively.

Water analysis for pH, temperature, turbidity, electrical conductivity (EC) and total alkalinity were done *in situ*. The water samples were taken to the Water Quality Analytical Laboratory at Entebbe and analysed for Biochemical Oxygen Demand (BOD), Total Suspended Solids (TSS), Total Dissolved Solids (TDS), soluble salts (NH_4^+, NO_2^-, NO_3^-, Total N, PO_4-P, Total P (TP), Ca, K, Na, F and soluble reactive silica). Analyses were based on standard water quality analytical methods (APHA 1995). The organic matter content in sediments was considered as the difference between TSS (105°C) and TSS (500°C). For this report, only TSS, TP, TN and organic matter are presented.

Atmospheric deposition

Dry atmospheric depositions

Air samples were collected with a TE-PUF Poly-Urethane Foam High Volume Air Sampler (Tisch Environmental Inc., Ohio, USA) using the US EPA Method T04, beginning in November 1999. The sampler was set up on the northern catchment of Lake Victoria at Kakira Sugar Plantation and Entebbe at Water Resources Management Department. About 250 m^3 of air was drawn periodically through the sampling unit over a 24 h cycle. Minimum and maximum temperature, and wind direction were also recorded during sampling. The samples were shipped to the National Water Research Institute, Canada for analysis. Detailed analytical procedures are described elsewhere (Environment Canada 1999; Karlsson *et al.* 2000). The PUF plugs were extracted using a soxhlet apparatus with hexane or hexane/dichloromethane in a 1:1 ratio. Extracts were evaporated, the solvent changed to isooctane, and then further evaporated with nitrogen. Fractionation of samples was by column chromatography with either neutral silica (activated) or florisil (1.2% deactivated) eluted sequentially with mixtures of hexane and dichloromethane (Environment Canada 1999). Samples were evaporated to 1.0 ml with nitrogen.

Analysis was performed by gas chromatography (GC) with ^{63}Ni electron capture detector (ECD) as described by Environment Canada (1999). Enantioselective analysis of α-HCH was performed with a GC with a mass selective detector (MSD). Mass spectrometric and GC inlet conditions are described elsewhere (Muir *et al.* 1999). The instrumental detection limit for the organochlorine compounds was 0.1 pg m^{-3} (Hoff *et al.* 1992).

Wet atmospheric depositions

Samples were collected using a NWRI Organic Precipitation Collector. The sampler opens and closes automatically when moisture contacts the heated sensor. The collector consists of a stainless steel funnel of 0.2 m^2 area which drains into a wetted Teflon column packed with XAD-2 resin. The XAD-2 resin removes the organics from the precipitation as it passes through the column by gravity flow. The column is kept wet by use of a U-tube at the column outlet. The collection columns (fresh or used) were kept in a refrigerator. Rainfall data was collected using a recording rain gauge.

Estimation of total loads

Loads of sediments and nutrients were computed as the product of the concentration by the flow at that date. The total annual load was estimated as the sum of the atmospheric deposition and the load from the terrestrial catchment. Terrestrial input was corrected for the ungauged part of the sub-catchment basing on the assumption that they equally contributed to the loads.

The wet atmospheric deposition loads over the lake were estimated as a product of the concentration by rainfall amount at that date. The lake was subdivided into three major isohyetal boxes (Box 12: Bukasa, Box 13: Entebbe, and Box 14: Lolui) (see Figure

2). The data was grouped per river, year and season [long rains (March 15th to June 30th), short rains (1st September to 15th December) and dry season (1st July to 30th August then 16th December to 14th March)], and analysed using General Statistics Software (Genstat) (Payne *et al.* 1993) using the least significant (LSD) for mean separation. Multivariate analysis (factor analysis, regression and correlation) was performed on the terrestrial loads to determine the temporal and spatial trends.

RESULTS

Average overall concentrations and loads

Table 1 shows the overall average TSS, OM, TN and TP levels in the three rivers (Bukora, Katonga and Kisoma). Data presented are six-year means. Mean TSS (105°C), TN, TP and OM varied from 19.0 to 305.0 mg/l; 0.82 to 4.03 mg/l; 0.21 to 0.23 mg/l; and 7.5 to 75.6 mg/l respectively. The TSS, OM and TN concentrations were stream dependent. River Bukora maintained significantly higher concentrations of TSS and OM compared to the other two streams, while River Katonga had the lowest ($P<0.01$). Conversely, TN concentration was highest for Katonga and lowest for Bukora ($P<0.01$). The TP values for the three streams were not significantly different.

