Non-point Source Pollution into Lake Victoria from Bukora, Uganda Sub-catchment

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Abstract

Non-point source pollution from agricultural land is a major contributor of N, P and sediments resulting into eutrophication and siltation of water bodies. The extent of this pollution is accelerated by poor land management practices that lead to extensive soil erosion. Pollutant concentrations and loads from two micro-catchments of Bukora sub-catchment, a predominantly agro-pastoral area of Rakai district, were studied over a three-year period. The two micro-catchments are drained by two rivers, which eventually discharge into Lake Victoria. Three hydrological stations were constructed onto the two rivers and water sampling and river discharge measurement routinely carried out. During the study period, highest rainfall amounts were recorded in April, while peak river discharge (flow rate) occurred during July, signifying a 3-months ground recharge period. Concentrations and loads of Total N (TN) and Total P (TP) were related to Total Suspended Solids (TSS) indicating the contribution of N and P-rich sediments to N and P loading. Seasonal trends in TSS, TP and TN concentrations and loads were closely related to river discharge. Mean annual concentrations for TN ranged from 3.2 to 10.4 mg L^{-1} with loads of 40 to 70 ton yr^{-1}. Annual means for TP ranged from 0.2 to 0.4 mg L^{-1} with loads of 4 to 51 ton y^{-1}, while TSS ranged from 12 to 94 mg L^{-1} with loads of 2 to 40 ton yr^{-1}. Concentrations and loads of TSS, TN and TP were reduced across a wetland, especially during periods of low flow. High sediment, N and P pollutant concentrations and loads are likely a result of extensive soil erosion in the area. Results call for promotion of better land management practices so as to reduce non-point pollution of rivers and consequently, lake Victoria.

Keywords: Eutrophication, Water quality, Watershed management, Wetlands.

INTRODUCTION

Non-point source pollution from agricultural land is a global issue that impacts aquatic environments in various ways. According to Ongley (1996), sediments cause siltation and the adsorbed phosphorus, pesticides, organic compounds and heavy metals may destroy aquatic habitats. Sediments carried in runoff water cause turbidity and reduce in-stream photosynthesis; nutrients stimulate algal growth and accelerate eutrophication. Elevated nutrient levels also promote growth of water hyacinths. Where such runoff comes from irrigated agricultural fields, salts and pesticides contaminate surface water. For Lake Victoria, 56% of the N and P loading is attributed to non point source pollution (LVEMP, 1994). Water pollution due to urban runoff can also seriously impact water quality. Development of urban centres reduces effective land surface available for water seepage and infiltration, leading to accelerated runoff. Disposal of untreated industrial wastes and raw sewage into water contributes directly to water pollution. Carpenter *et al.,* (1998) observed that water pollution from urban centres increases with level of population but cautioned that while industrial and municipal pollution sources can be controlled, non-point source pollution presents the greatest challenge.

Soil erosion control has been the major focus of most agricultural best management practices (BMPs) for non-point pollution. Logan (1993) identified BMPs to include structural, cultural or management practices. Structural practices such as construction of terraces and grassed waterways reduce runoff, increase infiltration and reduce soil erosion. Cultural practices such as conservation tillage, contour cropping and mulching protect the soil surface and reduce erosion. However, Logan (1990) observed that these practices may or may not increase infiltration, depending on soil physical properties such as hydraulic conductivity. Management practices (e.g. for fertilizer, pesticide, livestock and more generally, integrated pest and soil fertility management) affect the source of a potential contaminant/ pollutant by increasing their use efficiency.

Phosphorus is a potential source of pollution and is likely to come from excess manure accumulation from high cattle population areas such as the districts of Ntungamo and Mbarara. According to Chokmani and Gallichand (1997), water quality in a watershed dominated by animal production in Canada was related to land use practices, particularly the intensity of animal production. Shirmohammadi *et al.,* (1997) reported that the major cause of non-point pollution in an area with diverse land use was mismanagement of dairy manure.

Uncontrolled grazing and lack of fencing around stream channels in the watershed with dairy operations may result in direct deposition of animal waste into the stream causing elevated concentrations of N and P. Indeed, phosphorus enrichment into surface water bodies and eutrophication from non-point agricultural pollution sources (such as runoff) pose a major threat to ecological health globally. Calamari *et al.,* (1995) observed extremely high phosphorus loads in eight rivers of the Winam Gulf in Lake Victoria, Kenya, and noted that eutrophication was expected to become worse. Baker (1993) observed that non-point pollution was a major cause of eutrophication in Lake Erie and indeed much of agricultural land in the United States. The BMPs are aimed at reducing environmental pollution effects (e.g. P and sediment loading) into water bodies.

