Pollution loads into Lake Victoria from the Kenyan catchment

Okungu John, and Opango Peterlis

Ministry of Environment and Natural Resources (LVEMP)Water Quality Component
P.O. Box 1922, KISUMU. Telephone, 035-42350, 44584
E-mail jokungu@passage.africaonline.com

Abstract

Lake Victoria has experienced eutrophication problems. This is attributable to pollution due to an expanding population, a rapidly developing technology, and increased industrial and food production. Pollution from non-point sources can significantly influence an ecosystem. In this study, four parameters; Total Nitrogen (TN), Total Phosphorus (TP), Silicon (Silica) and Total Suspended Solids (TSS) were identified for the estimation of the pollution loads. Phosphates and Nitrates are the two principal plant nutrients that most often limit crop yields while silica is a key nutrient in diatom production and is taken up during the early growing season. Total Suspended Solids is comprised of organic and mineral particles that are transported in the water column. TSS is closely linked to land erosion and to erosion of river channels. A study was carried out to quantify the amount of nutrients (Total Nitrogen, and Total Phosphorus), Silica and Total Suspended Solids discharging into Lake Victoria from the Kenyan catchment and to identify the contribution of pollution load from each river system into Lake Victoria so as to prioritise intervention programmes. A monitoring network was set at representative sites in the whole catchment and water samples were taken on a regular basis for laboratory analysis. River discharge measurements were done across each river transect at the time of sampling. Integrated samples were also taken using a sediment sampler for suspended sediment estimation. Average discharge values and concentration were used for estimation of loads to the lake. River Awach Kibuon had the highest concentration of Total Nitrogen followed closely by Awach Tende then River Kuja. For Total Phosphorus Nyando river had the highest value followed by River Kibuon then Nzoia. The rest of the rivers had generally low concentrations. River Sondu had very low concentrations of TP.

Silicon concentration in all the rivers was moderate though Kuja River had the highest followed by Nyando and Kibuon Rivers. For TSS, rivers draining Kisii highlands Awach Tende and Kiboun and Kuja had very high values showing serious degradation. Nzoia and Nyando were also high. Sio had low concentrations. The loads in tonnes per year from the studied catchment were estimated as follows: TN – 12,193, TP – 2,113, Si – 140,849 and TSS – 4,390,644.

Key Words: Pollution, Discharge, Nutrients, Load, Degradation

Introduction

The threat of water pollution is real and present in every region of the world. This can be attributed to an expanding population, rapidly developing technology, and increased industrial and food production. If there was no human influence, water quality would be determined by the weathering of bedrock minerals, by atmospheric processes of evapo-transpiration and the deposition of dust and salt by wind, by the natural leaching of organic matter and nutrients from soils and by hydrological factors that lead to runoff, (UNEP, 1995).

The Lake Victoria basin is used as a source of food, energy, drinking and irrigation water, for shelter and transport and as a repository for human, agricultural and industrial waste. Development activities, discharge of nutrients and growth of population (about 3% in the

Kenyan side) has caused changes in the lake ecosystem. Massive blooms of algae have developed, water borne diseases have increased in frequency and water hyacinth has started choking important waterways and landings as well as water supply intakes (LVEMP, 1995)

Since 1993, the landscape has undergone changes with increasing intensity particularly in the recent decades due to human activities altering the environment and the natural resource base. The problems experienced are associated with population pressure, greater urbanisation, industrialization, intensified agriculture, over grazing, deforestation, wetlands destruction, soil erosion and greater use of pesticides.

High level of noticeable pollution is limited to the vicinity of effluent discharge from urban centres and industrial establishments, therefore, studies on pollution problems have concentrated a lot on point pollution sources, however, and overall pollution from non-point sources can significantly influence an ecosystem.

Nutrients are chemicals, which are essential for plant growth but required in small or trace amounts. Their absence will prevent plant production and reduce crop yields.
Phosphate and Nitrates are the two principal plant nutrients that most often limit crop yields.

In a natural ecosystem like a forest or grassland nutrients occur naturally in the soil and have originated from the bedrocks. Plants take up these nutrients during the growth and development. They are then incorporated into the plants tissues. After the death of the plant, the processes of decay and decomposition proceed whereby nutrients in the plants tissue are released back to the soil or water.

The natural situation above contrast with that found in agricultural system where crops are harvested and removed from the point of production to a distant point of consumption. In this way the fertility of the soil is exported in a consignment of produce. To counter the cumulative loss of nutrients from agricultural areas, fertilizers are normally applied to the agricultural land.

The main natural origin of phosphate is due to erosion, which is the chemical and mechanical weathering of rocks. During the erosion process, phosphate is mobilised partly as dissolved inorganic phosphate and partly adsorbed on or even into clay particles. The second most important source of phosphate is human excreta and detergents. Thus discharge of inadequately treated effluents, and inadequate disposal facilities introduce phosphorus into water. It is estimated that 2g of PO_4-P is excreted per person per day partly in urine and in faeces. For developed areas another 2g of tri-phosphate phosphorus come from detergents per person per day, which will hydrolyse, to PO_4- P (Golterman, 1993). The third and last main source is agriculture and other land uses. This source includes the leaching and drainage of fertilizers and other soil nutrients and the removal of soil particles. Manure from intensive and large-scale livestock production is also an important source of phosphorus.

Nitrogen enters water from very different sources. The nitrogen content of igneous rocks is only 46g per tonne (46 ppm) although that of certain sedimentary rocks may be ten times higher. Larger quantities of nitrogen come from erosion of both natural and artificially fertilized soils (Golterman, 1993).

