Buffering capacity studies in a rural and an urban wetland in Lake Victoria catchment, Uganda

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Abstract

Wetlands are known to filter water from catchments by retaining solid waste and eroded sediments from catchment areas. They reduce the impact of flooding, speed of flow, and hence store water while releasing it slowly. The extent to which the wetlands perform this role has been investigated in two wetlands, Kinawataka with an industrial and heavily populated catchment, and Kisoma with subsistence agricultural catchment.

Water samples were collected once a month from measurable streams entering the wetlands, along transects within the wetland and at the out flow. Parameters investigated included pH, conductivity, temperature, dissolved oxygen, electric conductivity, orthophosphates, total phosphorus, nitrates, total nitrogen and chemical oxygen demand.

Results showed that the urban Kinawataka wetland received a lot of pollution from its catchment and this was considerably reduced as the water moves through it to the out flow. Reductions of Total Nitrogen(TN) to about 50% and Total Phosphorus (TP) to about 10% were noted. The rural Kisoma wetland, however, received fewer nutrients from its catchment but releases more in its out flow. There were increases in orthophosphates to about 50%, TP to 40% and TN to 22%. In situations where wetlands received large volumes of water especially after a heavy storm or during floods, their capacity to buffer becomes impaired; hence materials from the catchment would pass through them un-buffered.

This paper discusses the performance of wetlands as buffering units for the reservoirs where the water is proceeding. 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 flows through them.

Keywords: Buffering capacity, wetland buffering, catchment, reservoir, nutrients

Introduction

The availability of usable fresh water depends, *first* on its replenishment on land as rain and other forms of precipitation from the clouds, and *secondly* the period it remains on land, rivers, lakes, wetlands, ground water and in the atmosphere (Beadle, 1974). The areas where water stays long enough are its reservoirs. Water will always find its levels while flowing from high altitudes to low areas (Wetzel, 1983). Water from an upstream catchment flows usually fast before it reaches the reservoirs. While flowing it collects and gets contaminated with dirt, sediments, nutrients and, other pollutants from areas where it passes. But before it reaches any of the reservoirs such as, ground water, streams, rivers, or lakes, it gets into wetland systems, which slow it down, and this facilitates the filtration of excess pollutants, nutrients loads and sediments. The wetlands remain wet for long periods because the water is not moving as fast as was the case in the upstream. They are the ecotones between the land and the reservoirs (Mitsch and Gosselink, 1993; Wetzel 1995). They modify whatever the water comes along with from the catchment before it continues to other reservoirs. The modification in the water quality involves removal of suspended solids and modification of nutrients, which makes the water to be used again, hence prevents the reservoirs from getting endangered by the materials the water could have come with. The wetlands therefore naturally act as "buffer zones" between the catchment and the reservoirs. Buffering capacity of wetlands therefore refers to the processes through which wetlands reduce the impacts that move with the water from the catchment area to the reservoir where the water is flowing. Technically, buffering capacity of wetlands cuts across a variety of disciplines ranging from physical, hydrological, biological to chemical processes.

Wetlands are known to buffer 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 going. Buffering as applied to wetlands functioning also involves 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 was aimed at investigating the aspects through which the wetlands can carry out the buffering function. Specifically, this study aimed at providing information on the buffering capacity of wetlands and baseline data for monitoring them.

Materials and methods

The study centred on investigating two wetlands with catchment characteristics likely to cause impact into water reservoirs. These were Kinawataka wetland (Figure 1) 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 part of Kampala City along Jinja road lying within UTM from 457 800, 39750 to 462 500, 33500. The study area 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 of Ntinda, Nakawa, Kyambogo, Naguru, Kireka, Mbuya, Mutungo, Luzira and Butabika.