Deterioration in water quality and accelerated nutrient levels in rivers draining into Lake Victoria have lead to a recent proliferation of water hyacinths, algal bloom and eutrophication of Lake Victoria waters and consequently, a threat to the lake fisheries. The objective of this study was to quantify major pollutants in the two rivers: Kibaale and Kisoma, that drain the Bukora sub catchment, a part of the Kagera pilot zone of Lake Victoria catchment. In this study the impact of current land use practices on water quality was monitored through its impact on seasonal concentrations and loading of major pollutants.

MATERIALS AND METHODS

This pilot study was located in Kyotera and Kakuuto micro-catchments of Rakai district (Fig. 1). The two micro-catchments amount to 2,100-km^2 total area and are part of the Kagera pilot zone of the Lake Victoria basin. The study area is predominantly an agro-pastoral zone characterized by extensive deforestation, bush burning and poor farming practices, leading to a range of environmental problems such as reduction in soil cover, severe soil erosion and extensive water pollution.

To study the impact of current land use practices on water quality, three hydrological stations were established as river sampling sites in 1998 in the two micro-catchments. Two of these stations (Kibaale and Bukora) are located on the same river, with Bukora being located down stream (Fig. 1).

This river flows from predominantly pastoral districts of Mbarara and Ntungamo, in south-western Uganda. Data collection commenced in July 1998 at each hydro-station. The water height in the river was recorded twice a day (9 a.m. & 3 p.m.). To monitor water quality and quantify pollutant loading in rivers, water sampling and river discharge at the three hydro-stations were carried out monthly. However, during the heavy rain season, weekly water sampling was carried out to obtain a better characterization of water pollutants. Water analysis for pH, temperature, turbidity, electrical conductivity (EC) and total alkalinity were done *in situ*. 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 and soluble reactive silica) were carried out at the Water Quality Analytical Laboratory, Entebbe, using standard water quality analytical methods (APHA, 1995; Anonymous, 1980). Pollutant loads were calculated by multiplying the average pollutant concentration by the corresponding river discharge/flow rates.