Total Suspended Solids (TSS) is comprised of organic and mineral particles that are transported in the water column. TSS is closely linked to land erosion and to erosion of river channels. It is an important measure of erosion in river basins and also closely linked to the transport through river systems of nutrients (especially phosphorus), metals and a wide range of industrial and agricultural chemicals. TSS levels and fluctuations influence aquatic life, from phytoplankton to fish. Conservative estimates has put sediment load of Sondu/Miriu at approximately 150 tonnes/km^2 and Nyando at 423 tonnes/km^2 (Chin *et al.* 2000).

Silica is a key nutrient in diatom production, a very common algal group, and is taken up during the early growing season. SiO_2 concentrations can limit diatom production if concentrations become depleted in surface waters. In rivers, dissolved silica concentrations depend primarily on the native rock types within the river basin.

In Lake Victoria catchment, agricultural activity accounts for about half of land use. Vegetation, forest, swamps and water bodies cover the rest. Agriculture whose policy is to increase food production contributes a high proportion of surface run off which is laden with large amounts of water pollutants including nutrients. Moderate soil erosion in the order of 5-10 tonnes/ha/year is associated with substantial losses in soil nutrients that contribute significantly to negative farm nitrogen and phosphorous balances (Van den Bosch *et al.* 1998).

The following conditions and practices contribute to the high load of nutrients and other pollutants entering the lake: -

1. Low soil fertility, which requires use of fertilizers to increase productivity.
2. Inappropriate methods of increasing or maintaining in situ soil moisture contents.
3. Lack of suitable and integrated agricultural practices in the catchment.
4. Conversion of wetlands, which are sediment, traps for agricultural production.

Massive algal growth is a common nuisance where dissolved nutrients are present especially nitrogen and phosphorus. Due to the reported eutrophication in Lake Victoria and the recent proliferation of water hyacinth it therefore became important to determine the sources of pollution to the lake and estimate the quantity of pollutants in order to institute intervention measures for environmental management.
A study was done to estimate the amount of nutrients and sediments entering the lake from the Kenyan part of the catchment. Contribution from each of the main rivers in the catchment was estimated.

1.1. Objectives of the Study

It has been suggested that sedimentation and nutrients runoff, urban and industrial point sources pollution and biomass burning have induced the rapid eutrophication of Lake Victoria. Afulo (1995) suggested that the increase in phosphorus is primarily due to increase in atmospheric deposition from forest burning and wind erosion. Bullock *et al.* (1995) estimated that 50% of Nitrogen input and 56% of the phosphorus input is due to run-off from agricultural land.

The effects of continuing soil erosion in excess of natural rate of replacement will cause reduction of natural soil fertility with consequent loss of crop production and /or increased need to use fertilizers. The objective of this study is therefore to quantify the amount of nutrients (Total Nitrogen, TN & Total Phosphorus, TP) and Total Suspended Sediments, (TSS) discharging into lake Victoria and to identify which river basin is contributing more nutrients and sediments into Lake Victoria so as to prioritize it for intervention programmes.

Materials and methods

1. A monitoring network was set at representative sites along rivers in the whole catchment.
2. Water samples were taken from these stations on a regular basis for laboratory analysis in clean plastic bottles.
3. Water quantity (discharge measurements) was done across the river transect at the time of sampling.
4. Integrated samples were also taken using a sediment sampler (hand sampler US DH-59) for suspended sediments estimation.
5. Water samples were analyzed in the laboratory
6. For estimation of loads to the lake data obtained from samples taken from the last sampling station to the lake on each river was used for calculations.

2.1. Total Nitrogen

Total (organic and inorganic) Nitrogen is converted to Nitrate by alkaline oxidation at 100º - 120º C. Total Nitrogen is then determined by analysing the nitrate in the digestate. Nitrate is reduced to Nitrite by cadmium in ammonium chloride buffer at pH = 8.5. Nitrite is diazotised with sulphanilamide and coupled with N- (1-napthyl) – ethylenediamine dihychloride to form a reddish purple azo dye, whose absorbance is measured by a spectrophotometer at 543nm. Detection limit is 0.025 mg/L.NO_2^- with l cm cell.

Materials

Autoclave.
Cadmium reduction column
Spectrophotometer
Refrigerator
Reagents

- Colour reagent (Phosphoric acid, sulphanilamide and N- (l-naphthyl)– ethylenediamine dihydrochloride + distilled water)
- Sodium nitrate KNO_3 (dried at 105ºC for 2hrs and stored in a desiccator)
- Di-sodium EDTA –(for control solutions).
- Potassium per-sulphate $K_2S_2O_8$
- Sodium hydroxide pellets
- Boric acid (H_3BO_3)

Methodology

Only freshly distilled water with an insignificant N_2 content was used in the analysis and for preparation of reagents. Samples were acidified in the field with 2ml per litre concentrated Sulphuric acid (H_2SO_4).

A suitable volume of sample was measured into digestion bottles and 5 ml of the oxidising reagent (Potassium per-sulphate in sodium hydroxide with distilled water) added into each bottle. The digestion bottles were closed and autoclaved at 121ºC for 30 minutes.

After the samples were cooled to room temperature, the digestion bottles were opened and l ml of borate buffer solution (H_3BO_3 and NaOH in distilled water) was added. The solution from the digestion bottles was transferred to a measuring cylinder, filled to 60ml with the ammonium chloride buffer and mixed. The 60ml was then transferred to a conical flack and poured into Cadmium reduction column.

The first 25ml was discarded and the rest collected in a measuring cylinder and 25mls poured into a conical flask and l ml colour reagent added. The absorbance was read from a spectrophotometer at 543nm wavelength.
The standards and the control solutions were treated the same way as the samples.

