ResearchGate

See discussions, stats, and author profiles for this publication at: https://www.researchgate.net/publication/238382066

Assessment of nutrient retention by Natete wetland Kampala, Uganda

Article *in* Physics and Chemistry of the Earth Parts A/B/C · December 2010

DOI: 10.1016/j.pce.2010.07.027

CITATIONS
23

READS
132

4 authors:



Violet Kanyiginya
Royal Museum for Central Africa
2 PUBLICATIONS **27** CITATIONS
SEE PROFILE



Frank Kansiime
Makerere University
77 PUBLICATIONS **2,243** CITATIONS
SEE PROFILE



Richard Kimwaga
University of Dar es Salaam
9 PUBLICATIONS **132** CITATIONS
SEE PROFILE



Damas ALFRED Mashauri
University of Namibia
43 PUBLICATIONS **611** CITATIONS
SEE PROFILE

Some of the authors of this publication are also working on these related projects:

MSc. Research View project

Assessment of the level of adoption of quality improvement tools in public hospitals in Namibia View project

All content following this page was uploaded by Violet Kanyiginya on 07 April 2020.

The user has requested enhancement of the downloaded file.

Physics and Chemistry of the Earth 35 (2010) 657–664

Contents lists available at ScienceDirect

Physics and Chemistry of the Earth

journal homepage: www.elsevier.com/locate/pce

Assessment of nutrient retention by Natete wetland Kampala, Uganda

V. Kanyiginya [a], F. Kansiime [a,*], R. Kimwaga [b], D.A. Mashauri [b]

[a] Makerere University, Institute of Environment and Natural Resources, P.O. Box 7298, Kampala, Uganda
[b] University of Dar es Salaam, Faculty of Civil Engineering and the Built Environment, Department of Water Resources Engineering, P.O. Box 35131, Dar es Salaam, Tanzania

ARTICLE INFO

Article history:
Received 2 February 2010
Received in revised form 13 July 2010
Accepted 25 July 2010
Available online 1 August 2010

Keywords:
Cyperus papyrus
Biomass
Natete wetland
Nutrient retention
Uganda

ABSTRACT

Natete wetland which is located in a suburb of Kampala city in Uganda is dominated by *Cyperus papyrus* and covers an area of approximately 1 km^2. The wetland receives wastewater and runoff from Natete town which do not have a wastewater treatment facility. The main objective of this study was to assess nutrient retention of Natete wetland and specifically to: determine the wastewater flow patterns in the wetland; estimate the nutrient loads into and out of the wetland; determine the nutrient retention by soil, plants and water column in the wetland; and assess the above and belowground biomass density of the dominant vegetation. Soil, water and plant samples were taken at 50 m intervals along two transects cut through the wetland; soil and water samples were taken at 10 cm just below the surface. Physico-chemical parameters namely pH, electrical conductivity and temperature were measured *in situ*. Water samples were analyzed in the laboratory for ammonium-nitrogen, nitrate-nitrogen, total nitrogen, orthophosphate and total phosphorus. Electrical conductivity ranged between 113 μS/cm and 530 μS/cm and the wastewater flow was concentrated on the eastern side of the wetland. pH varied between 6 and 7, temperature ranged from 19 °C to 24 °C. NH_4-N, NO_3-N, and TN concentrations were retained by 21%, 98%, and 35% respectively. Phosphorus concentration was higher at the outlet of the wetland possibly due to release from sediments and leaching. Nutrient loads were higher at the inlet (12,614 ± 394 kgN/day and 778 ± 159 kgP/day) than the outlet (2368 ± 425 kgN/day and 216 ± 56 kgP/day) indicating retention by the wetland. Plants stored most nutrients compared to soil and water. The belowground biomass of papyrus vegetation in the wetland was higher (1288.4 ± 8.3 gDW/m^2) than the aboveground biomass (1019.7 ± 13.8 gDW/m^2). Plant uptake is one of the important routes of nutrient retention in Natete wetland. It is recommended that harvesting papyrus can be an effective way of nutrient removal especially phosphorus which is not easily lost to the atmosphere like nitrogen. Natete wetland needs to be left in its natural state for better efficiency in nutrient retention. Bio-manipulation of the wetland by spreading the wastewater as it enters the wetland could enhance the interaction between plants and wastewater and subsequent nutrient removal.

© 2010 Elsevier Ltd. All rights reserved.

1. Introduction

Wetlands have been reported to be effective at reducing nutrient loadings from the catchment (Mitsch and Gosselink, 1986) thereby reducing eutrophication in adjacent water bodies. In Uganda, wetlands are often drained and filled for development; others are polluted from dumping of wastes from various sources (e.g. industry, agriculture and households (Kansiime et al., 2007a; Munabi et al., 2009). Natete is one of the wetlands in Uganda that is threatened with increased inflow of nutrients and extensive encroachment for various land use activities especially agriculture and high settlement densities. All these activities have altered the wetland ecosystem. Mugisha et al. (2007) pointed out that urban wetlands are degraded by anthropogenic activities which impair the ability of wetlands to provide ecosystem services like water treatment. Tropical wetlands have been reported to provide other ecosystem services like carbon retention and modification of microclimate (Kansiime et al., 2007b).

Kampala has experienced rapid population growth at a rate of 5.61% per annum (UBOS, 2002). The city has only one major wastewater treatment facility leaving other areas with onsite sanitation and others without any wastewater treatment facility. The latter discharge untreated wastewater into the surrounding environments like wetlands, an activity that poses environmental hazards (Nsubuga et al., 2004; Kulabako et al., in press; Nyenje et al., 2010).

The main objective of the study was to assess nutrient retention by Natete wetland and specifically to: determine the wastewater flow patterns; determine the nutrient retention by the soil, plants and water column; estimate the nutrients loads into and out of the wetland and assess plant biomass density and nutrient uptake by the dominant vegetation at selected locations in the wetland.

* Corresponding author. Tel.: +256 414 530135; fax: +256 414 530134.
E-mail address: fkansiime@muienr.mak.ac.ug (F. Kansiime).

