Buffering Capacity Studies in a Rural and Urban Wetlands in Lake Victoria Catchment in Uganda

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ABSTRACT

Wetlands are known to filter water from catchments by retaining solid waste, and eroded sediments from catchment areas. Wetlands also reduce the impact of flooding, speed of flow, and hence store water while releasing it slowly. The extent to which the wetlands perform these roles was investigated in two wetlands, Kinawataka wetland with an industrial and heavily populated catchment, and Kisoma wetland with subsistence agricultural catchment between January 1999 to July 2001.

Water samples were collected once a month from streams entering the wetlands, along transects within the wetland and at the out flow. Parameters investigated included pH, temperature, dissolved oxygen (DO), electric conductivity (EC), Total Dissolved Solids (TDS), orthophosphates, Total Phosphorus (TP), nitrates, Total Nitrogen (TN) and chemical oxygen demand (COD).

Results showed that the urban Kinawataka wetland receives a lot of pollution from its catchment and this is considerably reduced as the water move through it to the out flow. Reductions of TN by 50% and TP by only 10% were noted. The rural Kisoma wetland however receives fewer nutrients from its catchment but releases more in its out flow. There were increases in orthophosphates to about 50%, TP to 40% and nitrates to 22%. In situations where large volumes of water was received especially after a heavy storm or during floods, the wetland capacity to buffer was impaired and the materials from the catchment would pass through it unbuffered.

It is suggested that wetland buffering depends on the amount of nutrients and water inflow from the catchment, the wetland-slope, nature of the vegetation, size of the wetland, catchment rainfall and anthropogenic characteristics. The conditions within the wetlands modify the nature of the nutrients as the water flow through them.

Key words: Buffering capacity, wetland buffering, catchment, reservoir, nutrients

INTRODUCTION

The availability of usable fresh water depends on, *first* its replenishment on land as rain and other forms of precipitation from the clouds, and *secondly* the period it remains on land, in rivers, lakes, wetlands, ground water and in the atmosphere (Beadle, 1981). The areas where water stays long enough to cause distinct ecological characteristics from the upland are its reservoirs. The water from an upstream catchment is usually fast and contaminated with dirt, sediments, nutrients and other pollutants it dissolves as it moves downstream. Before it reaches any of the reservoirs such as, ground water, streams, rivers, or lakes, it gets into systems which slow it down and filter it to modify the excess pollutants, nutrients loads and sediments. These systems are called wetlands. They remain wet for long periods and although they act as reservoirs, they function to purify the water before it is re-used. They are the ecotones between the land and the water reservoirs (Mitsch & Gosselink, 1993; Wetzel 1991). They modify whatever the water comes along with from the catchment before it continues to other reservoirs. This permits the water to be used again and prevents the reservoirs from getting contaminated by the materials brought by the water. This very important function is performed naturally by wetlands. Buffering capacity of wetlands therefore refers to all the processes through which wetlands reduce the impacts of substrates that move with the water from the catchment area to the receiving reservoir. Technically, buffering capacity of wetlands cuts across a variety of disciplines ranging from physical, hydrological, biological to chemical processes.

Wetlands are known to act as buffers in several ways. They slow down the speed of the runoff water passing through them. As this happens they remove nutrients and prevent the rapid accumulation of these substances to the water bodies where the water is flowing. Buffering as applied to wetlands functioning involves several mechanisms with varying levels of efficiency depending on a combination of factors such as hydrologic load and nature of the wetland. Although it is appreciated today that the wetlands carry out this function, the extent to which they do so is not clearly understood. This study aimed at providing information on the aspects through which the wetlands are able to carry out the buffering of the water from the catchment to reservoirs.

MATERIALS AND METHODS

The study investigated two wetlands with catchment characteristics likely to cause impact into water reservoirs. These were Kinawataka wetland with an urban industrial and densely populated catchment and Kisoma wetland with a rural agricultural and pastoral catchment.