2.2. Total Phosphorus

Spectrophotometer
Autoclave
Reagents

- Phenolphthalein indicator in aqueous solution.
- Sulphuric acid 0.04M.
- Ammonium per-sulphate $(NH_4)_2S_2O_8$ or potassium per-sulphate $(K_2S_2O_8)$
- Sodium hydroxide, NaOH, lN.
- Ascorbic acid
- Potassium di-hydrogen Phosphate (KH_2PO_4) dried at 105°C for two hours
- Combined solution

Principle: - Ammonium molybdate and potassium antimonyl tartrate react in acid medium with orthophosphate to form a heteropoly acid – phosphomolybdic acid – that is reduced to intensely coloured molybdenum blue by ascorbic acid. All the glassware used were soaked in a 10% hydrochloric acid solution and rinsed with distilled water.

Twenty-five ml of the samples were transferred to the digestion flasks and 5 ml of the ammonium per-sulphate or potassium per-sulphate solution added. The solution was then autoclaved for 30 minutes at 121°C and then brought to room temperature. The 30 ml solutions were transferred into a reaction bottle and l ml ascorbic acid added, mixed and left for about 30 seconds after which l ml combined solution was added. The absorbance was measured on a spectrophotometer at 880nm within 10-30 minutes.

Silica

Samples for silica analysis were always stored in polythene bottles. All routine were performed in plastic equipment. Heteropoly Blue Method was used for the analysis

At about pH 1.2 ammonium molybdate reacts with molybdate reactive silica and phosphate to produce the two yellow heteropoly acids i.e. molybdosilicic and molybdophosphoric acids. The yellow molybdosilicic acid is reduced by means of ascorbic acid to the blue heteropolymolybdate. This blue colour is more intense than the yellow colour and provides increased sensitivity. The absorbance was measured using a spectrophotometer at 810nm.

Materials

Spectrophotometer
Cool boxes
Desiccator
Reagents

- Sulphuric acid
- Ammonium molybdate
- Oxalic acid
- Ascorbic acid
- Mixed reagent
- Na_2SiF_6 (Sodium Fluorosilicate) dried at 105°C for 1 hr and stored in a desiccator.

The samples, standards, blanks and control samples were placed into plastic beakers and 1.0mls of mixed reagent added. After 10 to 20 minutes, 1.0ml of oxalic acid was added and then mixed and that was followed immediately with 1.0 ml of ascorbic acid. Measurement of the absorbance was done 30 minutes later using a spectrophotometer at 810nm.

Suspended Solids

Materials

- Analytical balance capable of weighing down to four decimal numbers
- 0.45 µm GFC (glass fibre) filter papers.
- Vacuum pump
- Drying oven
- Desiccator

Method

Upon arrival to the laboratory, the samples were filtered through a pre weighed 0.45 µm GF filter papers under a vacuum pump.

The volume of the sample to be filtered depended on the turbidity of the sample. The higher the turbidity the lower the sample volume used so as to avoid clogging of the filter papers.

The filters were air dried in the laboratory and then oven dried at 105 °C for one hour, cooled in a dessicator weighed and again returned into the oven for further drying until a constant weight was obtained.

The final constant weight was used to determine suspended sediment concentration using the formula below:

$$\text{Suspended Sediment Concentration (mg/l)} = \frac{(A-B) \times 1{,}000{,}000}{\text{Sample volume (mls)}}$$

Where A = weight of filter paper plus filtrate in g

B = weight of filter paper alone in g.

The overall suspended sediment concentration of the river was the mean concentrations at the gauging sections of the river and the suspended sediment load the product of concentrations and the discharges.

RESULTS

Discharge

River Nzoia had the highest discharge at about 170m^3/s, followed at almost one-third the value by River Kuja then River Sondu. Table 1.

Table 1**:** Average discharge and pollutants concentration and loading for Rivers in the Kenyan catchment of Lake Victoria

River	Discharge, m^3/s	TN, mg/L	TP, mg/L	Si mg/L	TSS, mg/L	N- (t/yr)	P- (t/yr)	Si- (t/yr)	TSS- (t/yr)
Sio	7.26	0.650	0.12	11.29	172	149	28	2586	39498
Nzoia	170.27	0.897	0.25	10.87	466	4820	1365	58386	2504367
Yala	34.99	1.155	0.12	10.34	223	1275	130	11413	246044
Nyando	13.07	1.12	0.38	16.20	364	462	156	6682	150272
Sondu	44.92	1.080	0.02	12.00	202	1531	24	17011	286106
Kuja	66.06	1.440	0.14	17.00	419	3002	298	35440	873800
Tende	8.54	1.560	0.12	14.60	587	420	32	3933	158175
Kibuon	6.18	1.840	0.29	15.50	538	359	57	3022	104992
Nyamasaria	3.98	1.260	0.16	15.80	207	158	20	1984	25961
Seme	0.89	0.610	0.09	14.04	51	17	3	392	1429
Total	**356.16**	**11.61**	**1.69**	**137.64**	**3229**	**12,193**	**2,113**	**140,849**	**4,390,644**

Table 2: Shows Catchment area sizes, average discharge per unit area and mean annual rainfall in the catchments of major rivers entering Lake Victoria from the Kenyan basin of the lake.

River	Catchment area, km^2	*Discharge, Litres/ km^2/s	**Mean annual rainfall, mm
Sio	1,437	8.39	1589
Nzoia	12,842	9.19	1492
Yala	3,357	8.17	1589
Nyando	3,652	4.03	1307
Sondu	3,508	11.50	1511
Kuja	6,600	9.49	1519

* Calculated using mean discharge data for 50 years (1950 – 2000). Data generated under Water Quality and Limnological studies by Water Quality Component together with COWI Consultants and Planners AS (2001).