1474-7065/$ - see front matter © 2010 Elsevier Ltd. All rights reserved.
doi:10.1016/j.pce.2010.07.027

Nutrients assessed were nitrogen and phosphorus. For nitrogen, ammonium-nitrogen, nitrate-nitrogen and total nitrogen were assessed and orthophosphate and total phosphorus for phosphorus. The physical parameters measured were pH, electrical conductivity and temperature. Oxygen was not measured due to unavailability of a meter and chemicals for laboratory analysis. The study was limited to the main channel as the input into Natete wetland, the minor inlets from other sources in the catchment were not considered.

2. Materials and methods

2.1. Description of study area

Natete wetland is located in Rubaga division, Kampala Uganda Fig. 1 and is dominated by *Cyperus papyrus* (papyrus) vegetation with a few zones of *Typha latifolia* at the fringes. The wetland is located at geographical coordinates of $0^0\ 18^1$N and $32^0\ 30^1$E and covers an area of about 1 km^2. The wetland is mainly fed by a channel that runs from Ndeeba through Nalukolongo, where it is joined by other smaller channels from Wakaliga. The channel mainly consists of wastewater and solid wastes from homes and small scale industries. The wastewater flows into the wetland and comes out through a single channel from the other end of the wetland along Kampala–Masaka road.

2.2. Transects and sampling points

To determine the variation in water quality into, within and out of Natete Wetland, the wetland was mapped to obtain suitable sampling points. Two transects (TA and TB) were cut across the wetland to enable access into the wetland (Fig. 2). Transects were made by laying papyrus culm bundles in the path to ease movement in the wetland. The first transect (TA) was cut near the channel inlet and was 325 m long, while transect B (TB) was cut in the middle of the wetland and was 350 m long.

2.3. Determination of the wastewater flow patterns in Natete wetland

To determine the major flow paths of the wastewater in the wetland, electrical conductivity was used as a tracer; measurements of electrical conductivity were carried out at every 25 m along each transect as described by Kansiime and Nalubega (1999). Electrical conductivity has been used reported to be an accurate natural tracer for wastewater flows in natural wetlands (Kansiime and van Bruggen, 2001; Kelderman et al., 2007). Distances were measured from the southern to the northern side of a given transect. Measurements of electrical conductivity and temperature were taken *in situ;* weekly and for a period of 2 months using portable WTW conductivity meters.

2.4. Sampling and chemical analysis

Measurements of the physico-chemical parameters were taken at every 25 m whereas sampling for chemical analysis of soil, water and plants was done at an interval of 50 m along the transects. Comparisons were made for which medium stores the most nutrients.

Measurements of the physico-chemical variables were taken *insitu* using WTW microprocessor meters. The methods used for

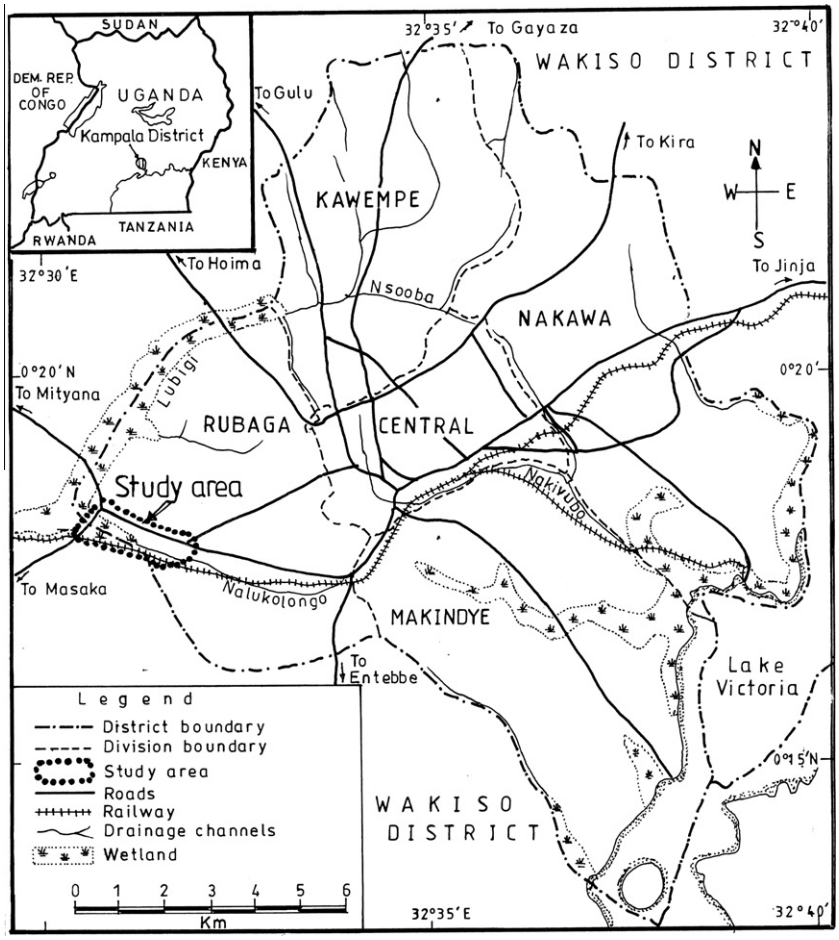

Fig. 1. Map of Kampala district showing the study area.