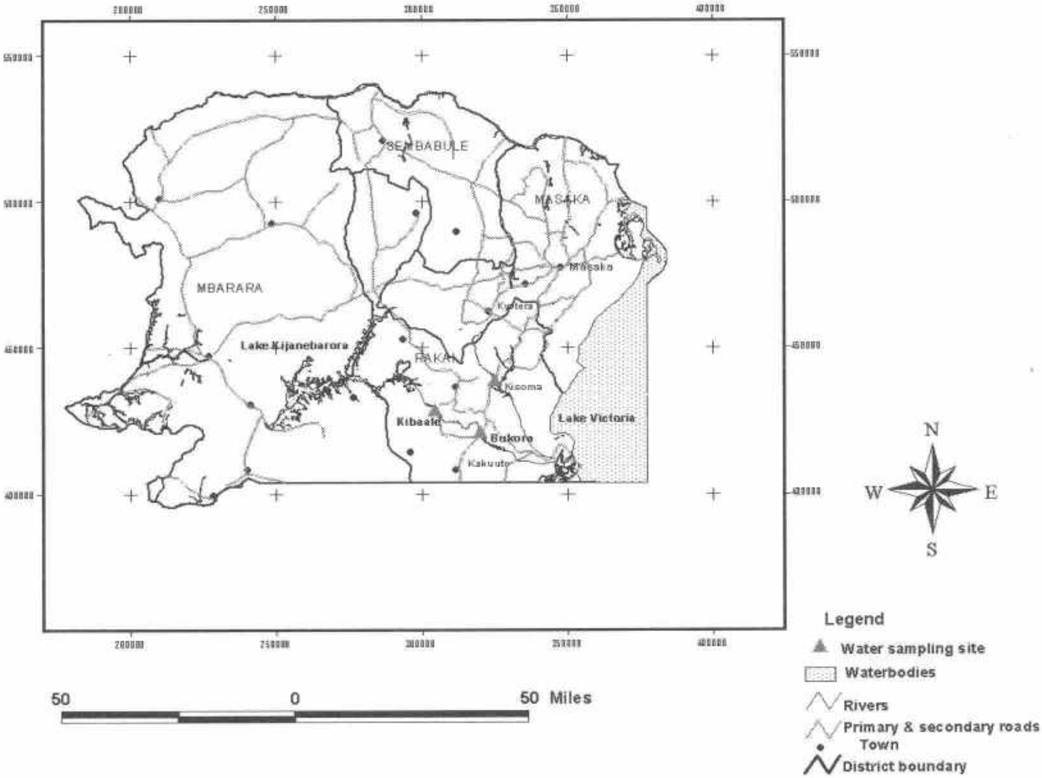

Figure 1. Location of experimental sites in Rakai district of south Uganda

RESULTS AND DISCUSSION

Variations Among Sites

Table I presents a summary of the variation in different variables by site. Values are averages of three years. Bukora had the highest flow rate and correspondingly, the highest loading of nitrate (NO_3^-), total N (TN), phosphate and total P (TP) compared to Kibale and Kisoma, with Kisoma having consistently low numbers, including Total Suspended Solids (TSS) load and EC. Higher flow rate and loading of various parameters than those of Kibale, signifies a contribution due to runoff from the Bukora micro-catchment. However, Kibale had higher phosphate (PO_4), TN and TSS concentration in water than Bukora, indicating that even though water entering Kibale may be more polluted with PO_4, TN and TSS, the concentration of these pollutants is lowered as the river flows from Kibale to Bukora. However, TN concentrations for Kibale and Bukora were not significantly different.

Table I. Water quality parameters at the three hydrological stations#

Parameter	Bukora	Kibale	Kisoma
Rainfall (mm)##	883	1002	834
Flow rate (cumecs)[1]	2.33a[2]	1.97a	0.43b
pH	7.07b	7.42a	6.80b
EC (uS cm^{-1})	272a	260a	247b
Concentration (mg L^{-1})			
Nitrate	0.17a	0.12ab	0.031b
Total N	6.10ab	7.95a	3.71b
PO_4-P	0.17b	0.23a	0.18ab
Total P	0.34a	0.36a	0.36a
TSS	55.6b	73.9a	17.8c
Load (ton d^{-1})			
Nitrate	0.074a	0.027b	0.004b
Total N	1.71a	0.84b	0.12c
PO_4-P	0.047a	0.036a	0.005b
Total P	0.06a	0.04ab	0.01b
TSS	15.3a	11.4a	0.79b

Values are averages of 3 years.

Rainfall figures are averages of 3 years 98/99, 99/00 and 2000/01.

[1] Flow rate (discharge) reported as cubic metres per second (cumecs).

[2] Means of the same variable followed by the same letter across different sites are not significantly different (P<0.05).

Kibale

Table II presents a summary of the variations in different parameters across years, for Kibale site. This site had much higher rainfall in 2001/02 compared to other years. However, this did not translate into higher flow rate since much of the flow recorded at Kibale is more of a reflection of the situation in other areas traversed by the river eg. Mbarara and Ntungamo districts. In fact, flow rate was higher in 1998/99 compared to other years, and this translated into higher loads for NO_3^-N, TN, PO_4^-P, TP and TSS and conversely, lower concentration values for TN and TP. However, concentrations for NO_3^-N and PO_4^-P were not significantly different between years, while that of TSS was actually lower in 2000/01 than other years. On the other hand, pH was higher in 1998/99 than 1999/00 and 2000/01.

Table II. Variation in water quality parameters at Kibale

Parameter	98/99	99/00	00/01
Rainfall (mm)[1]	737	940	1328
Flow rate (cumecs)	5.88a[2]	0.27b	1.69b
pH	7.92a	7.27b	7.12b
Concentration (mg L^{-1})			
Nitrate	0.13a	0.05a	0.17a
Total N	4.36b	10.43a	5.47ab
PO_4-P	0.17a	0.29a	0.23a
Total P	0.24b	0.38ab	0.44a
TSS	94.1a	92.1a	22.1b
Load (ton d^{-1})			
Nitrate	0.61a	0.002b	0.02b
Total N	2.08a	0.22b	0.83b
PO_4-P	0.069a	0.005b	0.039a
Total P	0.11a	0.01b	0.06b
TSS	39.2a	1.8b	3.1b

[1] Rainfall figures are annual totals.

[2] Means of the same variable followed by the same letter across different years are not significantly different (P<0.05).

Bukora

Table III presents a summary of the variations in different parameters across years for Bukora site. Like for Kibale, rainfall was lower in 1998/99 compared to other years. Flow rate and loads for TN and TSS were also higher in 1998/99 than in other years. However, total loads for NO_3^-N, PO_4^-P and TP were not significantly different between 1998/99 and 2000/01. Concentration for TSS was higher in 1998/99 while that of TP was lower in 1998/99 than in other years. Like Kibale, pH values for Bukora were much higher during 1998/99 than 1999/2000 or 2000/2001.