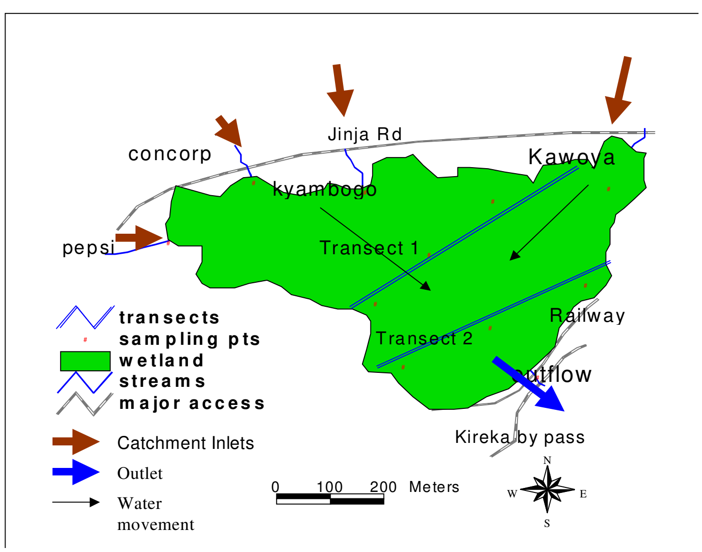

Figure 1. Kinawataka wetland

The wetland vegetation is dominated by *Papyrus* sp 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 was only one observable outlet stream- Kinawataka. This gave an opportunity to study what goes into the wetland, what is inside and what comes 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 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 3 points transversing 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 including 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%) *Papyrus* sp. 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.

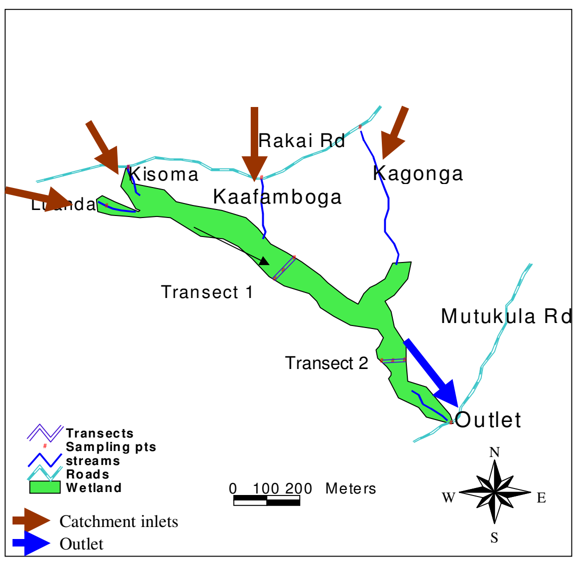

Figure 2. Kisoma wetland

Water samples were drawn from each sampling point using the integrated sampling methods (APHA, 1992). Standard scientific methods were then used for the nutrient analysis at the central laboratory for National Water and Sewerage Corporations, Bugolobi. The parameters investigated included discharge, pH, Temperature, Electrical Conductivity, Total Phosphates, Total Nitrates, Ammonia, Orthophosphates, Total Dissolved Solids and Chemical Oxygen Demand. Sampling was done at least once a month for 15 months except for hydrological discharge measurements which were obtained through field measurements using a dischargemetered propeller and hydrological flow gauge readings taken twice everyday at gauges fixed at all inflow streams and at the outflow of the wetland.

Results

Table 1 shows the summary of results 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 high concentration. An imaginary plot following (the direction of flow) of the mean values of the concentrations on Kinawataka map (Figure 1) shows levels of reduction in the total nitrates and phosphates as the water moves along the wetland. Tables 1 and 2 show the distribution of other nutrients like Ortho-phosphates and ammonium nitrates, which increase towards the outflow.