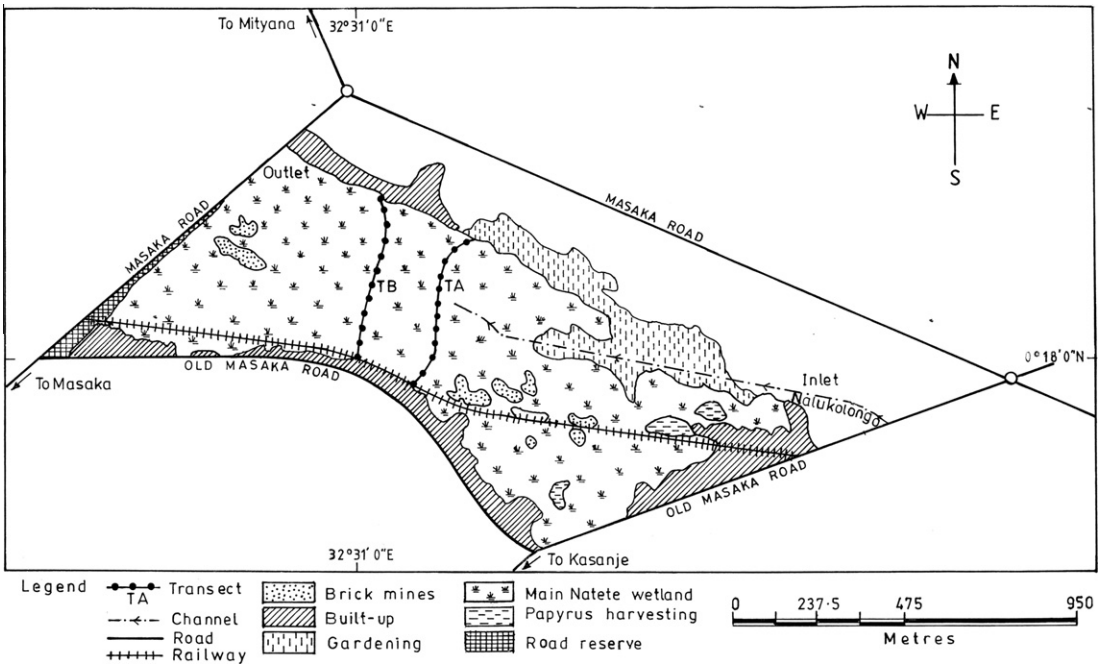

Fig. 2. Location of Natete wetland and study sites.

chemical analysis of water samples were those described in Standard Methods for Examination of Water and Wastewater (APHA, 1992). Concentrations of the chemical variables were measured using a HACH DR 4000 spectrophotometer. NH_4-N was determined by the Nesslerization method, NO_3-N by the cadmium reduction method and orthophosphate following the ascorbic acid method. Total phosphorus and total nitrogen were determined using the persulphate method.

For the soil samples, available phosphorus was determined using the Bray 1 method (Bray and Kurtz, 1945) while total phosphorus was determined using ascorbic acid method. Ammonium-nitrogen and nitrate-nitrogen were determined using steam distillation method with no pH adjustment. Total nitrogen was determined using the macro Kjeldahl method.

2.5. Biomass measurement

Biomass was measured in the middle of the wetland on TB; both above and belowground biomass was measured to determine which plant parts store more nutrients. The aboveground included culms and umbels while the belowground portions included roots and rhizomes. Determination of biomass density of wetland plants was carried out in selected three plots (1 m × 1 m). The aboveground biomass in a given plot was cut and separated into leaves and umbel. They were weighed using a spring balance (Salter) suspended from a fixed cross bar erected at the site to obtain the total wet weight of each plant part. The belowground biomass was removed by digging up all rhizomes and roots in a 1 m × 1 m plot and washing off all the dead materials, soil/peat. Out of the total wet weight of each plant part in a 1 m × 1 m plot, a sub-sample of 1 kg of each plant part was taken for sun drying at the Department of Soil Science, Makerere University. The sun-dried samples of each plant part were thereafter oven dried at 70 °C to constant weight. The wet weight to dry weight ratio of the 1 kg sub-sample was used to calculate the total dry weight in a 1 m × 1 m plot in the wetland. Total nitrogen and total phosphorus of dried plant parts were determined according to Novozamsky et al. (1983). Total nitrogen and total phosphorous were chosen as the basic elements for nutrients used up by the plants.

2.6. Nutrient loads

Discharge at the inlets and outlets was measured using a current meter wading propeller number 1-135308–135513 that was attached to an OTT hydrometer Z30 quarts timer. A staff gauge and a tape measure were used to measure the depth and width/length of the channels respectively. The number of resolutions measured by the propeller depended on the velocity of the water at the channel. The nutrient loads into and out of Natete wetland were determined by measuring the discharge at the inlet and outlet of the wetland and taking water samples at these points for laboratory analysis. The results of concentrations obtained from the laboratory were used to estimate the nutrient load at each station. The degree of nutrient retention that took place between stations (within the wetland) was calculated as a difference of the loads at the inlet and outlet.

2.7. Statistical analysis

Statistical analysis of results was done using Minitab Release 13.l for Windows. Analysis of variance (ANOVA) was used to find out differences between means of variables. Following ANOVA, Tukey's multiple comparisons for differences between means. Bartlett's and Levene's were used to test for homogeneity of variance and For the presentation of results, >, =, and < indicate significantly higher, not significantly different and significantly lower respectively.

3. Results and discussion

3.1. Electrical conductivity

Electrical conductivity (EC) was high on the lower (southern) sides of the wetland up to about the middle of the wetland where it decreased up to the edges of the northern parts of the wetland (Fig. 3). The highest conductivity recorded was 530 μS/cm, measured on transect A whereas the lowest was 119 μS/cm, measured on transect B. Electrical conductivity at the inlet ranged from 390 μS/cm to 590 μS/cm, whereas at the outlet conductivity ranged from 190 μS/cm to 300 μS/cm. The high EC in the southern