* *Source: The Study of The National Water Master plan, Data Book (DB.1). Hydrological (Study Supporting) Data. Republic of Kenya, Ministry of Water Development by JICA, 1992.

The total discharge for the studied rivers was about 356m^3/s of which Nzoia contributes about 48%.

Nutrients

The amounts of Nitrogen and Phosphorus concentrations from the same catchments never followed a similar pattern (Figure 1).

For total Nitrogen, River Awach Kibuon had the highest concentration per unit volume of water, followed closely by Awach Tende then River Kuja. All the rivers had concentrations more than 0.5 mg/L.

For Total Phosphorus, Nyando River had the highest value followed by river Kibuon then Nzoia. The rest of the rivers had generally low concentrations. River Sondu had very low concentration.

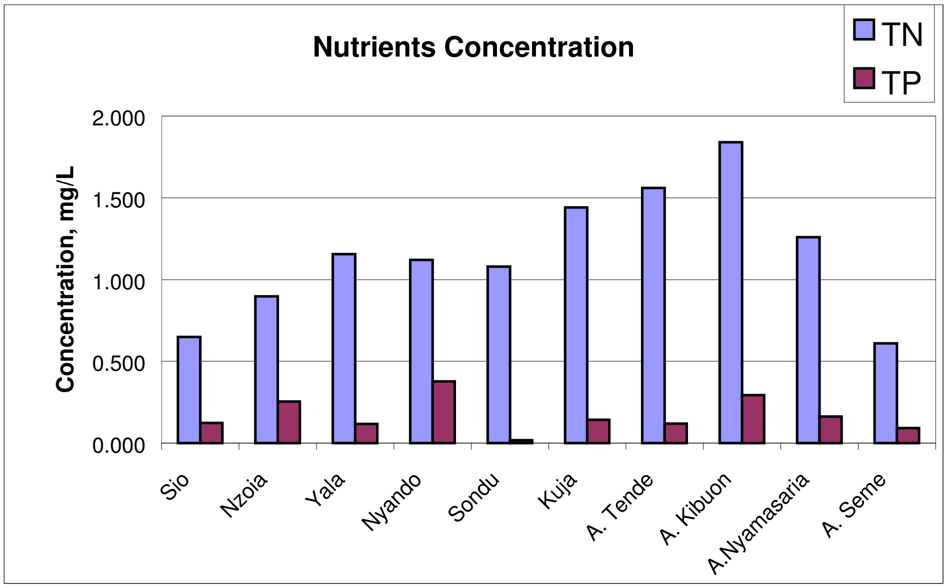

Fig. 1: Shows variation in average nutrient concentration at the last stations for the Kenyan Rivers in lake Victoria catchment.

Silicon

Silicon was moderately high for all the rivers. All the rivers had concentrations in the range of 10 – 17 mg/L. Kuja river was the highest followed by Nyando and Kibuon rivers. Figure 2.

Total Suspended Sediments

River Awach Tende was the highest followed by Awach Kibuon then Nzoia, Kuja and Nyando. Awach Seme was the lowest followed by Sio, Figure 3. Sio River was having low total suspended loads even during its high flows.

Total load into the lake

Loading of nutrients and suspended solids (transport) were generally influenced by the total river discharge. Sio shows lower transport in total nitrogen, silicon and suspended solids than expected from its discharge. Sondu had a very low discharge for phosphorus (Figures 4, 5, 6 and 7).

Summary

In terms of concentration per unit volume (mg/L) the ranking found was as follows:

Rank	TN	TP	Si	TSS
1.	Kibuon	Nyando	Kuja	Tende
2.	Tende	Kibuon	Nyando	Kibuon
3.	Kuja	Nzoia	Nyamasaria	Nzoia
4.	Nyamasaria	Nyamasaria	Kibuon	Kuja
5.	Yala	Kuja	Tende	Nyando
6	Nyando	Tende	Seme	Yala
7.	Sondu	Yala	Sondu	Nyamasaria
8.	Nzoia	Sio	Sio	Sondu
9.	Sio	Seme	Nzoia	Sio
10.	Seme	Sondu	Yala	Seme

In terms of transport of loads in tonnes per year the ranking was found to be as follows:

Rank	Discharge	Transport (tonnes/year)			
	m^3/s	TN	TP	Si	TSS
1.	Nzoia	Nzoia	Nzoia	Nzoia	Nzoia
2.	Kuja	Kuja	Kuja	Kuja	Kuja
3.	Sondu	Sondu	Nyando	Sondu	Sondu
4.	Yala	Yala	Yala	Yala	Yala
5.	Nyando	Nyando	Kibuon	Nyando	Tende
6.	Tende	Tende	Tende	Tende	Nyando
7.	Sio	Kibuon	Sio	Kibuon	Kibuon
8.	Kibuon	Nyamasaria	Sondu	Sio	Sio
9.	Nyamasaria	Sio	Nyamasaria	Nyamasaria	Nyamasaria
10.	Seme	Seme	Seme	Seme	Seme

Discussion

The rivers show different loads depending on the origin. The total loads by the rivers generally are a function of discharge with few exceptions. The total discharge seems to be influenced by the catchment size as the rainfall distribution in the catchment seems to be uniform and these rivers come from the highland areas with similar patterns of rainfall.

Nutrient concentrations in the rivers draining Kisii highlands are high indicating more degradation of the environment. In this area the predominant crop is maize so the soil remain bare before next crops are planted and grow to adequately cover the soil. Chabeda (1984) observed that Total Nitrogen from tributaries draining areas predominantly cultivated with wheat and maize are higher than for sugar belts. Total suspended loads for these rivers are also high. Most of the Nitrogen is possibly from the farmlands and may be in the form of NO_3^- washed with the sediments into the river. Musau (1981) showed that annual NO_3^- levels in rivers closely follow annual levels of fertilizer application within the catchment.