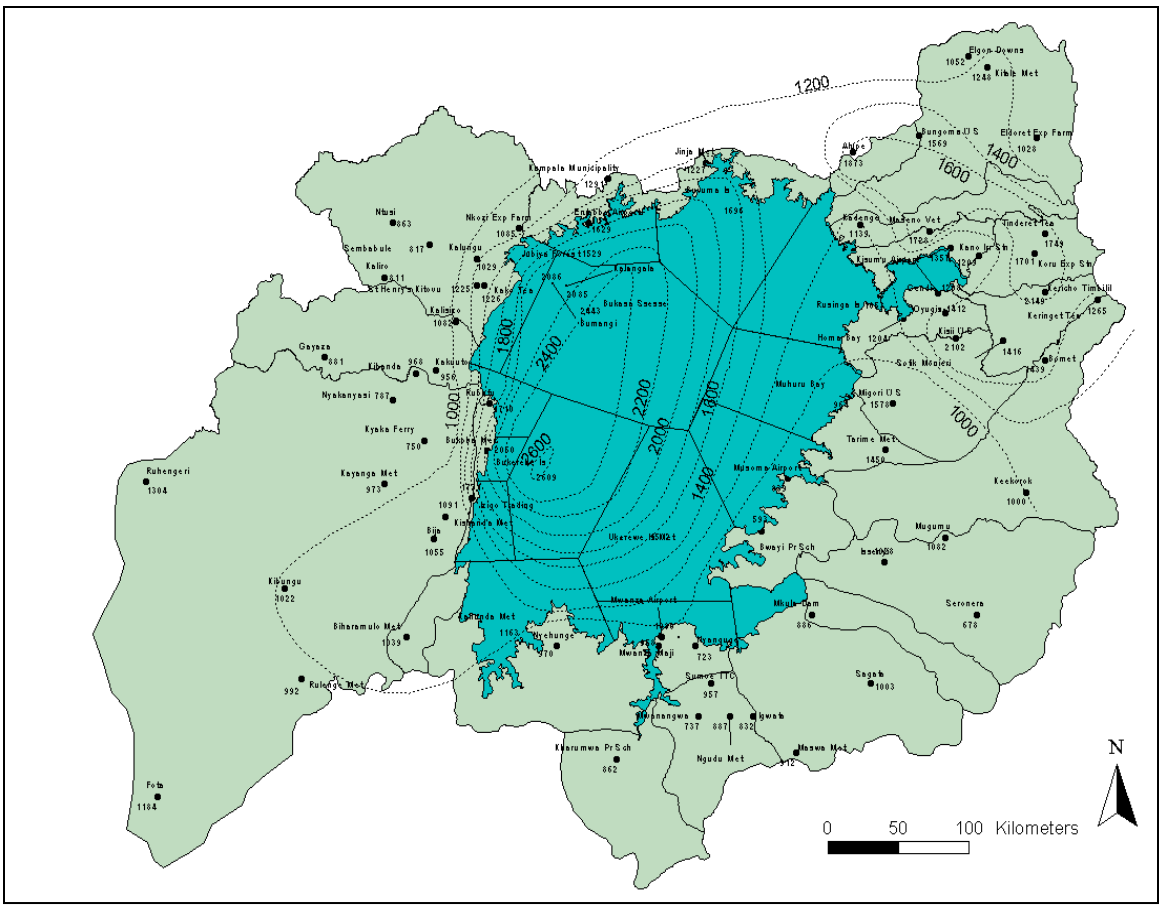

FIG. 2. Rainfall isolines and isohyets boxes in Lake Victoria

TABLE 1. Differences in selected water quality parameters as observed in the three streams (6-year means).

Stream	TSS (105°C)	TSS (500°C)	OM (mg/l)	TN (mg/l)	TP (mg/l)
Bukora	305.0	229.1	75.6	0.82	0.21
Katonga	19.0	11.8	7.5	4.03	0.21
Kisoma	202.0	150.7	51.7	1.18	0.23
LSD(0.05)	54.5	42.2	17.9	1.34	NS

Overall, Bukora maintained significantly higher flow rate over the six years than the other two streams ($P<0.05$), with Kisoma, which is a much smaller stream, having the lowest flow (Table 2). Correspondingly, TSS (105^{o}C), TSS (500^{o}C) and OM loads were significantly higher for Bukora and lowest for Kisoma ($P<0.05$). Mean TP load was slightly higher for Bukora than that of Kisoma ($P<0.10$) while TN loads for the three streams were not significantly different.

TABLE 2. Main effect of difference in stream on flow and pollutant loads (6-year means).

Stream	Flow (m^3/s)	TSS (105°C)	TSS (500°C)	OM (ton/day)	TN (ton/day)	TP (ton/day)
Bukora	7.04	129.9	63.3	21.3	0.76	0.25$^{\#}$
Katonga	2.31	9.1	5.9	7.4	1.06	0.07
Kisoma	0.54	5.9	3.4	1.1	0.07	0.01
LSD(0.05)	3.25	49.6	12.7	10.7	NS	0.21

$^{\#}$ Significant difference at $P<0.10$.