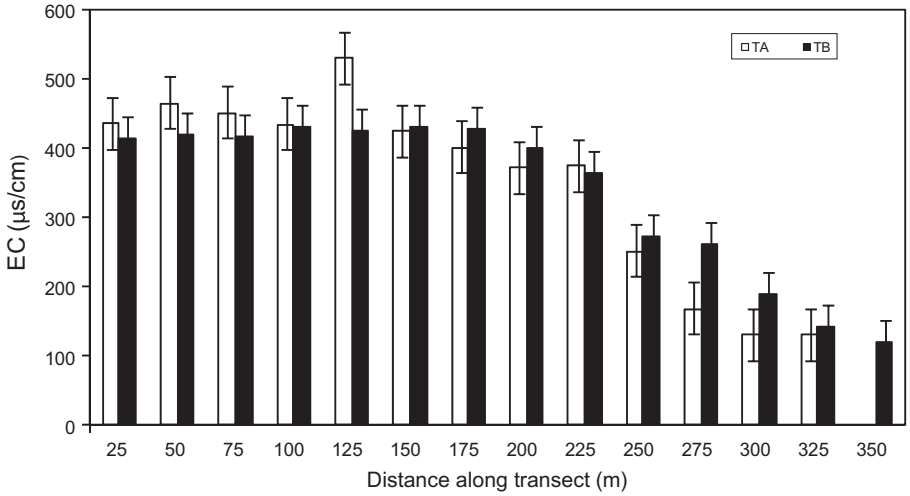

Fig. 3. Variation of electrical conductivity along transects TA and TB, bars indicate standard error of the mean (n = 8).

part of the wetland indicates that most of the wastewater flows through this region. These values are in the range reported by Kansiime and Nalubega (1999) for Nakivubo wetland and Kelderman et al., 2007 for Kirinya wetland. Both wetlands receive secondary treated wastewater.

The same regions of high EC correspond to greener and healthy papyrus as compared to the papyrus in a region with lower EC at the northern side where plants are stunted with a greenish-yellow colour. The regions of high EC also have a high water depth and with a loose floating mat than those with lower EC. In these areas, the mat of papyrus (where plant roots are anchored) are water logged and in most cases water oozes out as one steps on the mat. As reported by Kansiime et al. (2003), this an indication that there is a better interaction between wastewater and plants which enhances nutrient uptake by plants from the wastewater. Generally, regions within a distance of 0–150 m on TA had higher EC than TB; after which (from 150 m onwards) EC on TB becomes higher than TA up to the edges of the wetland on the northern side. This is because there are minor inflows on this side of the wetland from homes which contribute to the high EC on TB at the last portion of the wetland. The higher EC values in the southern parts can possibly be explained by the inclination of the wetland towards the southern side; indicating that wastewater flows along this region. Lower EC at the northern side means that the wastewater does not flow through these parts, this is also indicated by the shallow rooted papyrus mat (about 10 cm) and stunted papyrus assuming the nutrients for plant growth in these regions are low. In natural tropical wetlands where there is a deep water column, papyrus has been found floating (Muthuri and Jones, 1987; Kansiime and Nalubega, 1999; Kansiime et al., 2007b). Also, being on a more raisedground than the southern side, can explain why the wastewater does not reach these parts because of an inclination (probably created during the construction of a railway line) towards this side.

The pH ranged from 6 to 7 and in the range reported for tropical wetlands (Muthuri and Jones, 1987; Kansiime et al., 2007a). Generally electrical conductivity and pH showed the same trend being high on the southern edge of the swamp and decreased with increasing distance to the northern edge of the swamp. However the temperature of the water column did not vary much; it was varied between 21 °C and 23 °C (Fig. 4).

3.2. Nutrient retention

NH_4-N and NO_3-N concentrations were highest at the inlet and decreased along transects to the outlet registering the lowest concentrations at the outlet. There was a significant difference in NH_4-N between the inflow, within the wetland and out of the wetland (p = 0.08), Fig. 5. Tukey multiple comparisons indicated that NH_4-N concentration at the inflow > in the wetland > that the concentration at the outflow. NH_4-N was highest at the inlet because the inlet is an open channel with aerobic respiration taking place;

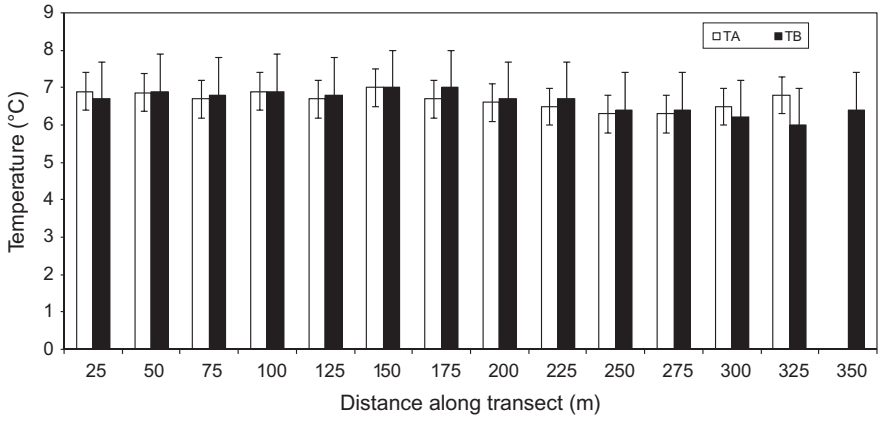

Fig. 4. Variation of temperature along transects TA and TB, bars indicate standard error of the mean (n = 8).

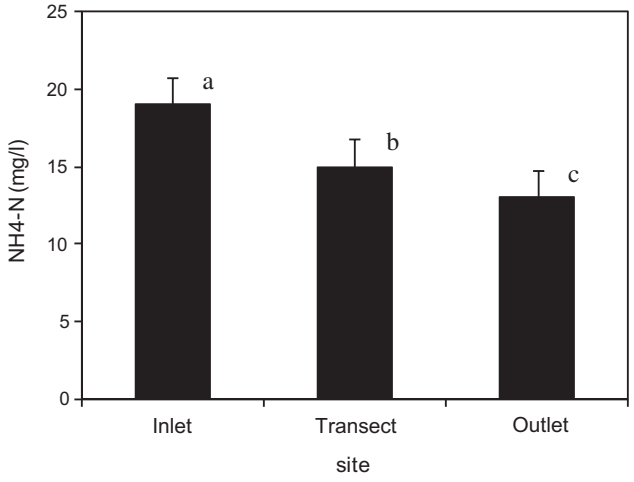

Fig. 5. Mean NH_4-N concentrations at the inlet, Transect B and outlet. Bars indicate standard error of the mean ($n = 9$). Graphs with the same letters are not significantly different from each other.

thus organic nitrogen was being converted to ammonia. According to Reddy and Patrick (1984), ammonification rates are fastest in the oxygenated zone and decrease as conditions switch to anaerobic. The trend also suggests that there was retention of nutrients by the wetland since concentration of nutrients was lower at the outflow from the wetland and this decrease may be attributed to uptake by plants and other processes like denitrification. This is revealed by the less greenness and lushness of the papyrus plants towards the outlet since there is low concentration of nutrients.