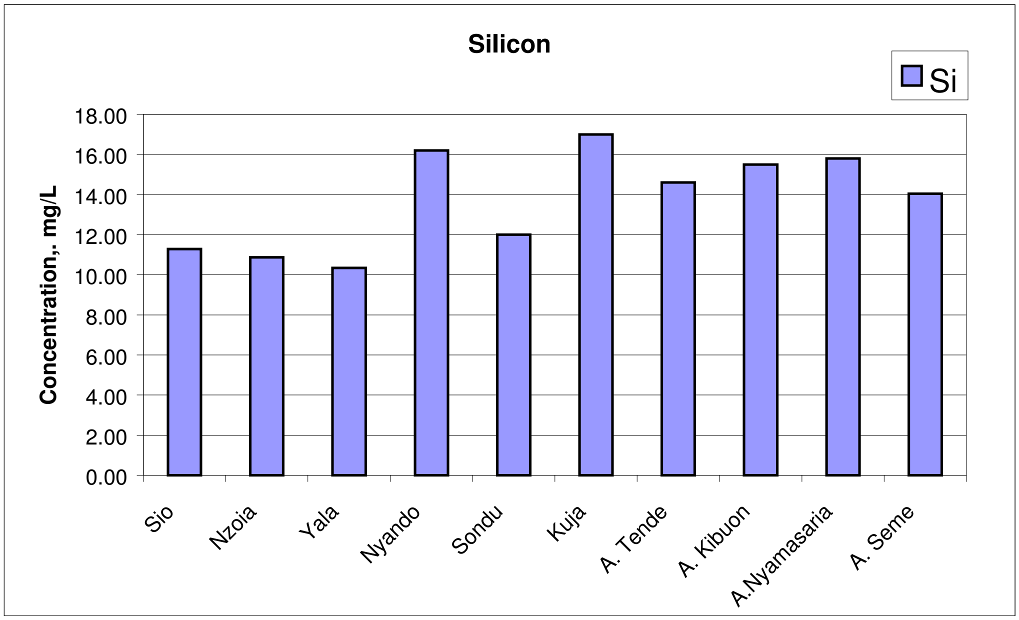

Fig. 2: Shows average silicon concentration in the rivers in the Kenyan catchment of Lake Victoria

The upper catchments of these rivers are fairly hilly and this adds to the erodability. As Chakela and Stocking (1988) observed that slope and rainfall are the dominant factors that largely explain the variation in soil erosion. Lamb (1999) reported that some of the fertilizers applied to agricultural lands is transported into streams by run off and sometimes represent up to about 80%. Mason (1981) showed that the loss of phosphates by leaching from agricultural land is very small, so that the input to rivers is largely by erosion.

Sio River contributes very low suspended sediments load compared to the other rivers even during its high flows, this possibly is because it passes mainly through areas with clay soils that normally do not release a lot of suspended solids. Catchments of Awach Kibuon, Awach Tende seem to have undergone the worst destruction and have a lot of soil loss into the rivers. Catchments of Nzoia, Kuja and Nyando have also suffered degradation.

River Nyando gave the highest Total Phosphorus values. This is possibly due to the high effluent loads, both domestic and industrial it receives around Muhoroni and high TP and TN doses of fertilizers applied in the catchment. Golterman (1993) reported that next to natural origin of phosphate, human excreta and detergents are the second most important sources of phosphate in rivers. River Nyando receives most of its point pollution sources from around Muhoroni area, which is less than 50km from the monitoring station, so high level of point pollution was noted.

The discharge of phosphorus into Lake Victoria possibly is the main factor for eutrophication. Dillon and Rigler (1974) found a linear relationship between phosphorus and chlorophyll: $\log_{10}[chl] = 1.583\log_{10}[P]-1.134$. Calamari *et al.* (1995) also noted that phosphorus is the limiting factor for primary production in Lake Victoria. The Silica values obtained are within the normal range found in rivers, which is between 1 to 30 mg/l (WHO, 1987).