Table III. Variation in water quality parameters at Bukora station

Parameter	98/99	99/00	00/01
Rainfall (mm)[1]	765	943	940
Flow rate (cumecs)	5.59a[2]	0.36b	3.26a
pH	7.50a	6.86b	7.10b
Concentration (mg L^{-1})			
Nitrate	0.17a	0.09a	0.22a
Total N	4.52a	7.32a	4.50a
PO_4-P	0.16a	0.16a	0.18a
Total P	0.26b	0.38a	0.35ab
TSS	89.2a	47.1b	
39.7b			
Load (ton d^{-1})			
Nitrate	0.071ab	0.002b	0.177a
Total N	2.10a	0.42b	0.15b
PO_4-P	0.067a	0.004b	0.09a
Total P	0.11a	0.01b	0.14a
TSS	40.9a	1.8b	7.5b

[1] Rainfall figures are annual totals.
[2] Means of the same variable followed by the same letter across different years are not significantly different (P<0.05).

Kisoma

Table IV is a summary of the variations in different parameters across years, for Kisoma site. Kisoma has its origin within this micro-catchment itself, therefore the discharge/ flow rate recorded reflects the conditions within the micro-catchment, unlike the first river which traverses a number of districts before it drains into Lake Victoria. Table IV shows that higher amount of rainfall was received during 2000/01 and correspondingly, higher flow rate, TP and TSS loads than in 1998/99 and 1999/00. Concentration for TSS was higher in 2000/01 (though not significantly different from that of 1999/00) and lowest in 1998/99. Loads and concentration for other variables did not differ significantly among years. Kisoma is a small seasonal stream with a lot of wetland vegetation at the point where the river is monitored. In addition, this stream covers a much smaller catchment area compared to the first stream (monitored at Kibale and Bukora) which traverses several pastoral districts from western Uganda, where it picks up a big load of nutrients along the way. Being a smaller stream with a smaller catchment therefore, Kisoma had a significantly ($P<0.05$) smaller flow rate than that observed at Kibale and Bukora in all three years, which in turn resulted in a much smaller loading for all parameters (Table I). Kisoma also had notably lower concentration values for all variables measured, except for TP and PO_4-P which were comparable in magnitude to those of Kibale and Bukora. The low flow rate, small size of the stream and its catchment plus differences in land use practices in the micro-catchments of the two rivers might probably account for the differences in measured parameters for the two streams.

From Tables I to IV, it can also be seen that the NO_3-N concentrations observed at the three river monitoring sites were much lower than the United States allowable maximum NO_3-N contaminant level of 10 mg L^{-1} (Logan, 1993). On the other hand, very high levels of TSS were observed in both rivers. Agriculture being the major activity for people in the study area, a large amount of sediment from erosion of cultivated areas is washed into rivers, and ultimately into the lake. Stachowicz (1993) observed that in south Poland, the greatest loss of nutrients occurred in the watershed with the most intense land use; nutrient loading was proportional to flow rate. Data by Calamari *et al.,* (1995) showed TP loads from rivers into the Winam Gulf of Lake Victoria, Kenya, amounting up to 400 ton yr^{-1}. Our results show mean annual TP loads ranging from 3 to 40 ton yr^{-1} and 5 to 50 tony r^{-1} for Kibale (Table II) and Bukora (Table III), respectively within the 3 years of monitoring.

Table IV. Variation in water quality parameters at Kisoma station

Parameter	98/99	99/00	00/01
Rainfall[1]	699	849	952
Flow rate (cumecs)	0.46b[2]	0.24b	0.98a
pH	6.95a	6.69a	6.91a
Concentration (mg L^{-1})			
Nitrate	0.03a	0.03a	0.03a
Total N	3.25a	4.30a	3.19a
PO_4-P	0.14a	0.21a	0.19a
Total P	0.25a	0.39a	0.41a
TSS	12.3b	18.2ab	22.6a
Load (ton d^{-1})			
Nitrate	0.005a	0.002a	0.005a
Total N	0.11a	0.12a	0.14a
PO_4-P	0.006a	0.004a	0.005a
Total P	0.01a	0.01a	0.04a
TSS	0.62b	0.38b	2.50a

[1] Rainfall figures are annual totals.
[2] Means of the same variable followed by the same letter across different years are not significantly different ($P<0.05$).