Kinawataka wetland is located 5 km from the eastern region of Kampala City along Jinja road lying between latitude 0°20'00"N to 0°.20'50"N; and from longitudes 32°37'40"E to 32°38'45"E. The study area (Figure 1) of about 1.5 km^2 is part of the 4.6 km^2 of Kinawataka which fringes Lake Victoria and protects the water quality of the inner Murchison bay from catchments inputs of Ntinda, Nakawa, Kyambogo, Naguru, Kireka, Mbuya, Mutungo, Luzira and Butabika. The wetland vegetation is dominated by *Cyperus papyrus* with patches of *Phragmites* spp., *Echnocloa* sp, and *Afromomum* sp. *Phoenix* sp and other sedges do appear mixed in the vegetation. The part of wetland studied (Figure 1) is fed by four major streams including Fuwengombe, Kinawataka, Vubyabirenge and Kawoya. There is only one main outlet stream- Kinawataka. This gave an opportunity to study what goes into the wetland, what is inside and what comes come out of the wetland. The wetland being in an urban catchment receives mainly municipal and industrial wastes from streams that drain from residential settlements and industrial zones of Kyambogo, Banda, Kireka and Ntinda. Two transects of about 300 m long and about 50 –70 m apart were carefully cut to allow access without sinking into the mud. Water samples were collected from all the inflow streams at three points transversing within the transects.

The other study area was Kisoma wetland found in Rakai District in western Uganda lying between 0° 38' 57 S and 0° 40' 50 S and between 031° 29' 04 E and 031° 32' 01 E. Kisoma wetland (Figure 2) is fed by four major streams namely Kagonga, Kafamboga, Kisoma and Luanda. There is one main outlet at Kisoma bridge along Kyotera – Mutukura road. The wetland is part of the Naludugavu wetland system of about 5km^2 and drains into Lake Victoria. The vegetation is dominated by (95%) *Cyperus papyrus* and other sedges do appear mixed in the vegetation. In this area, indigenous cattle are kept under nomadic pastoralism. Deforestation and cultivation on hilltops/ slopes accelerate soil erosion and silting of water bodies. Water samples were drawn from each sampling point using the integrated sampling methods (Wetzel, 1991). Standard scientific methods were then used for the nutrient analysis at the central laboratory for National Water and Sewarage Corporations, Bugolobi. The parameters investigated during the study included water discharge, pH, Temperature, EC, TN, TP, Ammonia, Orthophosphates, TDS, COD. Sampling