Annual trends of pollutant concentrations and loads

Mean annual TSS concentrations fluctuated irregularly during the 6 years of this study, with peak values observed in the year 2000 for Bukora, 2001 for Katonga and 2004 for Kisoma (Figure 3). Total suspended solids followed a polynomial trend in time of 5th order. The lowest values for TSS concentration occurred in 2002 for all three streams. These variations were statistically significant for Bukora and Kisoma ($P<0.05$), but not for Katonga. Like TSS, organic matter (OM) concentrations fluctuated irregularly across years, however, concentrations were overall not statistically different (data not presented). Figure 4 is a plot of variation in concentrations of OM with TSS (105^{o}C) for all three rivers. OM increased linearly with TSS (105^{o}C). This relationship was also found to be true for individual streams. The relationships were described by:

$OM = 0.2561*TSS - 0.307$; $R^2=0.75$ ($P<0.05$), (all streams)
$OM = 0.3415*TSS - 27.95$; $R^2=0.59$, ($P<0.05$), (Bukora), and
$OM = 0.2313*TSS + 7.264$; $R^2=0.69$, ($P<0.05$), (Kisoma)

There was a progressive increment in TN concentrations for Bukora and Kisoma over the six years of monitoring, with peak TN values observed in 2003. This increment was statistically significant for Kisoma ($P<0.05$) but not Bukora or Katonga. A significant linear relationship was also observed between TN and TSS (500^{o}C): TN = 0.0034*TSS – 0.3074; R^2=0.4425, $P<0.05$ for Bukora (Figure 5) and TN = 1.765*TSS + 0.2105; R^2=0.75, $P<0.05$ for Katonga (Figure 6). However, for Kisoma, the relationship showed significant dependence on season (see section on seasonal trends).

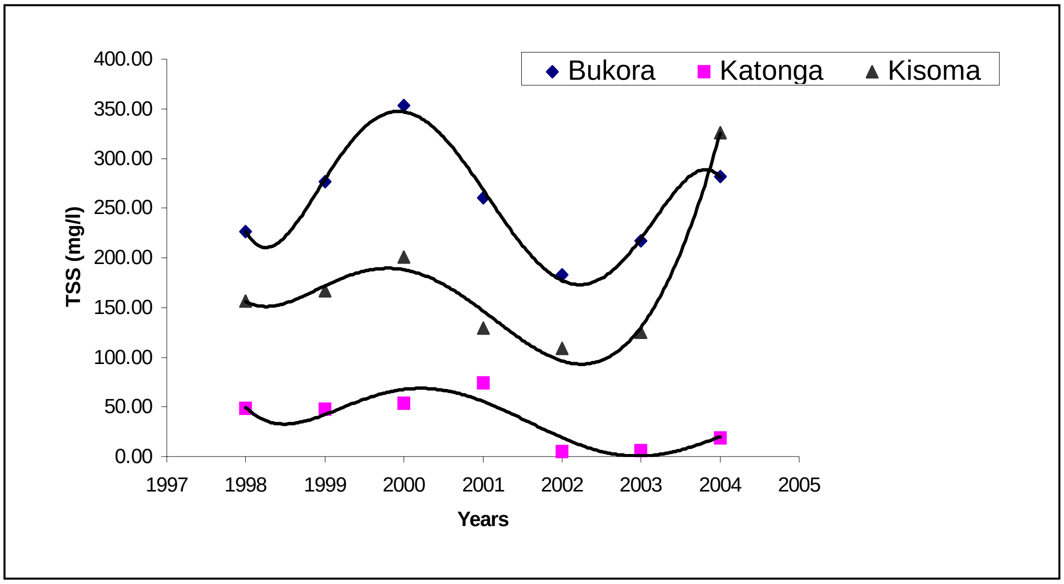

FIG. 3. Change in TSS (105^{o}C) level in three rivers of the Uganda Lake Victoria catchment.

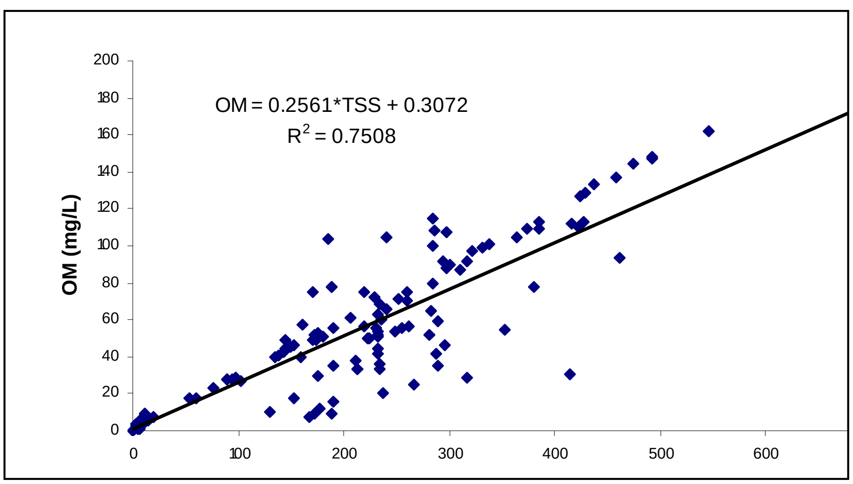

FIG 4. Loss on ignition (organic matter) as a function of TSS for all the three rivers (Bukora, Katonga and Kisoma).