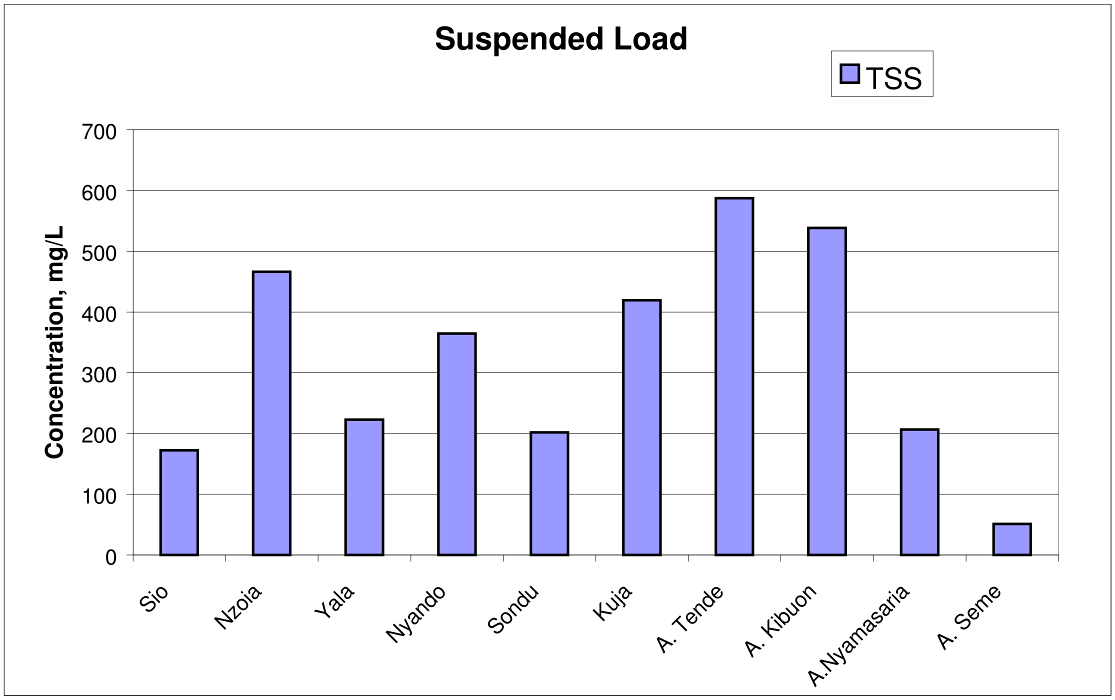

Fig. 3: Shows average Total Suspended Sediments load concentration in the rivers draining the Kenyan catchment of Lake Victoria.

The values obtained for the Total Nitrogen is in agreement with general values for African rivers, which show Nitrate (NO_3) of about 0.8 mg NO_3/l (UNEP, 1995)

Higher nutrient levels recorded in rivers during rainy months than dry months indicate significant contribution from diffuse sources while stations, which show little variation, indicate that their main sources are from point sources.

At upper stations of Nzoia, in the areas in Trans-Nzoia and Uasin-Gishu District the total Nitrogen values are high. However, due to the length of the river the final load measured at the last station is low because of reduction along the way.

In dealing with environmental management issues, care must taken so us to understand the system being managed. In most cases standards set for river water quality should not be used to conclude on the quality of the receiving body of water, say a lake.

The determination of load in a lake should result in the ability to produce a mass balance which provides an insight into the proportional contributions of different sources and which allows a control strategy to be optimised (Chapman, 1992).

The concept of loads with respect to river inflows to lakes and the impact on local lake water differs with the water discharge quantity and contaminant concentration. The effect in the whole lake will also depend on the size of the lake.

1. In case of a river with high water volume but having low contaminant load there will be slow, whole lake deterioration because of the overall high load. In such a case, there will be no effects on biota in the river since the concentration is low.
2. For rivers of low water volume, with high contaminant concentration there will be an overall low load, which will cause impairment only close to river input. In this case real effects will be observed on the biota in the river due to the high concentrations in a low water volume, but this in turn does not necessarily imply degradation of the whole lake, which may adequately accommodate the low load, delivered. Here some form of control would be applied to the river input, which would not apply under case 1 above, which actually represents a far worse condition for the general lake quality.

In the present study therefore, big rivers like Nzoia with low Total Nitrogen value have worse effects on the lake than the small river like Awach Kibuon, which has low discharges, but with high contaminant concentration (Total Nitrogen).

Conclusion

- Most rivers in the Kenyan catchment have high suspended solid loads.
- There is serious soil cover destruction in Kisii highlands and upper parts of Nzoia and Nyando rivers.
- River Sondu has low pollution loads from point sources.
- Rainfall, slope and land use patterns influence the level of soil erosion and release of nutrients into water bodies.

Recommendations

1. Intervention measures are required to arrest further deterioration of the catchment, particularly destruction of soil cover and poor land use practices.
2. Proper agricultural methods in the catchment should be practised. Soil conservation activities in the highly degraded catchments should be encouraged including in cooperation of buffer zones.
3. Integrated approach to catchment protection and planning should be emphasised.
4. Further studies to be conducted to assess the effects of the ongoing intervention measures by different Components of LVEMP.

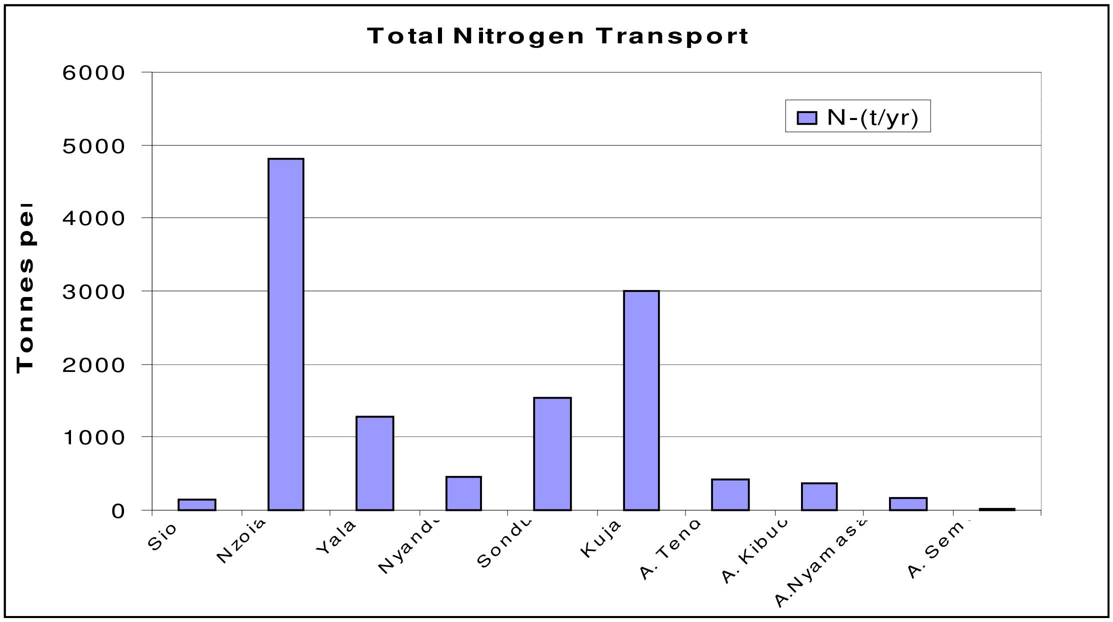

Fig. 4: Shows the average annual transport of Total Nitrogen into Lake Victoria from the Kenyan catchment in tonnes per year.