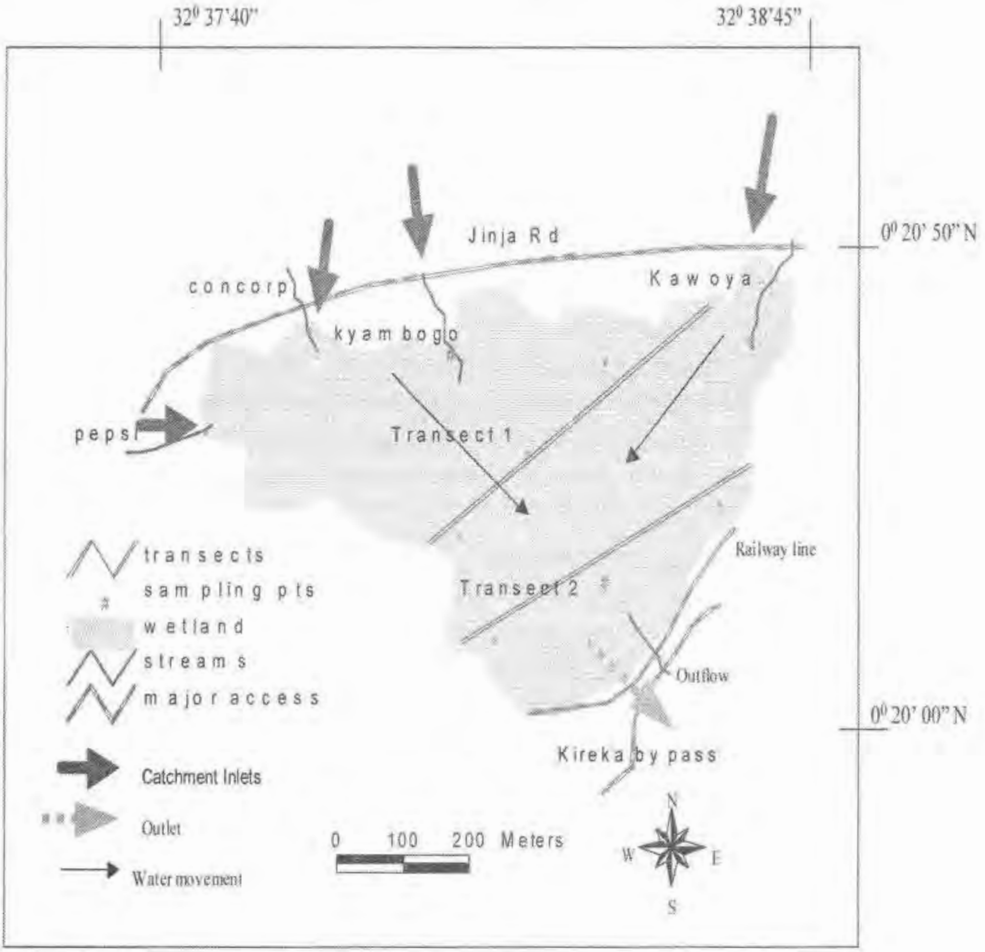

Figure 1. Kinawataka Wetland

was done at least once a month for 15 months. Hydrological discharge measurements were obtained using a discharge-metered propeller while the hydrological flow gauges were read from fixed gauges twice everyday at 9.00am and 3.00pm at all inflow streams and at the outflow of the wetlands.

RESULTS

Table I shows the summary of the results as obtained from all the inflows, the transects and the outflow from Kinawataka wetland. The results in the table show reduction in the nutrient concentrations within the wetland. The sites at the side of the wetland, which include points of entry into the wetland, have a