There was a significant difference in the concentration of NO_3-N between the sites ($p = 0$), Fig. 6.

Tukey multiple comparisons indicated that NO_3-N concentration at the inflow > in the wetland = outflow which could be attributed to biological oxidation of ammonium to nitrate. Conditions at the inlet were favorable for nitrification processes to take place; therefore more ammonium was being converted to nitrate. This is in line with Vymazal (1995) who reported that nitrification is influenced by concentrations of ammonium-N and dissolved oxygen.

Total nitrogen concentration in water column was significantly higher in the wetland whereas concentrations at inflow and outflow were not significantly different (Fig. 7). This could be due to the nitrogen cycling taking place in the wetland, where nutrients are produced by the decaying organic matter. Also the nutrients trapped in plant parts dissolve in the water or are deposited as sediment contributing to more nutrients in the wetland (Kansiime and Nalubega, 1999; Mugisha et al., 2007). Thus these sites were acting as sources instead of sinks. Taurai (2007) attributed this trend to the re-suspension of previously retained nitrogen during storms or extra nutrients coming from other sources in the sub-catchments. High TN in the wetland can also be due to biological nitrogen fixation. A wide variety of actinomycetes and free-living heterotrophic bacteria plus blue–green algae can fix nitrogen in wetlands (Johnson, 1991). Buresh et al., 1980 reported that nitrogen fixation in soil is greater in anaerobic than in aerobic conditions.

There was also significant difference in the concentration of total phosphorus between the inflow, in the wetland and outflow ($p = 0.029$), Fig. 8.

Tukey multiple comparisons indicated that concentrations of TP at the outflow > inflow = outflow. However phosphates were higher at the outlet than the inlet, this is possibly due to flushing during storm events thus organic phosphorus was being released as soluble phosphorus. Kadlec and Knight, 1996 stated that insoluble precipitates of phosphorus under some circumstances may re-dissolve when conditions in the matrix are altered.

Within the wetland and along the transects concentration of nutrients were significantly higher ($p = 0.027$) along Transect A than B (Fig. 9). This is due to their location with respect to the inflowing channel. Transect A is to the inflow (Nalukolongo Channel) than transect B receives high concentration of nutrients from the channel. Low concentrations of nutrients along TB suggest that some nutrients are retained between TA and TB.

Electrical conductivity was also significantly higher along transect A than that at transect B ($p = 0.035$). Electrical conductivity depicted a similar trend to ammonium-nitrogen whereby high values were recorded at the edge of the southern part of the wetland between 25 m and 125 m along the transect. Since conductivity has been reported to be a natural tracer of wastewater flow in tropical wetlands (Kansiime and Nalubega, 1999; Kelderman et al., 2007), it can be said that most of the wastewater in Natete wetland flows in the southern part of the wetland where the concentrations of NH4-N are high. A similar relationship

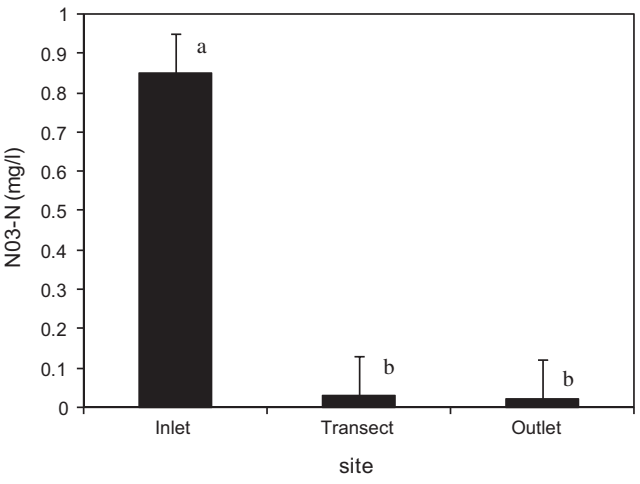

Fig. 6. Mean NO_3-N concentrations at the inlet, transect B and outlet. Bars indicate standard error of the mean ($n = 9$ for inlet and outlet and 64 for transect). Graphs with the same letters are not significantly different from each other.

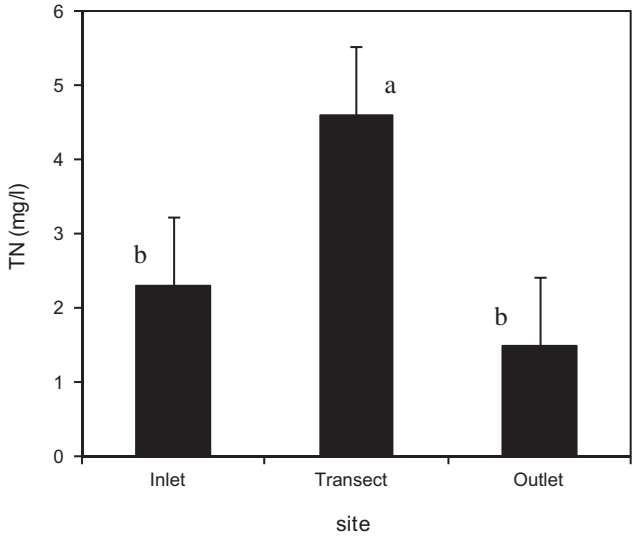

Fig. 7. Mean TN concentrations at the inlet, transect B and outlet. Bars indicate standard error of the mean ($n = 9$ for inlet and outlet and 64 for transect). Graphs with the same letters are not significantly different from each other.