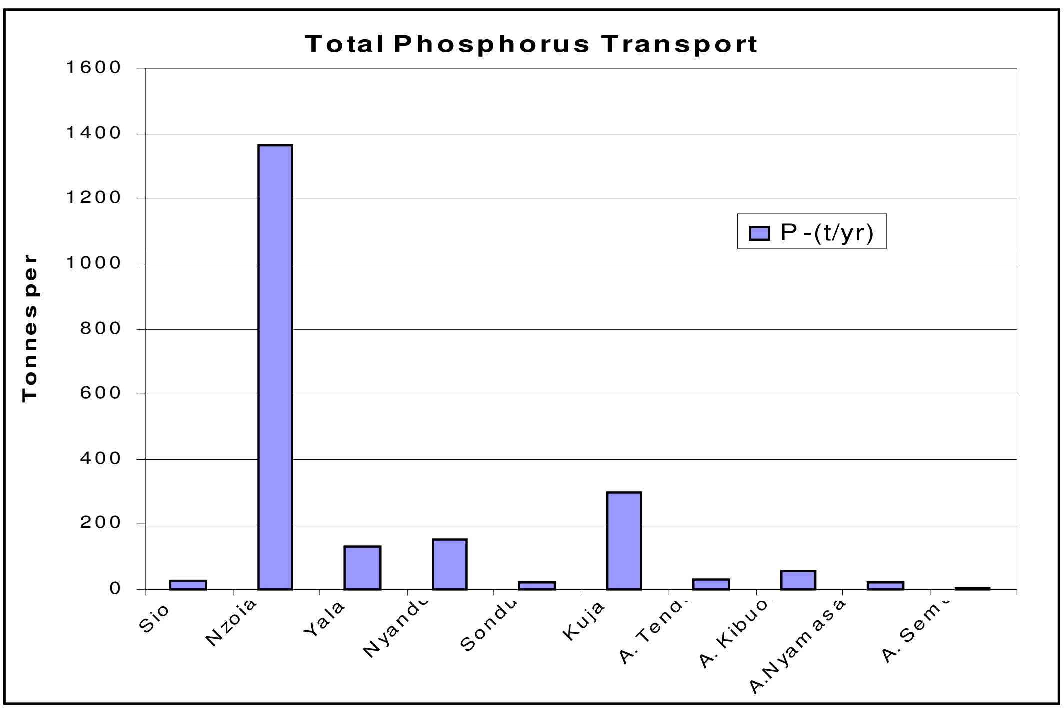

Fig. 5: Shows the average annual transport of Total Phosphorus into Lake Victoria from the catchment in tonnes per year.

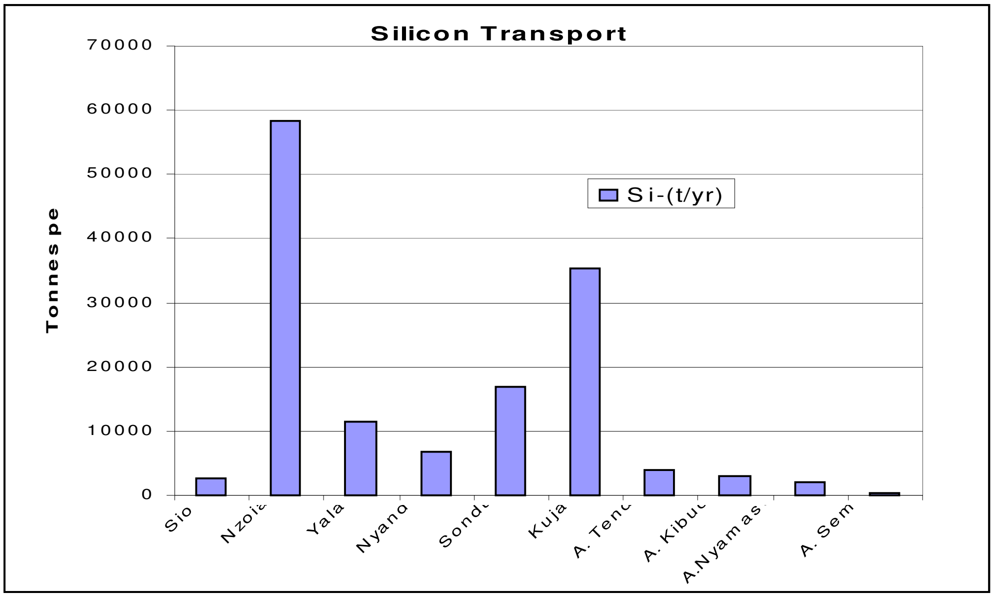

Fig. 6: Shows the average annual Silicon transport into Lake Victoria from the catchment in tonnes per year