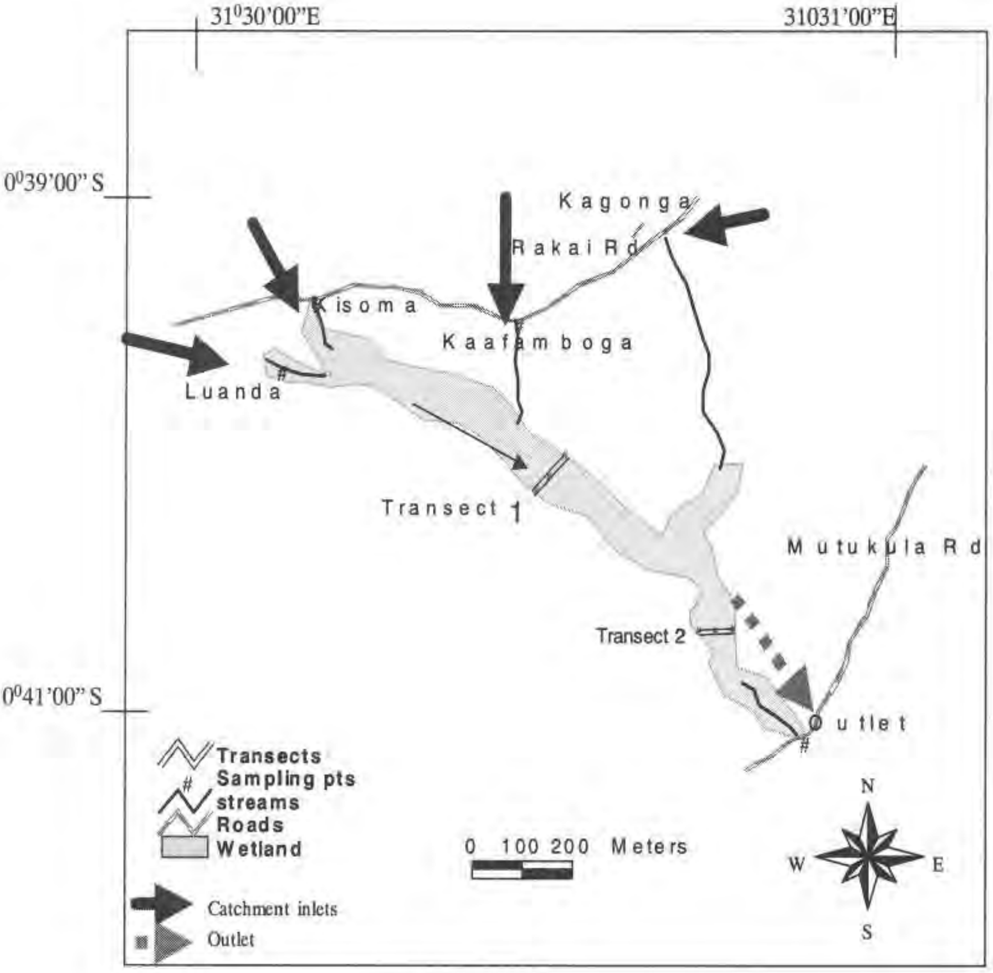

Fig 2. Kisoma Wetland

high concentration. An imaginary plot following (the direction of flow) of the mean values of the concentrations on Kinawataka map (Fig.1) shows levels of reduction in the total nitrates and phosphates as the water moves along the wetland. Tables I and II show the distribution of other nutrients like orthophosphotes and ammonium nitrates, which increase towards the outflow.

Table 1. Mean nutrient measurements from Kinawataka Urban Wetland between May 1999 – July 2001(In parenthesis is the sample size)

Sites	**EC** (uS/Cm)	**PO4** (mg/l)	**TP** (mg/l)	**NO_3** (mg/l)	**NH_3** (mg/l)	**TN** (mg/l)	**COD** (mg/l)
Pepsi	534.8 ± 51	0.68 ± 0.1	2.7 ± 0.9	0.25 ± 0.1	2.1 ± 0.6	72.1 ± 23.3	254.7 ± 4.6
Rwenzori	347.7 ± 27	0.47 ± 0.1	2.8 ± 0.8	0.24 ± 0.1	2.2 ± 0.5	75.8 ± 25.9	75.6 ± 17.8
Concorp	276.2 ± 30	0.28 ± 0.1	1.6 ± 0.5	0.39 ± 0.1	2.1 ± 0.4	76.4 ± 32.8	99.1 ± 29.3
Kyambogo	246.3 ± 17	0.20 ± 0.1	1.5 ± 0.5	1.48 ± 0.1	3.8 ± 0.6	76.9 ± 23.0	67.1 ± 42.3
Banda	275.7 ± 19	0.25 ± 0.1	1.6 ± 0.5	0.93 ± 0.1	2.4 ± 0.9	78.2 ± 29.7	68.2 ± 32.9
T1 - 1	294.8 ± 15	0.51 ± 0.1	2.7 ± 1.5	0.00	2.3 ± 0.7	52.9 ± 11.7	86.1 ± 20.3
T1 - 2	291.0 ± 9	0.94 ± 0.3	1.8 ± 0.6	0.00	2.5 ± 0.5	47.9 ± 13.3	235.3± 93
T1 - 3	299.2 ± 12	0.54 ± 0.2	1.7 ± 0.5	0.00	3.3 ± 1.4	62.9 ± 16.9	161.8 ± 41
T 2- 1	277.8 ± 14	0.38 ± 0.2	2.6 ± 0.9	0.31 ± 0.2	2.6 ± 0.7	48.6 ± 13.4	110.6± 35.1
T 2- 2	269.5 ± 14	0.57 ± 0.2	1.7 ± 0.3	0.15 ± 0.1	3.4 ± 0.5	49.1 ± 10.6	69.3 ± 18.1
T 2- 3	296.0 ± 9	0.46 ± 0.1	1.1 ± 0.2	0.14 ± 0.1	2.7 ± 2.8	42.8 ± 10.4	113.9 ± 29.7
L. Bank	187.2 ± 16	0.11 ± 0.1	0.5 ± 0.1	6.95 ± 5.9	0.8 ± 0.7	34.9 ± 6.8	67.7 ± 17
R. Bank	133.3 ± 13	0.13 ± 0.1	0.5 ± 0.1	0.69 ± 0.1	1.4 ± 0.8	25.6 ± 8.2	100.7 ± 34.2
Outlet	289.3 ± 15	0.35 ± 0.1	1.7 ± 0.7	0.24 ± 0.1	2.3 ± 0.6	38.0 ± 10.3	93.3 ± 35.4