Variations in Water Quality Parameters During The Study Period

Table V presents mean values for different parameters during the 3 years. Averaged over the three sites, rainfall was lowest in 1998/99 and highest in 2000/01. However, flow rate and pH were highest in 1998/99 and lowest in 1999/00 with a similar trend observed in the loads for NO_3^-N, TN, PO_4^-P, TP and TSS, while EC and concentrations for NO_3^-N, TN, PO_4^-P, TP and TSS followed the reverse trend. In a study of non-point pollution from Kakira sugarcane estate, Uganda, Idrakua (2002) observed a clear variation in concentration and loads of all parameters measured. In general for the three years, PO_4-P concentrations were within close range to those observed for rivers Awach, Oluch and Nyama Saria that enter the Winam Gulf of Lake Victoria, Kenya (Calamari *et al.,* 1995). However, the TP ranges for 1999/2000 and 2000/01 were relatively higher than the range of 0.011-0.358 mg L^{-1} reported for some rivers in the Winam Gulf, Kenya (Calamari *et al.,* 1995).

The mean annual loads for TSS, TP and TN ranged from 660 to 14,300 ton yr^{-1}, 4 to 40 ton yr^{-1} and 80 to 760 ton yr^{-1}, respectively. These high levels of pollutant loads are associated with severe soil erosion in this sub catchment area.

Table V. Water quality parameters during the study period

Parameter	98/99	99/00	00/01
Rainfall (mm)[1]	715	915	1073
Flow rate (cumecs)	4.09a[2]	0.29c	1.86
pH	7.46a	6.95b	7.02b
EC (uS cm^{-1})	200b	245a	216ab
Concentration (mg L^{-1})			
Nitrate	0.11ab	0.05b	0.19a
Total N	4.03b	7.55a	4.49ab
PO_4-P	0.16b	0.22a	0.21ab
Total P	0.25b	0.38a	0.40a
TSS	64.3a	64.3a	28.3b
Load (ton d^{-1})			
Nitrate	0.057a	0.001b	0.05ab
Total N	1.45a	0.20b	0.54b
PO_4-P	0.051a	0.004b	0.049a
Total P	0.08a	0.01b	0.08a
TSS	27.3a	1.4b	4.2b

[1] Rainfall figures are annual totals.
[2] Means of the same variable followed by the same letter across different years are not significantly different ($P<0.05$).

Seasonal Variations

Fig. 2 is a plot of the monthly variation in rainfall, flow rate, TSS and TN load averaged over 3 sites and 3 years. The highest mean rainfall was observed in April while the highest flow rate occurred in July, indicating a 3-months ground recharge period. Fig. 2 also shows that peak TN and TSS loads were observed in July (corresponding to peak flow rates during the same month). The similarity in monthly patterns is a clear indication that TN loading depends on flow rate. This relation is investigated further in Fig. 3. The dependence of TN and TP load on TSS is reflected in the good relationships between TN load with TSS (R^2=0.818) and between TP and TSS (R^2=0.627). These observations suggest that nitrogen and phosphorus-rich sediments carried along volatilisation to the atmosphere through burning of vegetation and eventual re-deposition far downwind in rain or dry pollutants into aquatic ecosystems (Carpenter *et al.,* 1998). Atmospheric deposition of P (UNEP, 2000) and P transportation as particulate P which is eventually converted into phosphate P (Carpenter *et al.,* 1998) may also contribute to P loading. According to Hecky (2003), the atmosphere contributes to most of the TP loading to Lake Victoria and originates from land-based activities leading to loss of vegetation and increased runoff.

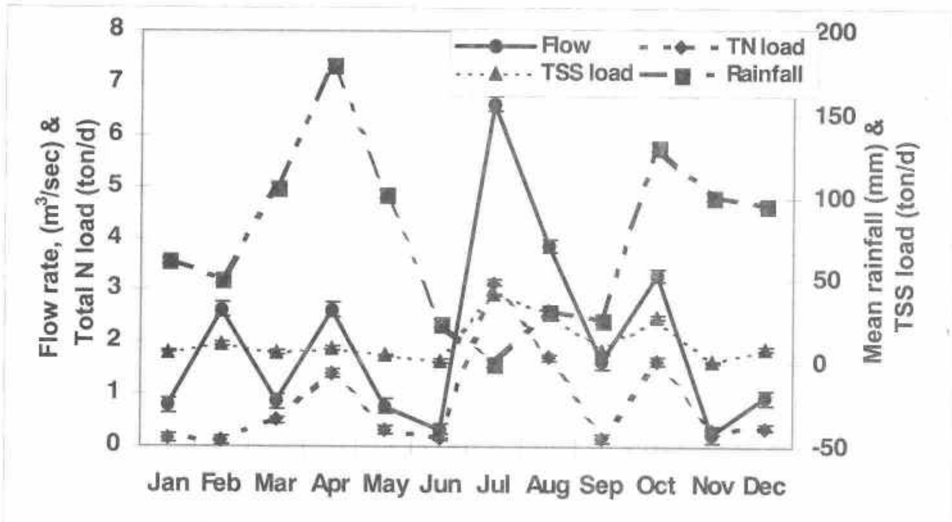

Figure 2. Monthly variations in rainfall, flow rate, suspended solids and nitrogen load averaged over 3 sites and 3 years