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

Sites	**EC**	**PO4**	**TP**	**NO3**	**NH3**	**TN**	**COD**
	(uS/Cm^2)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)
Pepsi	534.8±51.5(16)	0.68±0.14(19)	2.73±0.9(19)	0.25±0.06(11)	2.12±0.62(14)	72.13±23.3(19)	254.74±4.6(19)
Rwenzori	347.7±27.4(15)	0.47±0.09(17)	2.76±0.8(17)	0.24±0.04(10)	2.2±0.53(13)	75.8±25.9(17)	75.59±17.8(17)
Concorp	276.2±29.7(16)	0.28±0.07(18)	1.6±0.5(18)	0.39±0.09(11)	2.05±0.42(13)	76.35±32.8(18)	99.13±29.3(18)
Kyambogo	246.3±16.9(16)	0.2±0.04(19)	1.5±0.5(19)	1.48±0.4(10)	3.76±0.6(14)	76.9±23(18)	67.1±42.3(18)
Banda	275.7±18.8(15)	0.25±0.05(18)	1.55±0.5(19)	0.93±0.44(11)	2.4±0.9(14)	78.2±29.7(19)	68.2±32.9(19)
T1 - 1	294.8±14.8(6)	0.51±0.1499)	2.7±1.5(9)	0.00	2.3±0.7(9)	52.94±11.7(10)	86.1±20.3(8)
T1 - 2	291±.9(6)	0.94±0.3(9)	1.84±0.6(9)	0.00	2.45±0.5(9)	47.88±13.3(10)	235.3±93(9)
T1 - 3	299.2±12.2(6)	0.54±0.19(9)	1.69±0.5(9)	0.00	3.31±1.4(9)	62.88±16.9(10)	161.78±41.1(9)
T 2- 1	277.8±14.4(11)	0.38±0.15(14)	2.59±0.9(14)	0.31±0.2(5)	2.64±0.7(11)	48.56±13.4(13)	110.6±35.1(14)
T 2- 2	269.5±14.8(11)	0.57±0.15(13)	1.7±0.34(14)	0.15±0.03(4)	3.4±0.5(11)	49.1±10.6(13)	69.29±18.1(14)
T 2- 3	296±9.5(11)	0.46±0.09(14)	1.1±0.2(14)	0.14±0.05(6)	2.7±2.8(11)	42.8±10.4(13)	113.9±29.7(14)
L. Bank	187.2±15.5(9)	0.11±0.03(10)	0.5±0.14(10)	6.95±5.9(6)	0.84±0.7(10)	34.93±6.8(11)	67.7±17(10)
R. Bank	133.3±12.9(7)	0.13±0.05(9)	0.5±0.12(10)	0.69±0.14(5)	1.4±0.75(7)	25.56±8.2(10)	100.7±34.2(9)
Outlet	289.3±15.2(15)	0.35±0.06(17)	1.65±0.7(17)	0.24±0.08(9)	2.32±0.6(12)	38± 10.3(17)	93.25±35.4(16)

Table 2. Mean ± SE of nutrient concentrations from Kisoma Wetland between May 1999 – July 2001 (In parenthesis is the sample size).