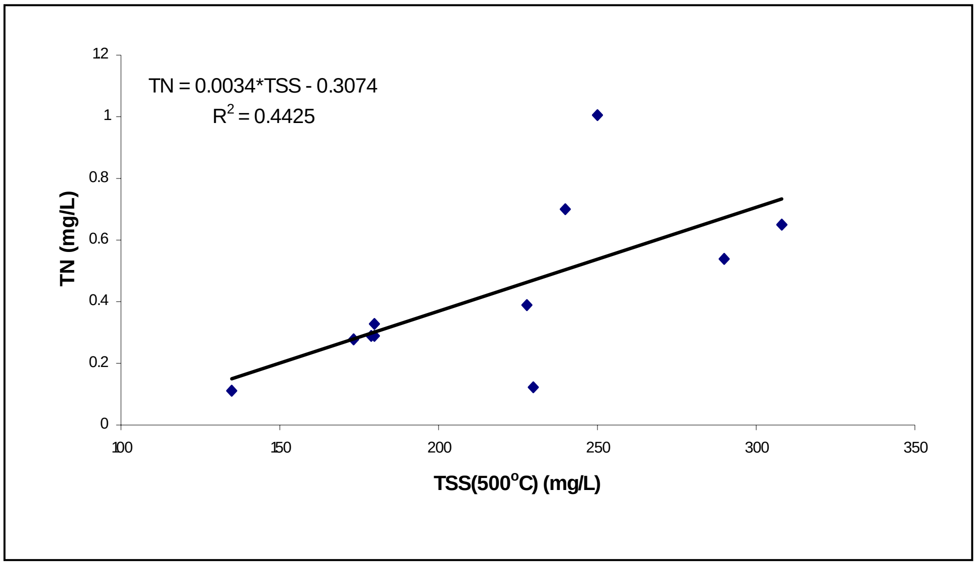

FIG. 5. Total N as a function of TSS (500°C) levels for River Bukora.

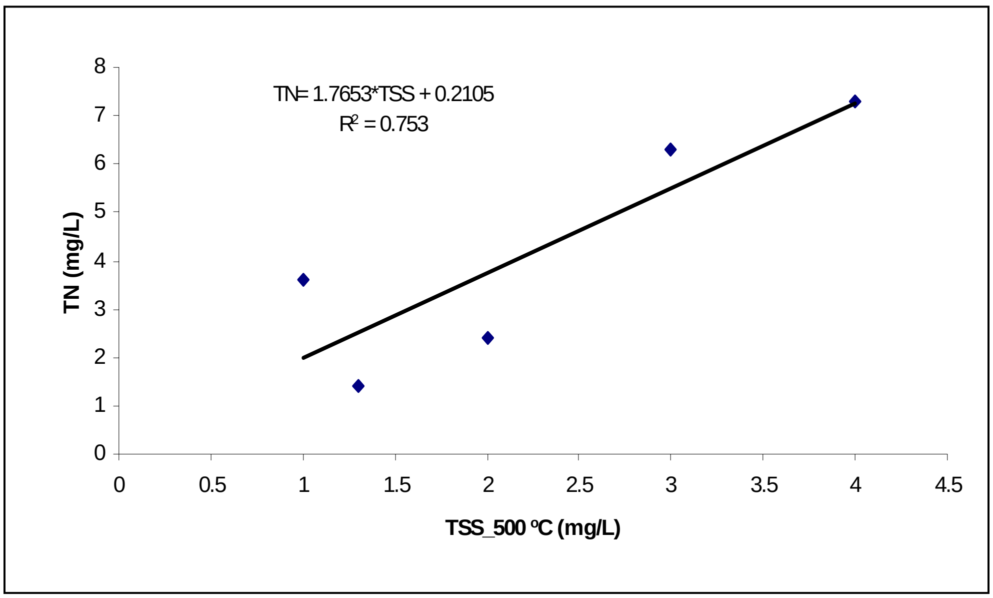

FIG. 6. Total N as a function of Total Suspended Solids (500°C) level for River Katonga.

There was an overall linear increment in TP concentration for all three sites over the six years, with the lowest TP values observed in 1998. However, individual TP mean values were overall not significantly different ($P>0.05$). The TP concentration was positively correlated with TSS (500°C): TP = 0.0011*TSS – 0.022; R^2=0.45, $P<0.05$ for Kisoma (Figure 7). However, this relationship was not significant for other streams.

Concerning the loads, the six years trend of TSS (105 and 500 °C), and OM was similar in Bukora, while no variation was observed for all the parameters in Katonga ($p<0.05$). TSS (105 and 500 °C) and OM loads fluctuated over the years, with peaks occurring every two years after 1998. Figure 8 shows the trend of TSS 105 °C loads over the six years in Bukora.