Effect of the Wetland

Fig. 4 and 5 present a summary of the changes observed in water quality parameters of the same river monitored at Kibale and Bukora, with Bukora on the downstream side of Kibale (Fig. 1). The river traverses a series of wetlands as it flows from Kibale to Bukora. Only variables where significant differences were observed have been presented. For both sites, river flow rate was highest in 1998/99 and lowest in 1999/00 (Tables II and III). It can be seen from Fig. 4 and 5 that during 1998/99 (high flow) minimal change in flow rate occurred and correspondingly, minimal changes in concentrations and loads of PO_4,

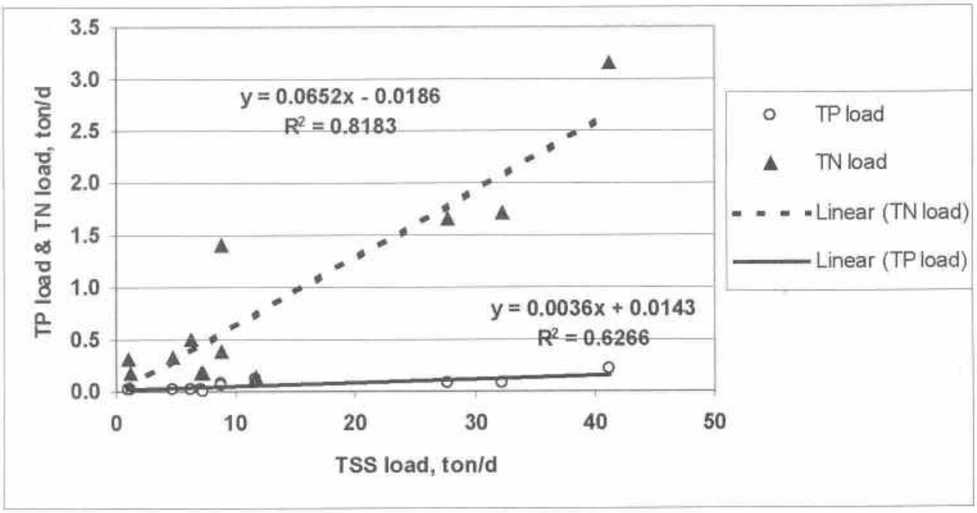

Figure 3. Relationships between TSS with TP and TN loads (values are means of 3 sites over 3 years)

TSS, TN and TP. However, NO_3^-N concentration increased by 54%. During 1999/00 (low flow), a 45% reduction in flow rate occurred across the wetland translating into 29%, 44% and 51% reduction in TN, PO_4^-P and TSS concentration, respectively; minimal changes in NO_3^-N concentration occurred. In the same year, a 99%, 56%, and 51% reduction in TN, TP and TSS loads occurred, respectively; no change occurred for PO_4^-P. During 2000/01, river flow rate was low to medium (1.69 to 3.26 cumecs for Kibale and Bukora, respectively). About 84% reduction in flow rate occurred across the wetland, translating into 18%, 21% and 19% reduction in TN, PO_4^-P and TP concentrations, respectively. On the other hand, TSS and NO_3^-N concentration increased by 44% and 23% (likely due to runoff contribution from the micro-catchment). In the same year high reductions were observed in PO_4^-P, TP and TSS loads but not TN.

From the above results, it is apparent that the beneficial aspect of wetlands in reducing pollutant concentration and load was mostly observed under periods of low flow (1998/99 in this case). During periods of high flow, the water may be flushed out of the wetland system before equilibrium is reached. Thus, the ability of the wetland to purify water depended in part, on the retention time of the pollutant within the wetland, which in turn is a function of flow rate. The role of wetlands in serving as a sediment and nutrient trap and microbial uptake, accumulation and loss of nutrients from water has been documented (Anonymous, 1994). Gilliam (1994) reported more than 90% reduction in sediment and nitrate concentrations in water flowing through riparian wetlands. He observed that riparian buffers were less effective for P removal, but they retained 50% of the surface water P entering them. It is also apparent that PO_4^- P and more so, NO_3^-N concentration and loads across a wetland were independent of river discharge (possibly being transformation products of organic and mineral P and N forms). As pointed out in Anonymous (1994), however, more studies are needed to understand the dynamics of these processes.