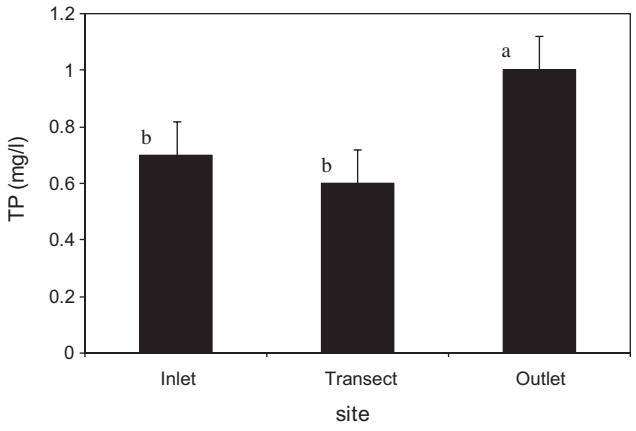

Fig. 8. Mean TP concentrations at the inlet, Transect B and outlet. Bars indicate standard error of the mean ($n = 9$ for inlet and outlet and 64 for transect). Graphs with the same letters are not significantly different from each other.

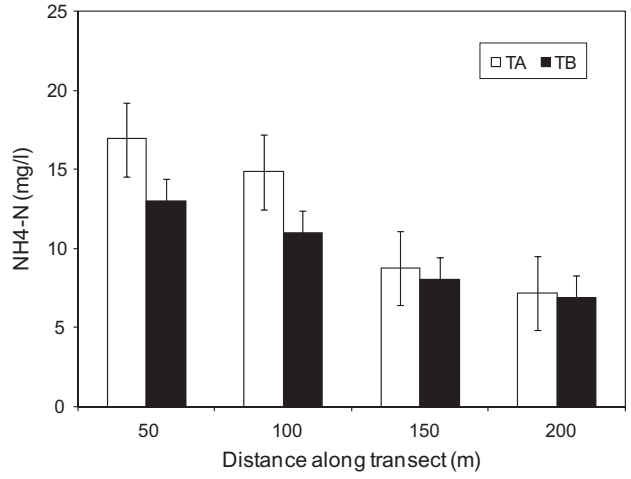

Fig. 9. Mean NH_4-N concentrations on TA and TB ($n = 32$). Bars indicate standard error of the mean.

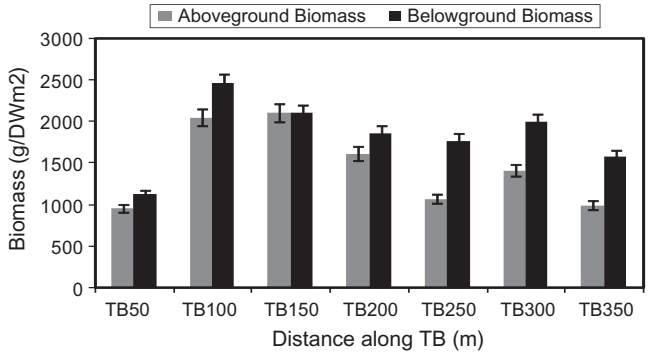

Fig. 10. Variation of above and belowground biomass of papyrus plant parts. TB50 refers to 50 m along transect TB from the southern part of the wetland ($n = 7$).

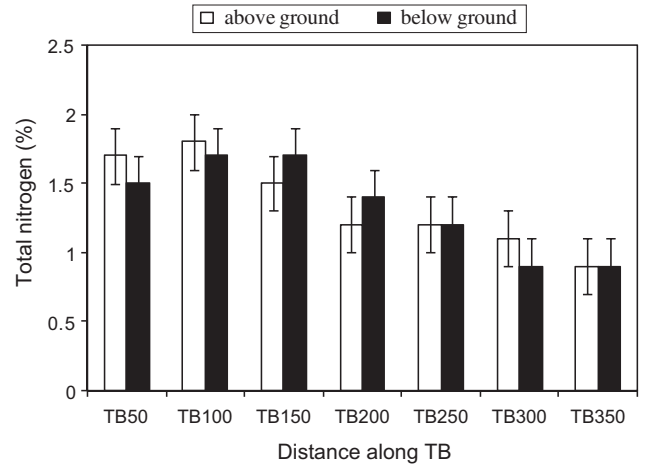

Fig. 11. Variation of total nitrogen in above and belowground papyrus plant parts ($n = 7$).

between wastewater patterns and nutrient concentrations was obtained in Nakivubo wetland by Kansiime et al. (2003). Therefore the lower nutrients in the edges of the swamp suggest that wastewater does not reach these regions as shown by the stunted papyrus plants.

3.3. Biomass productivity

Generally, the belowground biomass was higher than the aboveground biomass, Fig. 10. The biomass density of the aboveground biomass was not significantly different from that of belowground biomass ($p = 0.135$).

The belowground plant parts had higher nutrient content than the aboveground plant parts, though the difference was not significant ($p = 0.062$), Fig. 11. For nitrogen, concentrations were 9.4 ± 0.3% DW for aboveground plant parts and 9.3 ± 0.3% DW for belowground plant parts. This is because the aboveground portions are the photosynthetic and inflorescence parts, thus the high nitrogen content. Phosphorus concentrations were 1.4 ± 0.04% DW for aboveground and 1.9 ± 0.07% DW for belowground plant parts and the difference was significant ($p = 0.01$).

The higher biomass measured in the belowground plant parts is as a result of wetland plants taking up nutrients through their root system and since papyrus is a productive macrophyte, a considerable amount is bound in their rhizomes. Furthermore, rhizomes store nutrients from the aboveground biomass especially for aging plants (Muthuri and Jones, 1987). The higher biomass and nutrient concentrations in the belowground than the aboveground parts could also be due to senescence of the wetland plants. Vegetation nutrient concentrations have been reported to be highest early stages of growth, decreasing as the plant mature and senesce (Mugisha et al., 2007). Vymazal (2006) reported that as the rate of biomass and nutrient accumulation diminishes, translocation of nutrients and photo-assimilation from leaves to rhizome occurs. Similarly Denny (1984) indicated that the higher nutrient concentration in juvenile plants is a manifestation that N and P are taken up rapidly during early stages of growth and later translocated to the storage organs when the plants mature. Kansiime et al. (2003) also established a correlation between age of plants and nutrient content in Nakivubo wetland.