Table II. Mean nutrient measurements from Kisoma Rural Wetland between May 1999 – July 2001 (In parenthesis is the sample size)

Site	**EC**	**PO4**	**TP**	**NO^+_3**	**NH^+_4**	**TN**	**COD**
	(uS/Cm)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)
Kagonga	96.4 ± 11.6	0.35 ± 0.1	1.38±0.5	0.21±0.1	5.8± 2.3	48.9± 9.8	55.6 ± 10.5
Kaafamboga	124.8 ± 13.6	0.58 ± 0.3	1.91±0.8	0.17±0.1	3.5± 1.6	39.2± 6.6	130.6 ±38.9
Kisoma Upper	413.5 ± 74.5	0.35 ± 0.1	0.79±0.2	0.15±0.1	3.0± 1.04	4.4 ± 11	102.9 ±25.6
Luanda	225.2 ± 14.2	0.35 ± 0.1	0.94±0.3	0.19±0.1	2.6± 0.6	47.9±10.7	63.6 ± 11
T1 - 1	214.3 ± 35.8	0.28± 0.03	0.83±0.2	0.03±0.02	0.6 ± 0.2	73.0±13.9	52.5±13.5
T1 - 2	194.8 ± 30.8	0.1 ± 0.02	0.97±0.3	0.02±0.01	0.5 ± 0.1	87.5±17.2	71.4± 21.9
T1 - 3	180.8 ± 32	0.11 ± 0.1	0.73±0.2	0.04±0.03	0.4 ± 0.1	97.1± 15.9	42.3 ± 11
T 2- 1	256.0 ± 17	0.62 ± 0.3	1.86±1.1	0.12±0.04	1.1 ± 0.4	42.5±10.7	64.3±15.1
T 2- 2	210.5 ± 7.2	0.33 ± 0.2	0.98±0.3	0.17±0.1	1.2 ± 0.4	48.6±14.9	83.7±23.7
T 2- 3	178.5 ± 18.1	0.27 ± 0.1	0.92±0.3	0.15±0.1	1.3 ± 0.4	39.0±10.6	53.8±13.3
KisomaOutlet	229.8 ± 22.3	0.63 ± 0.2	1.81±0.7	0.22±0.1	0.9 ± 0.3	37.3±8.2	61.1±13.9

The Electrical Conductivity (EC) measured in the sampling sites of Kinawataka wetlands showed varying levels within the wetland. Highest EC was recorded from the streams (Figure 1), that received effluents from Pepsi factory, Industrial stream at Concorp and Kyambogo (Table 1). As the streams flow into the wetland, the water spreads diffusely and the EC reduces within the wetland. A reduction in EC was followed by its increase at the downstream of the wetlands, (Figure 3), which implies that the water was enriched with pollutants after a reduction along transects within the wetland.