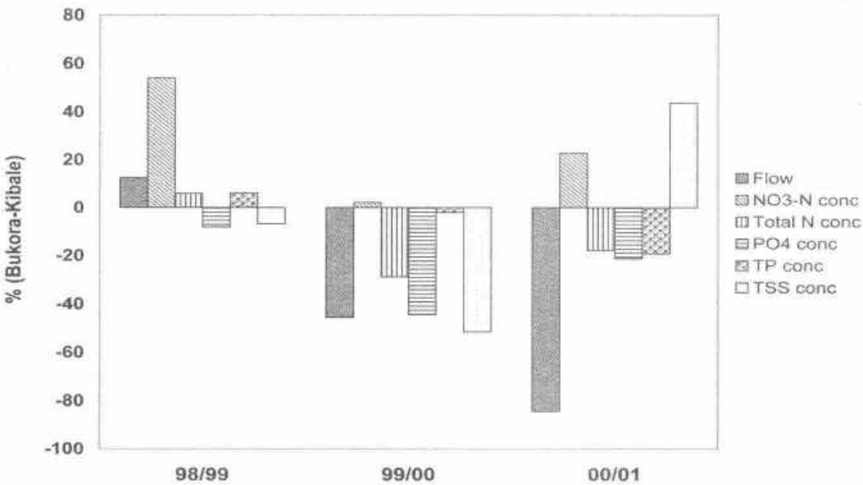

Figure 4. Changes in concentrations of different pollutants as water flows from Kibale to Bukora

Land Management Implications

The results of this study show that sediments, phosphorus and nitrogen were major causes to non point pollution of surface water. Inappropriate land management practices such as destruction of vegetation cover result in soil erosion and consequently, loss of nutrients. Stachowicz (1993) observed that non-point pollution contributing to nutrient loss in a watershed was greatest in an area with the most intense land use activities. Restoring vegetation cover, reducing biomass burning and increasing soil moisture retention will be necessary to reduce non-point pollution loading to Lake Victoria. In areas with intense livestock management, mismanagement of animal waste directly contributes to nutrient loading into rivers leading to pollution of water bodies.

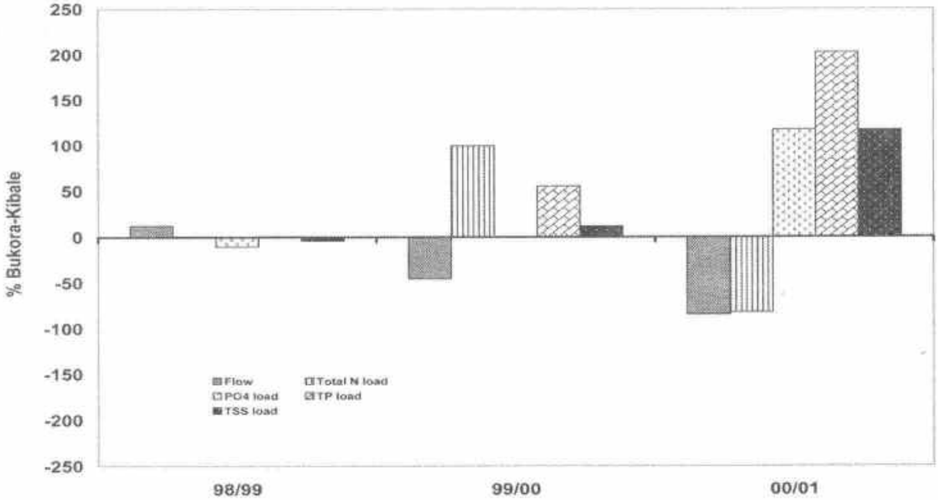

Figure 5. Changes in loads of different pollutants as water flows from Kibale to Bukora

According to Chokmani *et al.,* (1997), water quality in a watershed dominated by animal production was related to land use practices, particularly the intensity of animal production. Nitrogen, P, dissolved oxygen and faecal coliforms were the parameters most affecting surface water quality.