There was an increase in biomass of both above and belowground plant parts in the regions under the influence of wastewater and a decrease of biomass in regions where wastewater seem not reach. Kansiime et al. (2003), Kipkemboi et al. (2002), and Chale (1987) reported similar relationships in other natural wetlands. Since plants require nutrients for the production of new cells during growth, the availability of nutrients (like nitrogen and phosphorus), and their subsequent uptake by papyrus could explain higher biomass production in areas under the influence of wastewater (Muthuri and Jones, 1987; Kansiime et al., 2003; Mugisha et al., 2007).

3.4. Comparison of nutrient concentrations in plants, soil and water column

Total nitrogen and total phosphorus concentrations were compared in the water, soil and plant parts (both above and below-ground). It was established that plants stored the highest amounts of nutrients as compared to soil and water (Fig. 12).

The overall total nitrogen stored in the plants was 187,000 mg/kg; in the soil total nitrogen was 82,506 mg/kg and in water it was 36.8 mg/l. The overall total phosphorus stored in plants was 33,400 mg/kg; in the soil total phosphorus was 14,710 mg/kg and in the water column it was 4.6 mg/l. Total nitrogen was the highest in all the media (plants, soil and water), Fig. 13. This could be associated with nitrogen fixation and nitrogen release from decaying organic matter. The root rhizosphere of *Cyperus papyrus* has been reported to be well colonized by the N_2 fixing bacteria and high rates of nitrogen fixation have been recorded in intact root system of papyrus (Mwaura, 1981).

Plants require nutrients for cell development, some of the nutrients taken up are assimilated in the roots and rhizomes, while others are carried by the sap flow into the stalk and umbel and are incorporated into organic compounds. This is shown by the direct proportionality of wastewater flow patterns and nutrient content obtained earlier on. This explains the highest nutrient content in plant parts compared to soil and water.

3.5. Nutrient loads

Nutrient loads were higher at the inlet than the outlet of the wetland indicating retention (Table 1). The loading was directly proportional to the discharge obtained at the inlet and outlet of the wetland. This is in agreement with Taurai, 2007 who reported a direct proportionality of discharge and nutrient loading in Chinyika River, Harare and attributed this relationship to the numerous organic matter and soil that was being washed away from the catchment by runoff into the river. These nutrients were later retained by the wetland which explains the lower nutrients at the outlet.

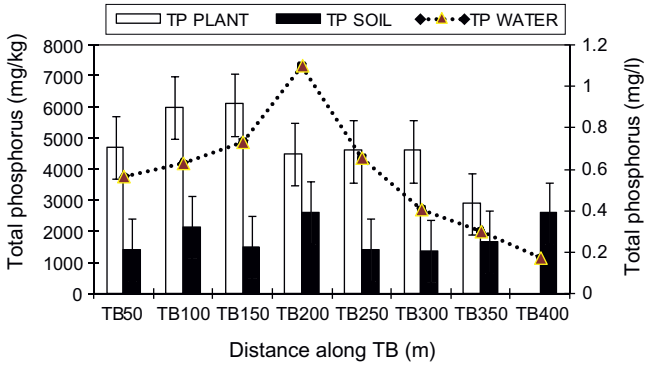

Fig. 12. Variation of TP in plant parts, soil and water along TB. Bars indicate standard error of the mean ($n = 8$).

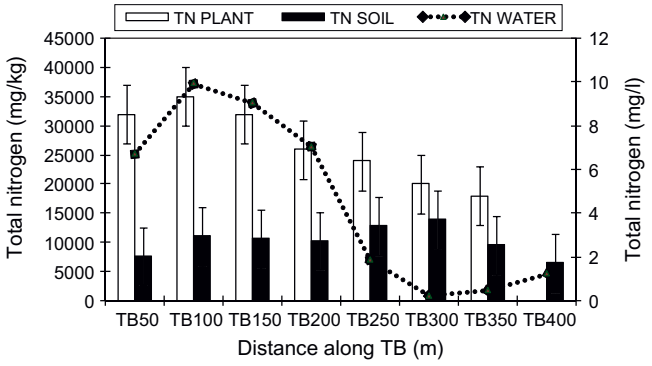

Fig. 13. Variation of TN in plant parts, soil and water along TB. Bars indicate standard error of the mean ($n = 8$).

Table 1
Average nutrient concentrations and loads in Natete wetland.

Variable	Concentration (mg/l)		Load (kg/day)		% Of nutrient retention
	Inlet	Outlet	Inlet	Outlet	
NH_4-N	16.28	12.42	12,096	2359	80.5
NO_3-N	0.74	0.02	518	9	98.3
PO_4-3	1.05	1.14	778	216	72.2

Discharge values were 0.8 m^3/s for the inlet and 0.22 m^3/s for the outflet.

4. Conclusions and recommendations

Electrical conductivity ranged between 113 μS/cm and 530 μS/cm and the wastewater flow was concentrated on the eastern side of the wetland. Temperature ranged from 19 °C to 24 °C and pH was between 6 and 7.

More than 50% of nitrogen compounds are retained by the wetland, nitrogen retention varied between 81% and 98%; where nitrate-nitrogen had the maximum retention of 98%, ammonium-nitrogen had a retention of 80% and total nitrogen retention was 85%. Generally, retention of nitrogen compounds in Natete wetland was more than that of phosphorus compounds. There was a release of phosphorus compounds thus there was no overall retention. Nutrient loads were higher at the inlet (1296 kgN/day and 138 kgP/day) than the outlet (242 kgN/day and 38 kgP/day).