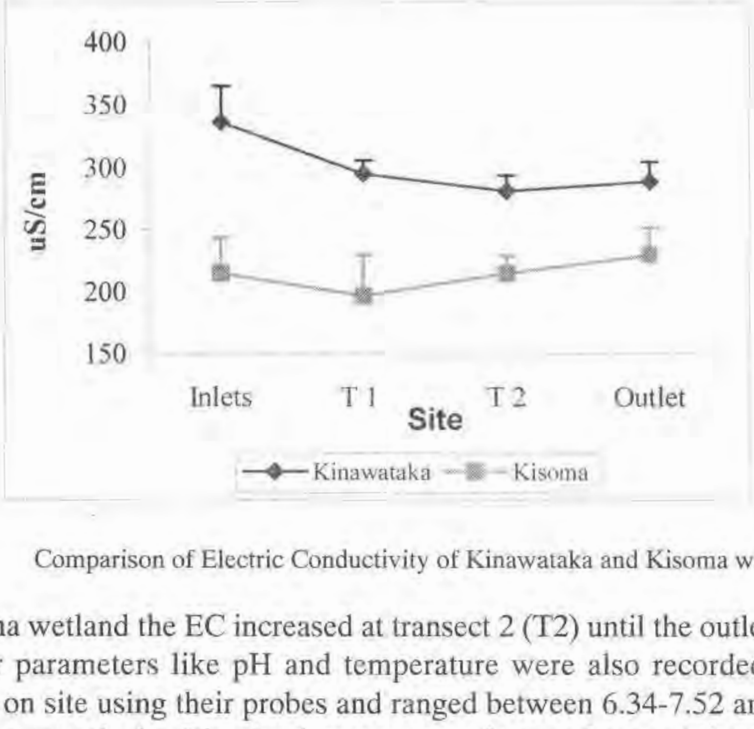

Figure 3. Comparison of Electric Conductivity of Kinawataka and Kisoma wetlands

At Kisoma wetland the EC increased at transect 2 (T2) until the outlet (Figure 3). Other parameters like pH and temperature were also recorded in both wetlands on site using their probes and ranged between 6.34-7.52 and 20.2°C – 24.9°C respectively. Dissolved oxygen was low and ranged from 0.1mg/l within the wetland transects to 1.5 mg/l at the outflow. Little variation was noted in the water temperature and pH. Water temperature ranged between 17 °C and 23°C.

At Kinawataka, streams that flow into the wetland were characterised by inflows of a high concentrations of total phosphorus and total nitrogen as compared to Kisoma wetland inflow concentrations (Figures 4). These are gradually reduced along the wetland towards the outflow but an increase in TP was observed in Kisoma Wetland. In the case of total nitrates (Figure 5), the wetland reduced the concentrations by about 50% by the time water moved out of the

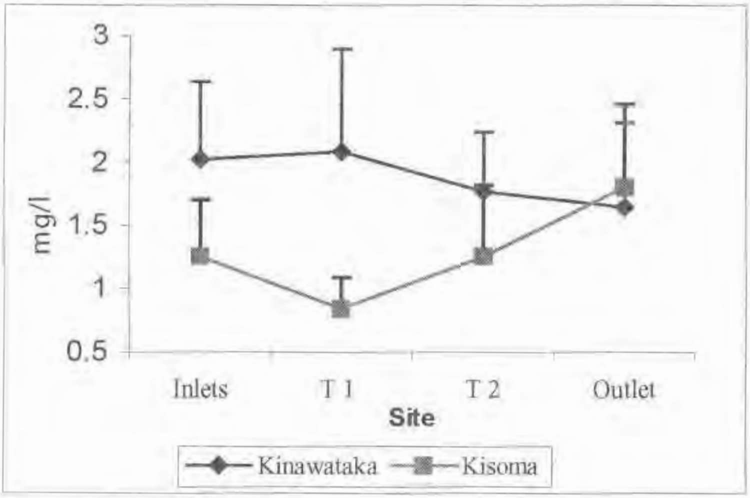

Figure 4. Comparison of Total Phosphorous (TP) in Kinawataka and Kisoma wetlands

wetland while the Total Phosphorus was reduced by about 10% (Table I) in Kinawataka wetland.

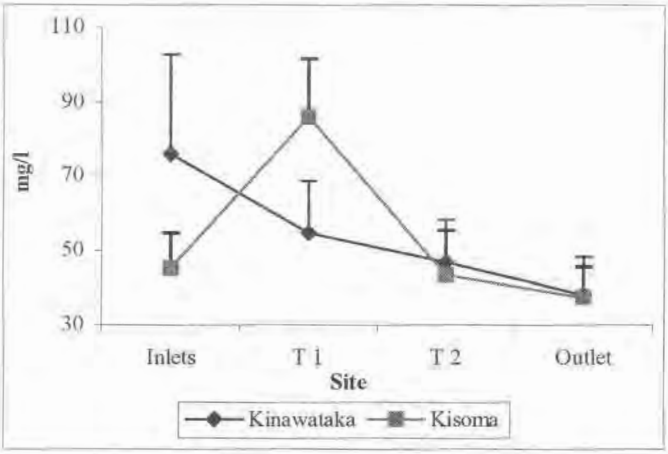

Figure 5. Comparison of Total Nitrogen (TN) in Kinawataka and Kisoma wetlands

There was however, a fluctuating content of ammonium nitrogen and orthophosphates (Figure 6 a&b) as water gradually flows further downstream and an increase in the COD at the transect 1. Orthophosphates increased at transect 1, while it reduced as the water flow towards its exit from the wetland.