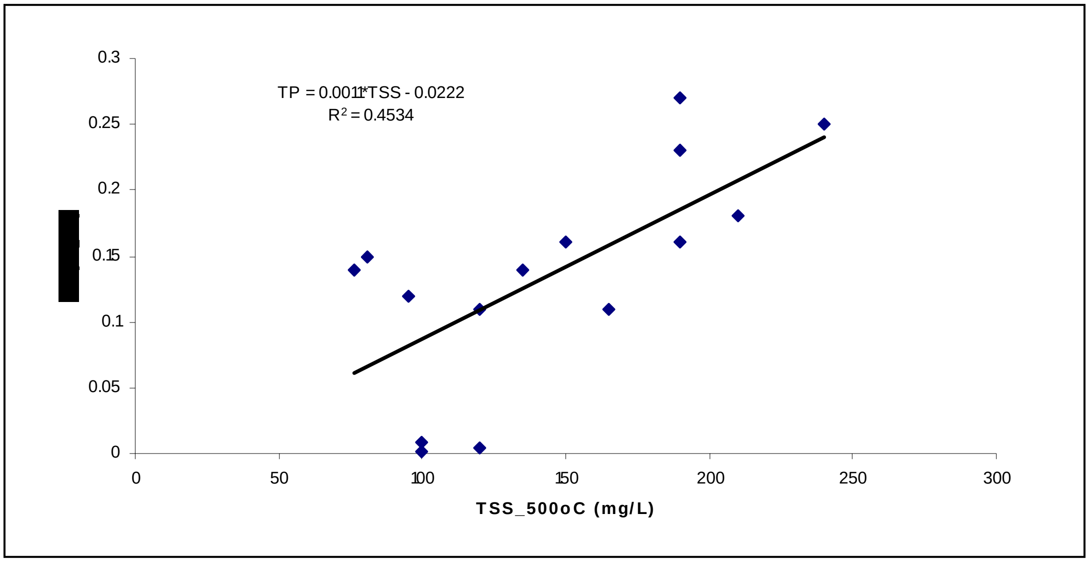

FIG. 7. Total P as a function of Total Suspended Solid (500°C) levels for River Kisoma.

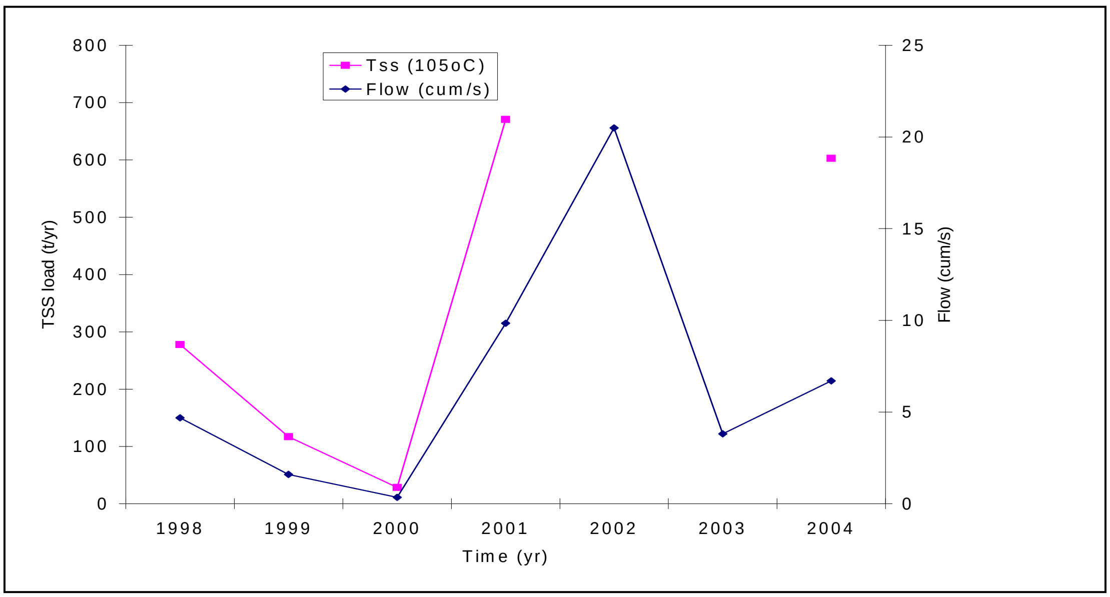

FIG. 8. Variation of TSS load (105 °C) with time and flow, River Bukora.

Seasonal trends of pollutant concentrations and loads

Table 3 presents data for seasonal effects on the flow and concentrations of different parameters. Data presented are mean values for the three rivers, averaged over a 6-year period. Overall, flow was highest during the long rains season (March 15^{th} to June 30^{th}) and lowest during the short rains (1^{st} September to 15^{th} December), although the differences in flow were not statistically significant across different seasons. Conversely, TN concentrations were highest during the short rains (periods of lowest flow) and lowest during the long rains ($P<0.05$). However, these seasonal differences were not significant for TSS, OM and TP.

Table 3. Seasonal concentrations of pollutants (6-year means).

Stream	Flow (m^3/s)	TSS (105^oC)	TSS (500^oC)	OM (mg/l)	TN (mg/l)	TP (mg/l)
Dry period	3.00	163.8	147.2	51.2	2.03	0.21
Long rains	4.94	140.8	119.4	44.8	0.95	0.28
Short rains	1.99	165.4	119.1	60.0	3.05	0.14
LSD(0.05)	NS	NS	NS	NS	1.34	NS

It is worthwhile to note that the effect of flow on water quality parameters was site and season dependent ($p<0.05$). Generally, the flow had moderate and significant linear relationship with TSS (105^oC), OM and TSS (500^oC) in Bukora. It was low or insignificant for Kisoma and Katonga. Figure 9 shows the seasonal variation of TSS (105^oC) with flow (only data for Bukora is presented). The correlation between TSS (105 ^oC) and flow was strong during the long rains for Kisoma and Bukora (R^2 = 0.51; R^2 = 0.49 respectively), and moderate or low for the other periods. TSS (105 ^oC) decreased with flow for Kisoma and Bukora.