Site	**EC**	**PO4**	**TP**	**NO3**	**NH3**	**TN**	**COD**
	(µS/cm)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)
Kagonga	96.4±11.6(18)	0.35±0.1(21)	1.38±0.5(21)	0.21±0.1(14)	5.82±2.3(16)	48.9±9.8(21)	55.6±10.5(20)
Kaafamboga	124.8±13.6(17)	0.58±0.3(20)	1.91±0.8(19)	0.17±0.1(12)	3.5±1.6(16)	39.2±6.6(20)	130.6±38.9(19
Kisoma Upper	413.5 ±74.5 (15)	0.35±0.1(18)	0.79±0.2(18)	0.15±0.05(11)	3.02±1 (14)	44.4±11(18)	102.9±25.6(17
Luanda	225.2±14.2(16)	0.35±0.1(19)	0.94±0.3(19)	0.19±0.1(12)	2.61±0.6(16)	47.9±10.7(19)	63.6±11(18)
T1 - 1	214.3±35.8(6)	0.28±0.03(9)	0.83±0.2(9)	0.03±0.02(2)	0.62±0.2(9)	73 ± 13.9(9)	52.5±13.5(9)
T1 - 2	194.8±30.8(6)	0.1±0.02(9)	0.97±0.3(9)	0.02±0.01(3)	0.45±0.1(9)	87±.5±17.2(9)	71.4±21.9(9)
T1 - 3	180.8±32(6)	0.11±0.04(9)	0.73±0.2(9)	0.04±0.03(3)	0.42±0.1(9)	97.12±15.9(9)	42.3±11(9)
T 2- 1	256±17(12)	0.62±0.3(15)	1.86±1.1(15)	0.12±0.04(9)	1.07±0.4(12)	42.5±10.7(15)	64.3±15.1(15)
T 2- 2	210.5±7.2(12)	0.33±0.19(15)	0.98±0.3(15)	0.17±0.05(8)	1.23±0.4(12)	48.6±14.9(15)	83.7±23.7(15)
T 2- 3	178.5±18.1(12)	0.27±0.1(15)	0.92±0.3(15)	0.15±0.1(8)	1.34±0.4(12)	39±10.6(15)	53.8±13.3(15)
KisomaOutlet	229.8±22.3(17)	0.63±0.2(18)	1.81±0.7(18)	0.22±0.1(14)	0.89±0.3(13)	37.3±8.2(17)	61.1±13.9(17)

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), which receives 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. At some stage, a reduction is followed by an increase in EC downstream of the wetlands, (Figure 3), which implies that the water was enriched with pollutants after a reduction along transects within the wetland.

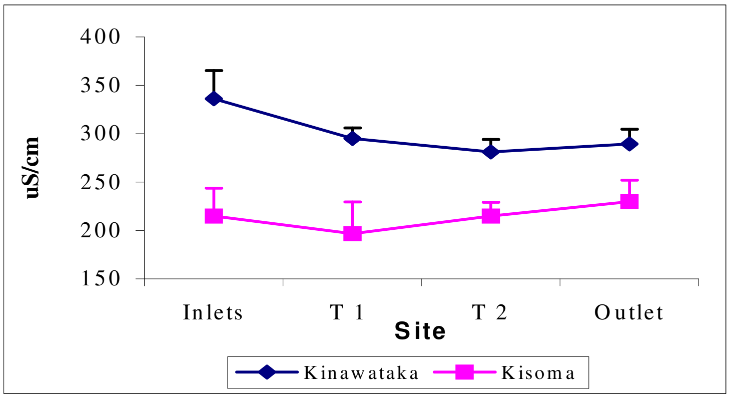

Figure 3. Comparison of electric conductivity trends (EC) in Kinawataka and Kisoma wetlands

The EC for Kisoma wetland varied with increasing levels as recorded at transect two (T2) up to the outlet (Figure 3). Other parameters like pH and temperature were also recorded on site in both wetlands 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 are characterised by inflows of 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 is observed in Kisoma Wetland. In the case of total nitrates (Figure 5), the wetland reduces the concentrations by about 50% by the time water moves out of the wetland while the total phosphates are reduced by about 10% (Table 1) in Kinawataka wetland.

There is however a fluctuating content of ammonium nitrogen and orthophosphates (Figure 6 a&b) as water gradually moves further downstream and there is a realised increase in the chemical oxygen demand at transect 1. Although there is noted orthophosphate increase at transect 1, it reduces as the water flows towards its exit from the wetland. There are noticeable 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.

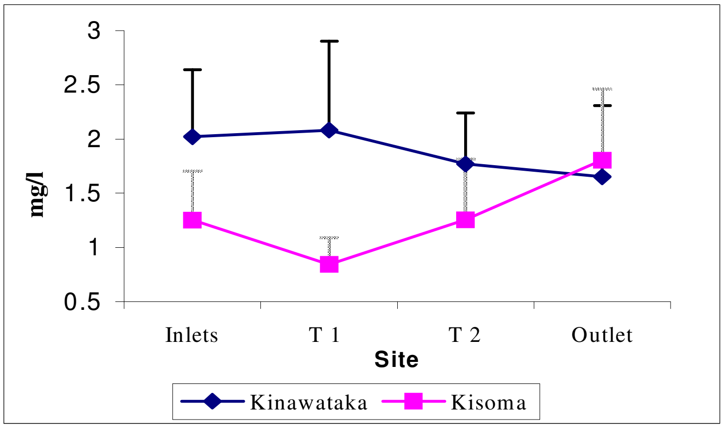

Figure 4. Total Phosphorous in Kinawataka and Kisoma wetlands.