There were fluctuations in the concentrations of the NH_4+ and the PO_4^{3}- within the wetland, together with subsequent decrease in concentrations at the outflow.

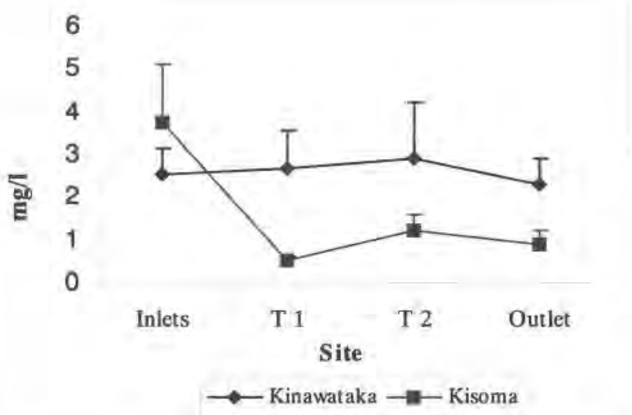

Figure 6a. Ammonium ions (NH3) for Kinawataka & Kisoma wetlands

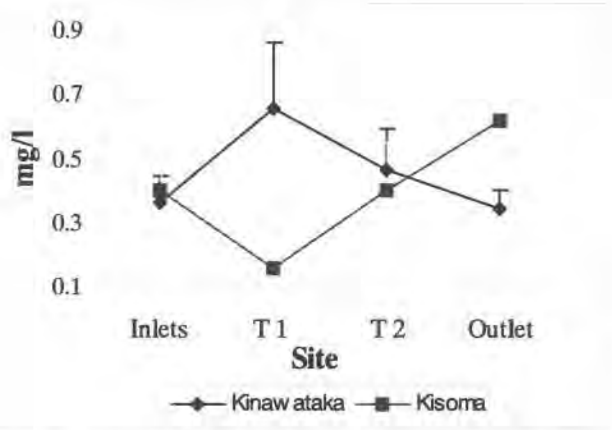

Figure 6b. Comparison of Orthophosphate in Kanawataka and Kisoma Wetlands

In Kisoma, a mean representing the inflow was obtained from the streams Kagonga, Kafamboga, Kisoma Upper and Luanda streams. Kagonga stream had the highest mean input of TP, NO_3, NH_3, TN, and COD while Kisoma Upper contributed the lowest concentrations of O-PO_4^{-}, TP, NO_3, and NH_3 but had the highest COD input. Compared to inflow concentrations, O-PO_4^{-}, TP and NO_3^{-} increased by 50%, 40% and 22%respectively, while the wetland reduced NH_3, COD and TN by 76%, 67% and 20% respectively.

DISCUSSION

Catchments have a regulatory influence on lakes in terms of nutrients and organic matter inputs (Wetzel, 1983). The activities of the catchment relate to the concentration of nutrients entering the wetlands. At Kisoma wetland, low nutrient concentrations were recorded at the inflow into the wetland but the outlet had higher concentrations. A number of reasons may be attached to this trend. Wetland vegetation can remove but can also store substantial amounts of nutrients. As they do this they potentially release nutrients to downstream ecosystems. This rise in nutrients down stream may also be due to anoxic conditions created by detritus feeding and break down of organic matter by organisms staying in the wetland with low oxygen tension (Barugahare, 2001).

The physical environment within the wetlands (transects) facilitate the changes in the nutrients chemistry and nutrient transformation processes take place and they contributed to apparent increase or decrease in concentration levels of certain parameters. Therefore the nutrients are released autochthonously resulting from the decomposition within the wetland. Parameters such as TSS of a wetland often reflect the trend of sediment removal by the wetlands and not the type of nutrients in the in-flowing waters. To an observer, TSS is a good indicator of buffering. In both wetlands, the high concentration of TSS measured at their inflow was considerably reduced by the wetland.