Plant uptake is a more important route of phosphorus removal in Natete wetland. Harvesting papyrus can be an effective way of nutrient removal if only the papyrus is not left to decompose in the wetland and contribute to more nutrients. The papyrus can be used in making fences and mats. As a way of ensuring the continued functioning and better service provision by this wetland, urban agriculture should be banned and all encroachments halted. This will increase the wetland area and time over which biological, physical and chemical processes operate. Practices of channelizing the wetland should be avoided. Currently, the wetland is being channelized to reduce incidences of flooding. However, we recommend that the wastewater should be spread over large expanse of the wetland (bio-manipulation) to enhance wastewater plant interactions. This can be done by making secondary (lateral) channels to convey water to wetland areas on either side of the channel.

Acknowledgements

The authors thank WaterNet for sponsoring this study. Assistance from the University of Dar es salaam, Tanzania and Makerere University Institute of Environment and Natural Resources are highly appreciated.

References

APHA, 1992. Standard Methods for the Examination of Water and Wastewater, 19th ed. American Public Health Association, Washington, DC.
Bray, R.H., Kurtz, L.T., 1945. Determination of total, organic, and available forms of phosphorus in soils. Soil Science 59, 39–45.
Buresh, R.J., Casselman, M.E., Patrick, J.R., 1980. Nitrogen fixation in flooded soil systems: a review. Advances in Agronomy 33, 149–192.

Chale, F.M.M., 1987. Plant biomass and nutrient levels of a tropical macrophyte (*Cyperus papyrus* L.) receiving domestic wastewater. Hydrobiological Bulletin 21, 167–170.

Denny, P., 1984. Permanent swamp vegetation of the upper Nile. Hydrobiologia 110, 79–90.

Johnson, C.A., 1991. Sediments and nutrient retention by freshwater wetlands: effects on surface water quality. CRC Critical Reviews in Environ Control 21, 491–565.

Kadlec, R.H., Knight, R.L., 1996. Treatment wetlands. CRC Press, Boca Raton, FL. 893 p.

Kansiime, F., Nalubega, M., 1999. Wastewater Treatment by a Natural Wetland: the Nakivubo Swamp, Uganda. Processes and Implications. PhD thesis, A.A. Balkema Publishers, Rotterdam, The Netherlands.

Kansiime, F., van Bruggen, J.J.A., 2001. Distribution and retention of faecal coliforms in the Nakivubo wetland in Kampala, Uganda. Water Science and Technology 44 (11–12), 199–206.

Kansiime, F., Kateyo, E., Oryem-Origa, H., Mucunguzi, P., 2007a. Nutrient retention in pristine and disturbed wetlands. Wetlands Ecology and Management 15 (6), 453–467.

Kansiime, F., Saunders, M.J., Loiselle, S.A., 2007b. Functioning and dynamics of wetland vegetation of Lake Victoria; an Overview. Wetlands Ecology and Management 15 (6), 443–451.

Kansiime, F., Nalubega, M., van Bruggen, J.J.A., Denny, P., 2003. The effect of wastewater discharge on biomass production and nutrient content of *Cyperus papyrus* and *Miscanthidium violaceum* in the Nakivubo wetland, Kampala, Uganda. Water Science and Technology 48 (5), 233–240.

Kipkemboi, J., Kansiime, F., Denny, P., 2002. The response of *Cyperus papyrus* (L.) and *Miscanthidium violaceum* (K. Schum) Robyns to eutrophication in natural wetlands of Lake Victoria, Uganda. African Journal of Aquatic Sciences 27, 11–20.

Kelderman, P., Kansiime, F., Tola, M.A., van Dam, A., 2007. Plug-flow modelling of phosphorus retention in papyrus wetlands. Wetlands Ecology and Management 15 (6), 481–488.

Kulabako, N.R., Nalubega, M., Wozei, E., Roger Thunvik, R. (in press). Environmental health practices, constraints and possible interventions in peri-urban settlements in developing countries – a review of Kampala, Uganda. International Journal of Environmental Health Research.

Mitsch, W.J., Gosselink, J.G., 1986. Wetlands. Van Nostrand Reinhold Company, New York.

Mugisha, P., Kansiime, F., Mucunguzi, P., Kateyo, E., 2007. Wetland vegetation and nutrient retention in Nakivubo and Kirinya wetlands in the Lake Victoria basin of Uganda. Journal of Physics and Chemistry of the Earth 32, 1359–1365.

Munabi, C., Kansiime, F., Amel, A., 2009. Variation of water quality in Kakira catchment area, Jinja – Uganda. Physics and Chemistry of the Earth 34, 761–766.

Muthuri, F.M., Jones, M.B., 1987. Primary productivity of papyrus (*Cyperus papyrus*) in a tropical swamp; Lake Naivasha, Kenya. Biomass 18 (1), 1–14.

Mwaura, F.B., 1981. Nitrogen Fixation in the Papyrus Swamps of Lake Naivasha. M.Sc. Thesis, University of Nairobi.

Novozamsky, I., Houba, V.J.G., van Eck, R., van Vark, W., 1983. A novel digestion technique for multi-element plant analysis. Communications in Soil Science and Plant Analysis 14, 239–248.

Nyenje, P.M., Foppen, J.W., Uhlenbrook, S., Kulabako, R., Muwanga, A., 2010. Eutrophication and nutrient release in urban areas of sub-Saharan Africa – a review. Science of The Total Environment 408 (3), 447–455.

Nsubuga, F.B., Kansiime, F., Okot-Okumu, J., 2004. Pollution of protected springs in relation to high and low-density settlements in Kampala – Uganda. Journal of Physics and Chemistry of the Earth 29, 1153–1159.

Reddy, K.R., Patrick, W.H., 1984. Nitrogen transformations and loss in flooded soils and sediments. CRC Crit Rev Environ Control 13, 273–309.

Taurai, B., 2007. The assessment of nutrient loading and retention in the upper segment of the Chinyika River, Harare: implications for eutrophication control. Water SA 33 (2), 279–284.

UBOS (Uganda Bureau of Statistics), 2002. Ministry of Finance, Planning and Economic Development (Uganda).

Vymazal, J., 1995. Algae and element cycling in wetlands Chelsea. Lewis Publishers, Michigan. 698 p.

Vymazal, J., 2006. Removal of nutrients in various types of constructed wetlands. Elsevier Publishers. pp 49–62.

View publication stats