In this agro-pastoral area where the study was conducted, there is urgent need to address the soil erosion problem so as to ultimately curb water pollution. This may partly be achieved through scaling up of the better soil management practices (currently initiated on a pilot basis on farmers' fields in the sub catchment), revegetation of bare hills, protection of wetlands, protection of river banks using buffer strips, contour tillage, conservation tillage and use of cover crops. According to Carpenter *et al.,* (1998) vegetation buffer strips reduced P transport to streams by 50 to 85%. Many of these activities call for delineation of pollution "hot spots" and targeting remedial measures to these areas as well as community action to enforce existing land management by-laws. As Carpenter *et al.,* (1998) pointed out, the most important barriers to control of non-point pollution are social, political and institutional. Promoting of sound management practices for fertilisers and pesticides is also an important aspect of controlling non-point pollution. Logan (1990) observed that whereas traditional soil erosion control practices could reduce sediment and P losses, pest and fertility management approaches will also be required to achieve significant reductions in pesticide and nitrate contamination of surface and ground water. Improved land management practices should also aim at promoting better livestock management to ensure that animals are confined to a specific grazing areas (eg. fencing as opposed to free grazing) so as to minimise the direct deposition of animal waste into water streams. Shirmohammadi *et al.,* (1997) observed that the major cause of non-point pollution in an area with diverse land use was mismanagement of dairy manure. According to Carpenter *et al.,* (1998), aggressive treatment of dairy manure in Florida, USA reduced total P concentrations in surface water in the range 62 to 87%.

Adoption of improved land management practices is often hampered by the high labour requirements associated with some of the technologies. In addition, many such practices take long for results to be reflected in water quality improvement. Research has shown that P load reductions into a lake from contaminated dairy sites was only realized after a long time following introduction of appropriate pollution reduction strategies. Phosphorus loading into Lake Erie (USA) from point sources were reduced from 15,260 ton yr^{-1} to 2449 ton yr^{-1} in 13 years (International Joint Commission, 1987). Baker (1993) advised that major approaches to reduce agricultural non-point pollution should focus on accelerated voluntary farmer adoption of BMPs with respect to tillage, fertilizer and pesticide management, and livestock waste handling. In the study area, the emphasis is to promote improved land management, soil and water conservation as well as water harvesting technologies. Mulching and agro-forestry are promoted. These efforts are aimed at achieving better soil and water conservation, through erosion control and improved watershed management. Presence of a 3-months recharge period between maximum rainfall and peak river discharge and pollution loading presents an opportune time for management and policy measures to be put in place to counter a would be influx of pollutant loads into the lake. The results also emphasise the value of wetlands in reducing P, N and sediment loading in water bodies, through their role in water filtration. Practices that conserve wetlands would therefore contribute to reduction of water pollution.

SUMMARY AND CONCLUSIONS

Phosphorus, nitrogen and total suspended solids are among the major pollutants identified in the two streams, likely due to extensive soil erosion in the region. Total suspended solids were a major contributing factor to N and P loading into the river and consequently into the lake. There was an overall decrease in mean annual pH of river water over the three years, although not reflected in monthly variations. Seasonal trends in TSS, P and N concentrations and loads were closely related to river discharge. Within the 3 years of monitoring, mean annual concentrations for TN ranged from 3.2 to 10.4 mg L^{-1} with loads of 40 to 70 ton yr^{-1}; TP concentrations ranged from 0.2 to 0.4 mg L^{-1} with loads of 3.6 to 51 ton yr^{-1} while TSS concentrations ranged from 12 to 94 mg L^{-1} with loads of 1.8 to 40 ton yr^{-1}. These values were higher than those reported for Kakira estate into the Fielding Bay (Idrakua, 2002) but are much lower than those reported for some rivers in the Winam Gulf of Lake Victoria, Kenya (Calamari *et al.,* 1995). Highest TP, TN and TSS loads were observed in July corresponding to the highest flow rates. Presence of a wetland resulted in an overall reduction in the level of P, N and TSS during years of low flow. Results of this study call for promotion of improved land management practices such as through scaling up of soil erosion control activities initiated in the sub catchment, better handling and use of agricultural chemicals as well as better animal husbandry practices to ultimately control water pollution.

RECOMMENDATIONS

In order to combat non-point pollution, there is need to adopt improved land management practices in the entire Lake Victoria catchment. Revegetation of bare hills (a common erosion "hot spot" feature in Rakai), protection of river banks and wetlands, contour and conservation tillage practices, coupled with better management of agricultural chemicals are but some of the better land management practices that need to be promoted. Many of these activities need a collective community action to enforce community land management by-laws where they exist and formulate new ones where necessary. In areas with high livestock populations, better management of dairy manure will also reduce pollution. Community sensitisation will be necessary in this regard.

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