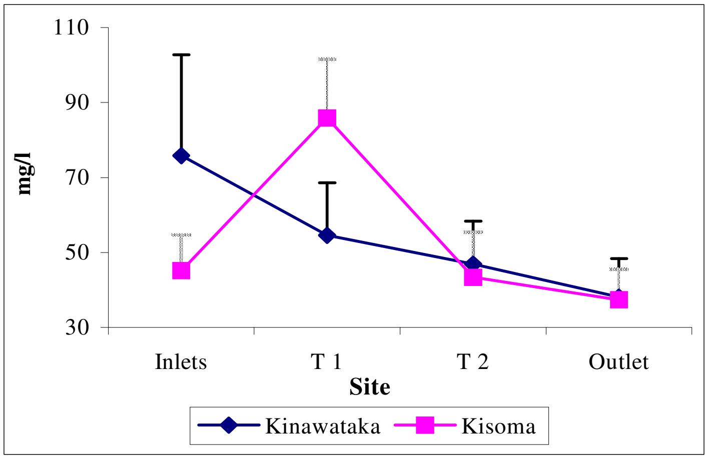

Figure 5. Comparison of Total Nitrogen in Kinawataka and Kisoma wetlands

In Kisoma, a mean representing the inflow was obtained from Kagonga, Kafamboga, Kisoma Upper and Luanda streams. Kagonga stream has the highest mean input of TP, NO3, NH_3, TN, and COD while Kisoma Upper contributed the lowest concentrations of O-$PO4^-$, TP, NO3, and NH_3 but had the highest COD input. Compared to inflow concentrations, O-$PO4^-$, TP and NO_3^- increased by 50%, 40% and 22%respectively, while the wetland reduced NH3, 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).

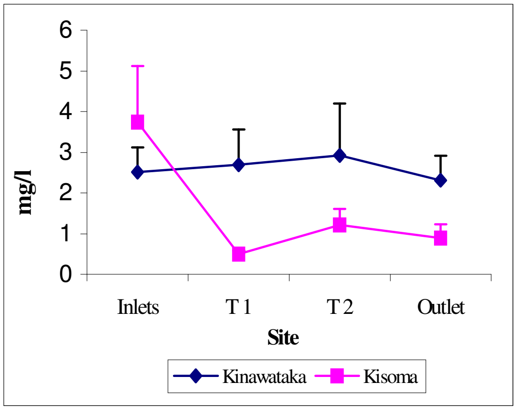

Figure 6a. Ammonium ions (NH3) for Kinawataka and Kisoma wetlands

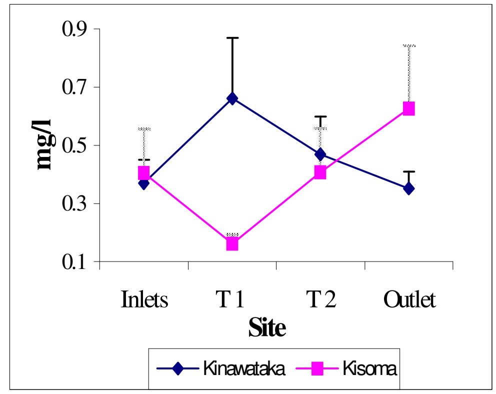

Figure 6b. Orthophosphate in Kinawataka and Kisoma Wetlands

The physical environment within the wetland (transects) facilitate the changes in the nutrients chemical and nutrient transformation processes take place and they contribute to apparent increased 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 the in-flowing waters. To an observer, TSS is good indicator of buffering. In both wetlands the high concentration of TSS measured at their in-flow is 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 on 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 may be associated with the dumping and infilling of the excavations resulting from stone mining with garbage and industrial wastes (Kansiime and Nalubega, 1999). 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 (Kyambadde *et al.,* 2001). There may be an inflow not detected during sampling, that may be enriching the system with nutrients and it is suggested that this can be traced to the source using electrical conductivity.