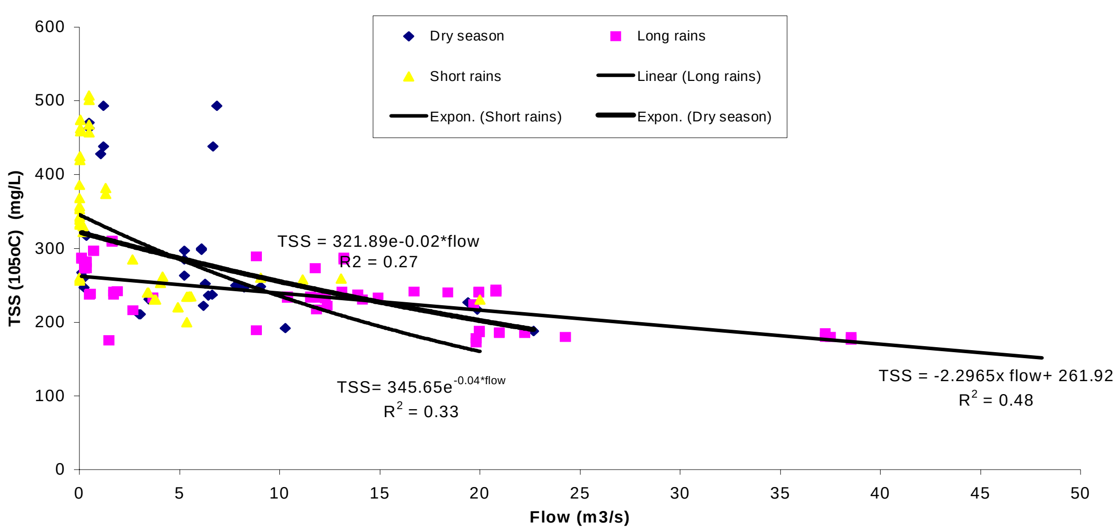

FIG. 9. Variation of TSS (105^oC) levels with flow for different seasons for Bukora

In general the seasonal relationship between flow and TSS (500°C) , TN, OM and TP with flow was low or insignificant especially for Kisoma and Katonga. Concerning TN and TP the only dependence with flow was observed in Bukora. TN decreased with flow during the dry season in Bukora (R^2=0.60) ($p<0.05$). TP increased moderately with flow during the long rains, and decreased exponentially with it for the two other seasons ($p<0.05$). Organic matter was independent of flow for all seasons and all rivers ($p=0.05$).

TN decreased significantly with TSS (500°C) during the wet season, (TN = -0.0016*TSS + 0.487; R^2=0.760, $P<0.05$) while for the dry season, no relationship was observed (Figure 10).

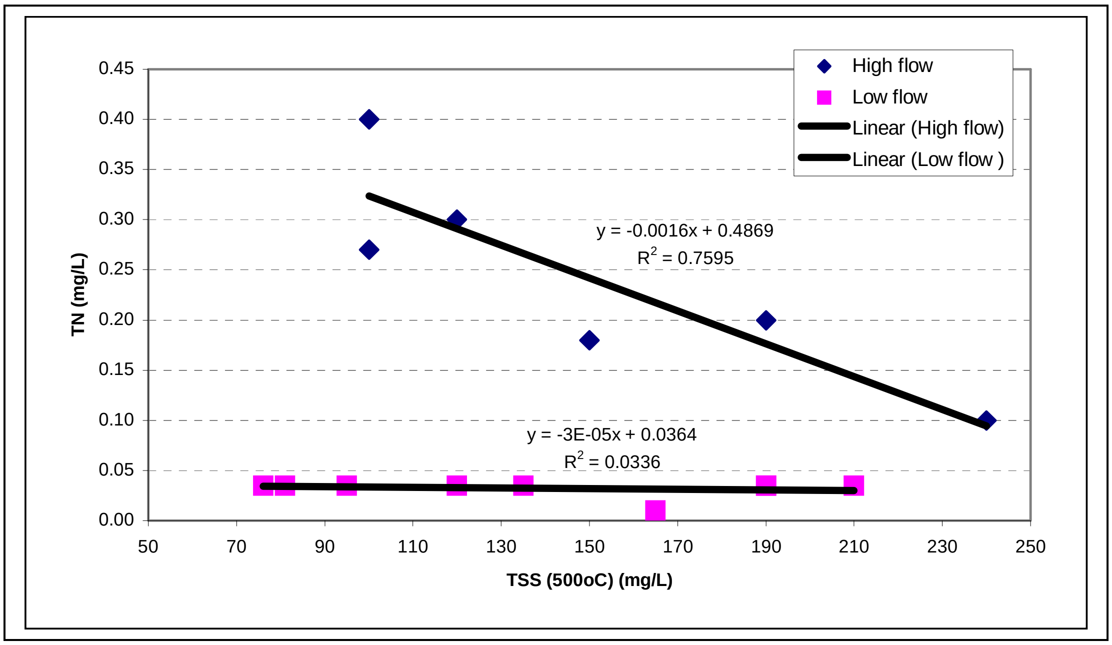

FIG. 10. TN as a function of TSS (500°C) levels for River Kisoma.