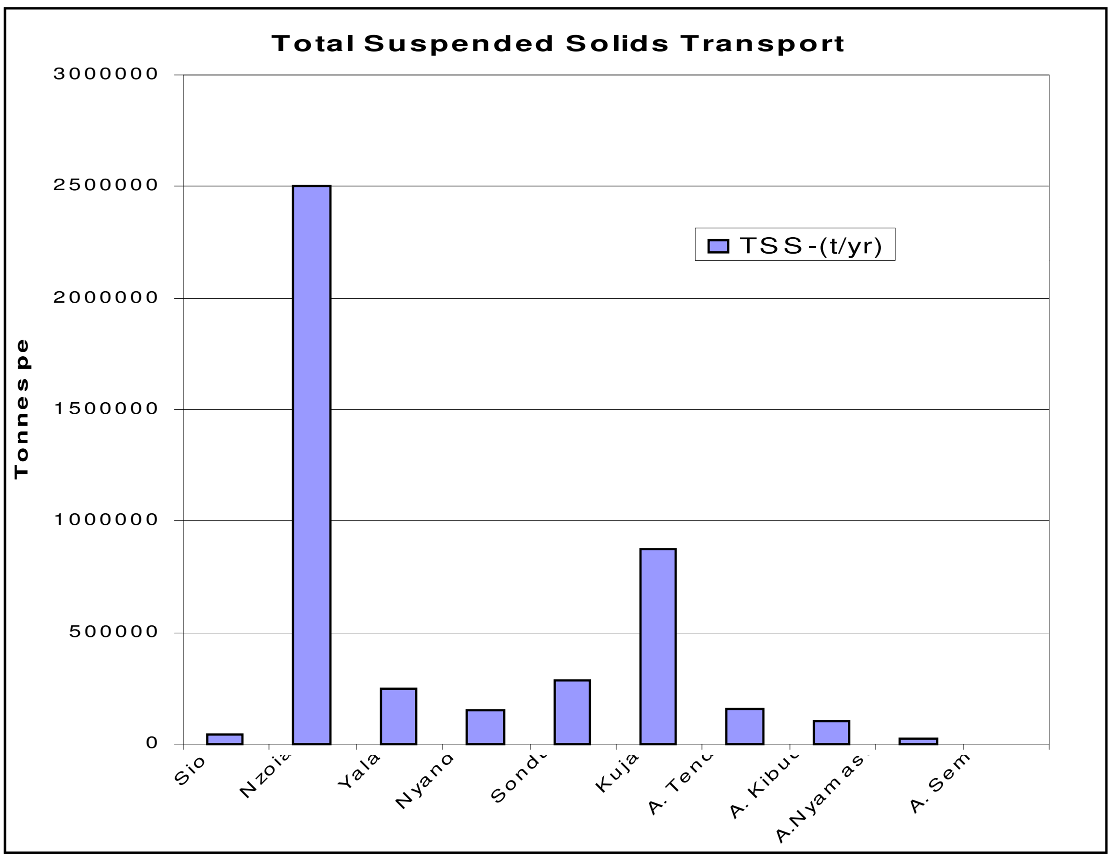

Fig. 7: Shows average Total Suspended Sediment load into Lake Victoria from the catchment in tonnes per year. The contribution of Awach Seme of 1429 tonnes per year is so small compared to the others that it is not seen in the scale.

Acknowledgement

The Authors sincerely thank LVEMP for putting relevant facilities in place which made it possible for the Scientists to gather data for the study and writing of this paper.

Special thanks go to the staff of Water Quality Component particularly Management of Pollution Loading personnel who generated both the analytical and hydrological data. We are also grateful to the Project Manager, Water Quality Component for his encouragement.

References

Afulo Otieno A.T, 1995. Pollution of lake Victoria by inorganic fertilizers used in West Kano irrigation Scheme, a MSc. Thesis , Moi University

Bullock, A., Keya, S.O., Muthuri, F.M., Bailey-Watts, T., Williams, R. and Waughray, D., 1995. Lake Victoria Environment Programme Task Force II. Final report by the regional consultants on Tasks 11, 16 and 17 (Water quality, land use and wetlands). Wallingford, U.K: Centre for Ecology and Hydrology (CEH) and FAO.

Calamari, D. Akech, M.O. and Ochumba P.B.O., 1995. Pollution of Winam Gulf, Lake Victoria, Kenya: A case study for preliminary risk assessment. Lakes & Resevoirs: Research and Management 1995 **1**: 89-106.

Chabeda, P.I.M, 1984. A survey of Eutrophication and Water Pollution in four rivers in the Northern half of the Lake Basin. Lake Basin Development Authority, Kisumu.

Chakela, Q. and Stocking, M., 1988. An improved methodology for erosion hazard mapping Part II. Application to Lesotho. Geogr. Ann 70 A(3) 181-189

Chapman, D., 1992 (Eds).Water Quality Assessment – Aguide to use of biota, sediments and water in environmental monitoring.

Chin Ong, Smithson, P., and Michele, S., 2000. Assessment of Sediment and Nutrients in River Nyando in Improved Land Management in the Lake Victoria Basin. Final technical Report, ICRAF.

Golterman, H.L. (1993). Aquatic ecosystems, Physiological Limnology, 1993, IHE,Delft, The Netherlands.

JICA, 1992. The Study of The National Water Master plan, Data Book (DB.1). Hydrological (Study Supporting) Data. Repubulic of Kenya, Ministry of Water Development.

LVEMP, 1995. Lake Victoria Environmental Management Project Document, Governments of Kenya, Uganda and the United Republic of Tanzania.

Lamb, J. C., 1999. Water quality and its Control. IHE, Delft, The Netherlands

UNEP, 1995. GEMS Water Quality of World River Basins, UNEP Environment Library No. 14, Nairobi.

Van den Bosch, H., Gitari, J.N., Ogaro, J.N., Maobe, S. and Vlaming, J., 1998. Monitoring nutrient flows and economic performance in African farming systems (NUTMON) III. Monitoring nutrient flows in three districts in Kenya. Ag. Ecosyst. & Env. **71**: 63-80.

WHO, 1987. GEMS, Global Environmental monitoring System. Water operational Guide, Geneva.