Nutrient uptake by wetlands can be demonstrated by the very high concentrations of nutrients entering Kinawataka wetlands and their reduction within the system as water moves down stream. The nutrients are modified within the wetland as they are considerably reduced as water moves 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 their faecal coliform and total phosphates probably because of raw and partially treated domestic sewage entering into the streams, flowing into Kinawataka (Opio *et al.,* 2001). The high nutrient recording at Pepsi factory may be due to the hydroxides used to wash the soda bottle at the factory (Kansiime, *Pers. Com*). The increase in phosphates downstream 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 into the wetlands depend on other factors such as the discharge from the catchment. Inflows depend a lot on catchment rainfall but for the case of Kinawataka, the effluents from industries and residential estates supplement the catchment discharge to an extent that there is a relatively high in put through the year. During the dry season considerable discharge into the wetland can be recorded for Kinawataka while none would be entering Kisoma (Okonga, 2001, *Pers. Comm.*). The size and the topography of the wetland where the effluent spreads is also another factor. 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 is common during the rainy seasons in town.

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 the wetlands and the role it plays in filtering the contaminated flow. It is important to note that wetlands have limited capacity to adequately deal with whatever comes with the flow. Therefore, reduction in upstream releases by treatment of the effluents coming from the catchment by having a well designed catchment management practice is suggested for the safety of maintaining the water quality of the Lake Victoria.

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References

APHA, 1992. Standard methods of examination of water waste water. Greenberg, E. *et al.,* 18th edition.

Beadle L.C., 1974. The Inland waters of Tropical Africa. Longman, New York.

Barugahare V., 2001. Distribution, Diversity and Abundance of Macro Invertebrates, Kinawataka and Kisoma Wetlands Uganda, MSc Thesis, Makerere University.

COWI/VKI, 1998. Kampala water quality monitoring programme: Murchison bay water quality project.

Debusk F. W.,2001. Phosphorous recycling in Wetlands. University of Florida, Co-operative Extension Service.

Kansiime F. and Nalubega M., 1999. Wastewater treatment by a natural wetland: the Nakivubo swamp, Uganda.

Kansiime F., 2001. Institute of Environment and Natural Resources, Makerere University, P. O. Box 7062, Personal Communication.

Kyambadde R. H. Busulwa, P. Mafabi and A Malinga, 2001. Buffering capacity of a wetland with a rural catchment - Kisoma, Sango Bay Uganda. LVEMP Wetland Management, Ministry of Water Land and Environment Technical Report

Mitsch W.J And Gosselink J.G., 1993. Wetlands. Van Nostrand Rheinhold, New York.

National Environment Management Authority (NEMA), 1998. State of the Environment Report – Uganda

Okonga J., 2001. Water Resource Management Department, Ministry of Water Lands and Environment, Kampala. Personal Communication.

Okurut T., 1999. Optimisation of a constructed wetland in Uganda for Municipal waste water treatment. National Water and Sewarage Coorporation, Uganda.

Opio, A., Kansiime F., F. W., Bugenyi, P., Mafabi and Busulwa. H., 2001. Bacteriological indicators of buffering in an urban wetland of Kinawataka, Uganda.

Reddy, K. R. And Smith W.H., 1997. Aquatic plants for water treatment and resource. Manolia Publishing, Inc. Orlando, Florida.

Wetzel G. R., 1983.   Limnology, 2nd Edtn. Saunders College Publishers.

Wetzel R.G., 1991.   Limnlogical Analyses, 2nd Edition. Springer