Table 4 presents data for pollutant loads as affected by differences in seasons. Data are means of three streams, averaged over a 6-year period. The TSS (500°C) load was highest during the long rains (season of highest flow) and lowest during the short rains ($P<0.10$). However, these seasonal differences did not significantly affect OM, TN and TP loads.

TABLE 4. Main effect of seasonal differences on the pollutant loads (6-year means).

Season	TSS (105°C)	TSS (500°C)	OM (ton/day)	TN (ton/day)	TP (ton/day)
Dry	47.6	19.7#	10.2	0.39	0.06
Long rains	67.7	40.7	14.7	0.76	0.24
Short rains	29.5	12.1	4.9	0.74	0.03
LSD(0.05)	NS	12.7	NS	NS	NS

Means are significantly different at 10% level.

Total loads

The average catchment loads for the different water quality parameters is presented in Table 5. The export per unit area is relatively higher in Bukora sub-catchment compared to Katonga. The export of TN, TP and TSS from Bukora was one and half times greater for TN, six times for TP and about thirty times greater than the corresponding value from Katonga.

TABLE 5. Average annual loads of total nitrogen, total phosphorus and suspended solid from the catchment and atmospheric deposition.

Source	Location	TN	TP	TSS
		Kg/yr/km^2		
Catchment	Bukora	41.0	12.8	6702.8
	Katonga	27.8	1.8	238.4
Wet atmospheric deposition	Box 12	1038.5	141.9	2534.2
	Box 13	1897.7	159.7	3726.8
	Box 14	469.9	207.8	4281.2

Table 6 shows the total load from the different sources of pollutants in Uganda, excluding the northern shore streams. Results show that most of the load is coming from the atmosphere for nutrients (TP and TN), the catchment contribution being of only 7% for TN and about 5% for TP.

TABLE 6. Total load into Lake Victoria.

	Source	TN	TP	TSS
		t/day		
Input	Catchment	2.1	0.29	154.1
	Atmosphere	26.4	5.6	116.1
Output	River Nile	388.2	21.7	No data

DISCUSSIONS

In light of the above results the quality of water in rivers draining the Uganda catchment of Lake Victoria varied significantly across seasons, years and from one sub-catchment to another. These differences are attributed to a number of factors, including the size of the sub-catchments and their response time, the nature of the river, topography, climate, type and distribution of different land-use and their management, and type and distribution of soils.

Bukora and Katonga drain from relatively wider catchment, meaning that most of the river discharge measured reflect multitude of conditions even in the far upstream position. This is reflected in the observation that downstream flow was somewhat higher during the dry season than in the short rain season (Table 2). Previous studies indicated, in fact, that discharge at Bukora stream actually reached the peak in July, during the dry season (Semalulu *et al.* 2003) indicating a response time of about a month. The response lag for Katonga is relatively higher because of the wetland nature of this river (Okonga, personal communication). Bukora is not covered by vegetation throughout the year. As a consequence, much of the sub-catchment contributions are gradually filtered as water flows, most especially for Katonga. The tide induced by vegetation in wetlands increases with flow, promotes sedimentation, and increases their effective area and retention time, thereby improving chelation opportunuities (McClain *et al.* 1994; Brandes *et al.* 1996). Sedimentation has been reported to be significant for the retention of nitrogen (McElroy 1978) and metals, except manganese and nickel (McElroy 1978). This explains partly why TSS concentration reduces with flow for all rivers even during the wet seasons and the variability in TP and TN.

Seasonal changes in sediment and particle size can also explain the variation of nutrients especially TP. Concentrations of sediments, TN and TP reduced as flow increased within a season reducing the strength of the association between flow and other the parameters studied. However, the high load of sediments and nutrients during the dry period is explained by high flow from further areas of the catchment and the fact that dry season is not always markedly defined. The dry season is often interrupted by sporadic storms, which in turn contribute to unexpected flow. The existence of vegetation in the rivers masked the impact of climatic variability on the flow on both Katonga and Kisoma.

The difference in the loads between Bukora and Katonga may also be attributed to the difference in sizes. According to Oyebande (1981) catchments in Nigeria below 10,000 km^2 can yield up to eight times more sediment per unit area than those whose size is greater than 10,000 km^2. In Lake Victoria, Bukora (8,392 km^2) exports 30 times more sediments than Katonga (15,244 km^2). It is believed that smaller catchments are generally steeper, and so tend to exhibit higher specific sediment yields. Bukora has many rounded and flat topped hills, with slope steepness reaching 30^o (Langdale *et al*. 1964; Ssali and Isabirye 1998) while Katonga is made of plateaus with relatively lower steepness, which controls differently the transfer of sediments and nutrients into aquatic ecosystem through its influence on the spatial pattern and temporal pattern of stream flow generation processes (Langdale *et al*. 1964; Ambroise 1990; Anderson and Harding 1991; Lufafa *et al*. 2003).