Reduction in the EC within the wetlands may be due to ionic removal by plants from the water passing through the wetland (Reddy and Smith, 1987). However some chemical processes which require oxygen (Figure 6) may be responsible for the decomposing and release of other forms of nutrients into the water (Okurut, 1999). Subsequent increases of the nutrients detected within the wetlands may be due to such releases or an external inflow joining the wetland at certain points not easily detectable but can be traced to point source. It is suspected for the case of Kinawataka, that the increase of electrical conductivity towards the outflow might be associated with the dumping and infilling of the excavations resulting from stone mining, and filling of excavations with garbage and industrial wastes. The leachate from the dump may be entering the wetland between transect 2 and the outflow. The low spring inflows from the left and right banks of the wetland have little impact on the dilution of the cumulative nutrients at this stage. The EC changes also show the diffuse movement of water within the wetland. Similar explanations explain the increase of

EC within the wetland at Kisoma. There may be an inflow not detected during sampling, that may be enriching the system with nutrients and it is suggested that this should be traced to the source using electrical conductivity.

Nutrient uptake by wetlands was demonstrated by the very high concentrations of nutrients entering Kinawataka wetlands and their reduction within the system as water moved down stream. The nutrients are modified within the wetland and are considerably reduced as water moved out of the wetland. Similar results were observed by the studies of nutrient removal from wetlands (Kansiime and Nalubega 1999). The reason for the high concentration of nutrients entering the wetland is associated with human activities in the catchment. There is a big industrial estate at Ntinda - Kinawataka that presumably does not have proper pre-treatment facilities for their organic waste. It has also been observed that the effluents coming out of Kyambogo estates are very rich in faecal coliform and total phosphates probably because of raw and partially treated domestic sewage entering into the streams, flowing into Kinawataka (Opio, 2001). The high nutrient recording at Pepsi factory may be due to the hydroxides used to wash the soda bottle at the factory (Kansiime and Nalubega, 1999). Orthophosphates increase downstream and reduction of Total Nitrogen in both wetlands has been realised during this study. The existence of aerobic-anaerobic interface near the wetland soil surface greatly facilitates the coupling of nitrification and denitrification which facilitate the removal of inorganic nitrogen as both nitrate and ammonium (DeBusk, 2001).

The functioning of an urban wetland may not necessarily be similar to wetland with a rural catchment. The capacities to deal with what goes-on in the wetlands depend on the discharge from the catchment. Inflows depended a lot on catchment rainfall in Kisoma wetland, but for the case of Kinawataka, the effluents from industries and residential estates supplement the catchment discharge to an extent that there is a high input into the wetland through the year. During the dry season considerable discharge into the wetland was recorded for Kinawataka while little or no discharge would be entering Kisoma. The sizes of the wetlands together with their topography are other factors that control speed and retention wastewater from catchment. Wetlands with small area receiving a lot of storm water would have their buffering function impaired because their capacity to deal with floods, and excess nutrients from catchment temporarily stops. In this case the wetland has exceeded its buffering capacity and would no longer be carrying out the buffering function. This was observed to be common during the rainy seasons in the urban wetlands.

In conclusion, wetlands are very important because they buffer Lake Victoria. Kinawataka buffers the inner Murchison Bay, which is a source of drinking water for Kampala City. It has been demonstrated during this study that some pollution from the catchment can be retained by the wetland thus preventing the impact that would happen in the reservoir, Lake Victoria. Results of this study are therefore very important in explaining the ecological significance of wetlands and the role they play in filtering the contaminated flow. It is important to note that wetlands have a limited capacity to adequately deal with whatever comes with the flow. Although a considerable nutrient reduction modification has been observed in both wetlands studied, it is necessary to control the kinds of pollutants that may be released from the catchment area. Therefore, for wetlands to perform well as buffering ecotones for lakes, a well-designed catchment management practice is recommended for the case of Kinawataka urban wetland by instituting pre-treatment facilities for the industries and residential wastewaters, after which, the wetland would carry out the function of the tertiary treatment of the wastewaters for the safety and maintenance of the water quality of Lake Victoria. In the case of Kisoma wetland, a good land use management practice with well planned soil water conservation method is recommended.

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