The impact of land use on water quality is readily inferred from the vast accumulation of literature (Sonzogni *et al.* 1980; Smith *et al.* 1989; Sharpley *et al.* 1990; Young *et al.* 1996). There is good correlation between soil type and land-use/cover distribution in both sub-catchments (Tenywa *et al.* 1999), although Bukora sub-catchment soils are very rich in phosphorus and organic matter compared to those of Katonga (Majaliwa 2005; Mulebeke 2004). Generally, perennial crops are grown on deep soils, while rangelands, which generate most of the runoff, are established on very shallow soils of ridge summits. In the catchment, degraded rangelands have been identified as hot spot areas for sediments and nutrients exports (Majaliwa *et al.* 2004). The distribution and the cover status of this particular land-use are different for both catchments. Experimental measurements have demonstrated that in the two sub-catchments, soil loss in Bukora from rangelands was about twenty times the value recorded in Katonga mainly because of poor ground cover in Bukora sub-catchment (Magunda *et al*. 2003; Majaliwa 2005; Mulebeke 2004).

Land-use management is perhaps the most important factor amplifying soil erosion (El-Swaify 1982; AID 1988; Meybeck *et al.* 1989; Zake and Nkwuine 1995). It was observed that Lake Victoria catchment rivers passing through forested lands were less enriched by nutrients as compared to those crossing agricultural lands. In the Lake Victoria catchment, land-use types highly susceptible to erosion, are still located on very steep slopes, and are more often coupled with poor land management, such as lack of erosion control structures, overgrazing, and burning (Tenywa *et al.* 1999; Magunda and Majaliwa 2002). Studies have demonstrated that atmospheric deposition load increases are associated with increased burning and soil erosion in the catchment, emphasizing the role played by the land-use systems and management in the deterioration of the quality of the Lake Victoria and its tributaries (Cole *et al.* 1993; Peierls *et al.* 1991; Field-Juma *et al.* 1995). Bukora being an area with intensive livestock management, the difference in the levels and loads of pollutants with Katonga could also be attributed to mismanagement of animal waste associated with open grazing (Semalulu *et al.* 2003). Although there was no clear increasing trend in TSS overtime, TP slightly increased over the years indicating changes in sub-catchment exports. These changes reflect increasing land-use/cover and soil degradation in the two sub-catchments.

Atmospheric deposition remains the major contributor of TN and TP loads into Lake Victoria. TP and TN from the atmophere arise from several local and regional sources. The major sources of nitrogen, in the atmosphere include burning of fossil fuels and forests, volatilization from feed lots and fertilizer fields. Phosphorus deposition may also arise from phosphorus rich soil particles originating from fertilized and exposed agricultural fields or heavily grazed lands.

The preliminary study by LVEMP (2002) overestimated TN exported per unit land for both sub-catchments and underestimated TP for Bukora. The difference is attributed to the number of observations (measurements) used to estimate these parameters and the working assumptions made due to lack of data. For example, export coefficients were assumed to be unique for a given land-use/cover without taking into account the location, topography, management and rainfall erosivity of that location.

CONCLUSIONS AND RECOMMENDATIONS

The assessment of sediment and nutrient loads has revealed seasonal and annual variations between rivers draining the Uganda catchment of Lake Victoria from 1998 to 2004. Bukora sub-catchment had relatively high flow and higher concentrations of TSS, OM and TN, and therefore higher loading of sediments and nutrients compared to Katonga sub-catchment. The contribution of the catchment load into the lake is relatively small compared to atmospheric deposition, and did not exceed 10% of the total load. It is therefore recommended that:

- Non-point pollution loading be controlled in the catchment, by adopting best management practices, which have been identified, including contour bunds, mulching and afforestation of bare and degraded hills and other marginal lands which are potential sources of sediments and nutrients into the lake. These practices have also been shown to improve the productivity of farm plots and so the benefits accrue to the farmer as well as the lake.
- Sensitization of people within the catchment on the use of best management should intensify, in order to increase the rate of adoption of these technologies ; and therefore reduce ‘ flushier loads ‘ and flash flooding. Priority should also be given to marginal land cropped to annuals and degraded hillsides which are potential sources of runoff, soil and phosphorus.
- Activities leading to an increase in atmospheric deposition such as burning and overgrazing should be controlled in the catchment.
- There is need to rehabilitate, protect and improve the quality of wetlands in the catchment, in order to further reduce the load of nutrients into the lake.
- Harmonization of regional policies on best management practices should be developed and enforced.
- Monitoring of the northern shore streams should be initiated in order to estimate the contribution of this sub-catchment, and the whole catchment into the lake and monitor improvements in water quality as expected with better land management practices.
- There is need of more data to improve on the load estimates both from land and atmosphere. In particular dry deposition and wet deposition measurements need to be increased in number to provide more confidence in the estimates.
- If capacity is a constraint in the laboratory, priority should be given to the analysis of TN, TP and TSS.

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